

Thirty Years of Weather Change and Effects on a Grassland in the Peloncillo Mountains, New Mexico

By William H. Moir

In this paper I describe and compare grassland changes since 1977 at the Central Peloncillo Research Natural Area (CPRNA) with temperature and precipitation data from its nearby weather station. The grama grasslands there have thrived through two distinctive climate periods since 1977. The current period began with warm and dry years beginning around 1993 and continuing to the present. The cover, frequency, and diversity of herbs and shrubs in this grasslands have been precisely measured from permanently marked transects in 1977, 1984, 1996, 2002, and 2007. The grasslands flourish despite year-to-year and seasonal weather fluctuations. Because grasslands in the Southwest are so variable, the dynamics of this grassland cannot be generalized elsewhere, nor is their future maintenance a certainty; but there are reports of long-term, persisting “relict” or “recovered” grasslands without management intervention in from other locations in southern New Mexico, Arizona, and western Texas.

Introduction

It is well known that plant productivity in grasslands is affected by weather patterns. Yearly precipitation is often singled out to predict annual biomass yields. However, most reports from grasslands in the Southwest also conclude that effects of precipitation are modified by management practices such as wildlife or livestock grazing, fire regulation, range restoration, control of invasive herbaceous or woody plants, and reduction of soil compaction or erosion.¹⁻⁵ I first described the grama steppe and its environment in 1979.⁶ New information and advances in rangeland ecosystem knowledge prompted this report describing vegetation responses to weather patterns along with collateral observations of some of the factors affecting grassland vitality and maintenance.

Using data from a weather station established in 1977 near the grama grassland, I describe an interval of wet, cool

years changing to a dry, warm, continuing drought. Then I describe the grama steppe, which had been measured and remeasured from 1977 to 2007 from three monitoring locations. The factors cited above have been defined, controlled, or measured for at least 30 years. In addition, the soil studies, grazing practices, lack of wild or prescribed fires, and plant diversity of the grassland present an argument—for this example, at least—as to why this particular grassland is more-or-less resilient and without clear overall trends to varying precipitation and temperature regimes over the three decades. The data also show, even with these other factors accounted for at some gross level, that weather changes and vegetation response remain unclear in detail. Perennial grasses appear and disappear, increase or decrease, or have abrupt peaks. Shrubs come and go—or keep out. Senescent grass clumps are common in some years but are replaced entirely with vigorous clumps by 2007. Despite its apparent resilience, there is otherwise no overall striking or trendy response of this grassland to the two very distinctive climatic episodes. But, as I will conclude, some common or popular ideas about grassland management do *not* apply. This example stands at a threshold of climatic and biotic uncertainty, and there is no prevailing or compelling management truth about what works best for preserve or wildlife managers or ranchers of the Malpais Borderlands.^{7,8}

The Grama Steppe Grassland

The grassland is a grama steppe at the Bioresearch Ranch in the Peloncillo Mountains, Hidalgo County, New Mexico (transect 16 is at lat 31°43'54.2" N, long 108°58'53.2" W), managed as a research natural area.⁹ The vegetation satisfies descriptions of desert grassland¹⁰ but lacks key plants of desert affinity or desert-grassland transition such as creosote bush (*Larrea tridentata*). The elevation of the grassland at 1,570–1,720 m (5,150–5,650 feet) places it well above grasslands that border Sonoran or Chihuahuan deserts.



Grama steppe at Central Peloncillo Research Natural Area near transect 16, January 2011. The stick at white-thorn acacia (*Acacia constricta*) is banded at 1 and 2 m above the soil surface. This shrub is more dense and taller in the right background near the southeastern edge of the alluvial fan where soil erosion occurred.

The rhyolitic landform of this grama steppe is an intracanyon alluvial fan apparently deposited in the late Holocene.¹¹ The fan is mostly inactive as an alluvial deposit because entrenched washes divert runoff from adjoining slopes that might otherwise braid its surface, create rills, or cause sheet erosion.¹² The gravelly, coarse-loamy texture of the deep soils (Aridic Haplustolls on the upper fan, Typic Haplustolls on the lower fan) are, in effect, sponges soaking up on-site precipitation. The exception is the southeastern edge of the fan at