LONG TERM DYNAMICS OF A DEGRADED ARID SHRUB LAND: DELAYED RESPONSES AND THE IMPORTANCE OF SPATIAL PROCESSES

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1. INTRODUCTION

In arid environments, vegetation dynamics are often unpredictable, nonlinear, and strongly influenced by environmental and anthropomorphic drivers (Westoby, Walker & Noy-Myer 1989, Friedel 1991, Archer, Schimel & Holland 1995, Wondzell and Ludwig 1995). Conversely, vegetation states are often be quite stable over time, and without intensive inputs degraded conditions may persist for decades despite removal of agents of degradation (Milton *et al.* 1994, Fredrickson *et al.* 1996). In addition, arid landscapes are spatially heterogeneous in edaphic factors and vegetation characteristics such as seed source following disturbance. Characterizing vegetation dynamics in response to management practices in arid environments requires long term experiments that capture important temporal influences of infrequent, episodic events and an understanding of spatial influences across the landscape on those dynamics.

In 1938, United States Department of Agriculture scientists led by Mr. Ken Valentine established an experiment on the Jornada Experimental Range in south central New Mexico to evaluate effects of shrub removal from a degraded site dominated by *Larrea tridentata* Sess. & Moc. Ex DC (creosotebush). This experiment has been well maintained by USDA scientists over the past 65 years, and vegetation responses to these treatments have been published in recent years (Gibbens *et al.* 1993, Havstad *et al.* 1999). Vegetation responses were measured again in 2001 to assess long term variability in vegetation dynamics and to evaluate spatial influences of vegetation responses.

2. MATERIALS AND METHODS

The Jornada Experimental Range is located 37 km north of Las Cruces, New Mexico, USA. The specific study area is located on typic Paleorthid soils that have formed on an old alluvial fan. Long term average annual precipitation is 250 mm, with approximately 140 mm falling from early July through September. Further site description is provided in Gibbens *et al.* (1993). Vegetation is dominated by three primary shrubs – creosotebush, *Prosopis glandulosa* Torrey (honey mesquite), and *Flourensia cernua* DC (tarbush). Other important non-graminoids include *Parthenium incanum* H.B.K. (mariola), *Gutierrezia sarothrae* Pursh (broom snakeweed), and *Zinnia acerosa* DC (desert zinnia). The principal perennial grasses are *Bouteloua eriopoda* Torr. (black grama), *Sporobolus contractus* A.S. Hitch. (spike dropseed), and *Muhlenbergia porterii* (bush muhly).

In 1938 sixteen plots (four rows of four 21.3 m x 21.3 m plots) were established at each of two sites (Parker Tank and Gravelly Ridges). The original experiment consisted of four treatments: hand removal of shrubs severed at ground surface, furrowing (shallow, hand raked furrows designed to trap surface water), seeding (broadcast application of seeds of native perennials), and lagomorph exclusion. Livestock have been excluded from these study areas since 1938. All plots were sampled for shrub canopy cover and perennial grass basal cover using a line intercept transect method prior to initial treatment applications. All plots were resampled using the same methodology in 1947, 1960, 1967, and 2001. The shrub clearing treatment has been reapplied immediately following each sampling date. The vegetation cover data were analyzed using PROC GLM with a two-way analysis of variance (SAS Institute Staff 1996). Normal probability plots and Wilk-Shapiro test statistics from PROC UNIVARIATE were utilized to assess the normality of the residual values. For several grasses and shrubs, non-normality was detected. Analysis of variance was then repeated with ranked responses and normality of the residuals was reexamined. For black grama, the principle perennial grass species of interest, analyses were performed to assess the effect of treatments on percent cover expressed as categories of 0%, between 0 and 1%, and ≥1%. In 2002-2003, a 17 ha area around the Gravelly Ridges site was ground surveyed for location and distribution of black grama plants to evaluate responses over time of individual experimental plots at this one site given their spatial position within the larger landscape.

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3. RESULTS AND DISCUSSION

Repeated shrub removal (shrub cover ranged from 0 to 6% over the 62 year period) increased (P#0.05) basal cover of black grama and other perennial grasses. Black grama occurred on only 6 of the 16 intact shrub plots in 2001, and on 5 of those 6 plots black grama basal cover was <1% (Table 1). In 1947, over 90% of all plots contained at least some basal cover of black grama prior to an extended 6 year drought during the early to mid 1950s. Immediately after the drought in 1960, only 28% of the plots contained at least some black grama. However, by 2001, 44 years after the end of this prolonged drought, 56% of the plots that had been periodically cleared of shrubs contained black grama, while only 37% of the plots left intact contained at least some basal cover of black grama. Thus, plant community structure in this arid environment is strongly shaped by disturbance regimes, especially prolonged drought (Herbel and Gibbens 1996) and, secondly, by plant competition.

Table 1. Number of plots with black grama basal cover of either ≥1%, between 0 and 1%, or 0% on shrub cleared and uncleared plots at the Gravelly Ridges and Parker Tank sites in 1938, 1947, 1960, 1967, and 2001. Within each site, 8 plots were periodically cleared of shrubs and 8 plots were undisturbed from 1938 to 2001.

Year	Gravelly Ridges						Parker Tank					
	Shrubs Cleared			Shrubs Not Cleared			Shrubs Cleared			Shrubs Not Cleared		
	≥ 1%	>0 & <1%	0	≥ 1%	>0&<1%	0	≥ 1%	>0 & <1%	0	≥ 1%	>0&<1%	0
1938	0	8	0	0	6	2	6	2	0	3	5	0
1947	0	8	0	0	5	3	0	8	0	0	8	0
1960	0	4	4	0	0	8	0	1	7	0	4	4
1967	0	6	2	0	0	8	0	1	7	0	2	6
2001	1	6	1	0	3	5	0	2	6	1	2	5

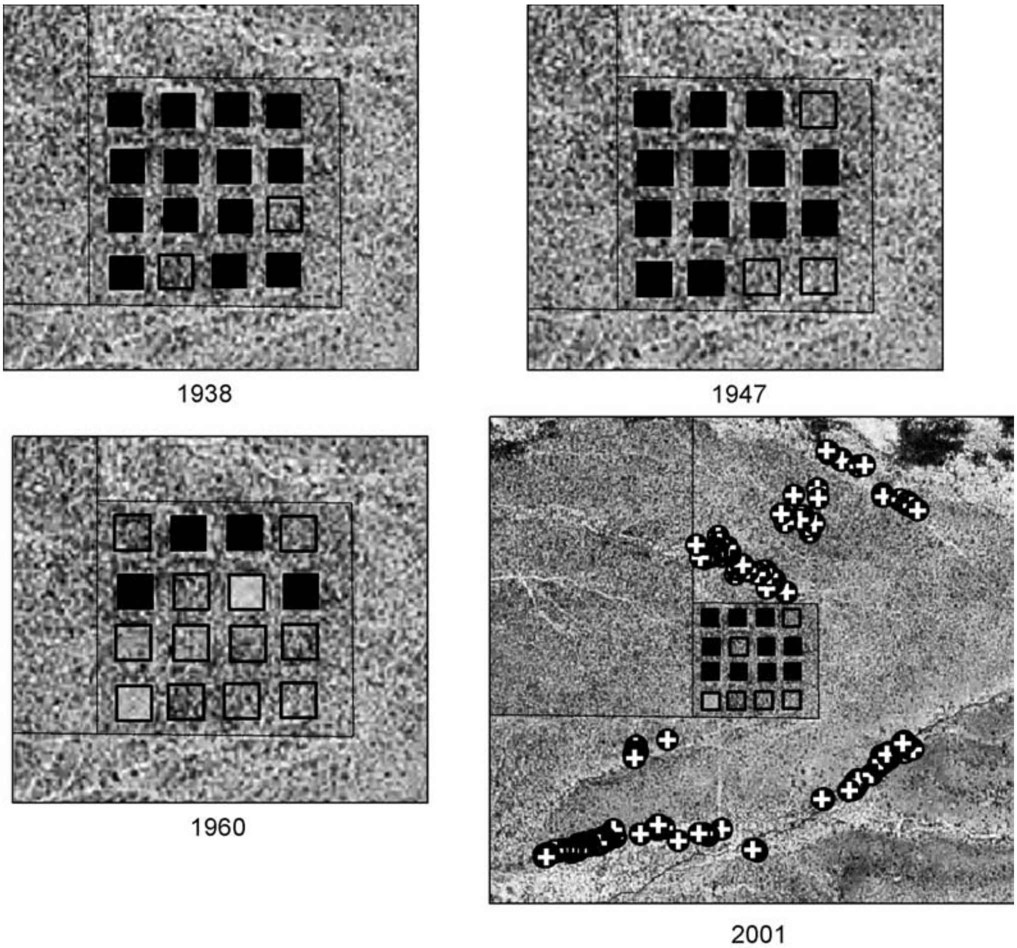

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Figure 1. Plots (outlined in black) within the Gravelly Ridges site that contained black grama (solid black) in 1938, 1947, 1960, and 2001. Spatial location of black grama plants across the landscape outside of the experimental plots as global positioned in 2002-2003 are represented by the symbol '+' in the 2001 aerial photograph. Experimental plots where black grama plants re-established from 1960 to 2001 were spatially adjacent to small arroyos where black grama plants had persisted over the past 6 decades.

The location of individual plots at the Gravelly Ridges site within the larger landscape also influenced black grama recovery following drought. Prior to treatment application in 1938, there were 14 plots at the Gravelly Ridges site which contained some black grama basal cover (Fig. 1). In 1947, prior to the extended and severe drought of the 1950s 13 plots still had black grama. After the drought in 1960 only 4 plots contained black grama, and in 2001 10 plots had some black grama. Black grama persisted around this experimental site in microsites where nutrient and soil water contents are expected to be greater than surrounding upland sites. Occurrence of black grama plants outside the study area at Gravelly Ridges in 2003 is shown in Fig 1. Study plots on the south end (bottom of the figure) of the experimental site still did not contain black grama 63 years after the study was initiated. Our results suggest that the major seed source for dispersal is outside the site and north of the study plots at Gravelly Ridges. Thus, re-establishment of black grama at the Gravelly Ridges site is dependant not only upon vegetation structure, but also upon spatial processes of seed dispersal.

Many studies on rangelands are conducted over time periods that are too short to capture the inherent spatial and temporal variability of these systems. Extreme or pulse events that result in infrequent responses are one example that requires long term data, but delayed response is another aspect that is less well-studied. Our objective was to examine the response of Chihuahuan desert rangelands following the removal of shrubs over a period of >60 years in order to capture both extreme events and delayed responses to treatments. Basal cover of perennial grass species responded to the shrub removal treatment. However, there were two important observations relative to this quantified response. First, differences were not evident for at least 50 years. Spatially explicit processes, such as seed dispersal into these experimental plots from adjoining areas, were likely the important constraint on reestablishment of perennial grasses (Fig. 1). Second, the temporal variability in basal cover of grasses and canopy cover of shrubs in control plots illustrate the inherent dynamics of this arid shrubland. An extreme and extended drought period occurred from 12 to 17 years after the experiment was established. This climatic variability masked treatment responses until nearly 50 years after they were first implemented. In this arid system, we need to consider not only the acute extreme disturbance but also the spatial context of the land area disturbed

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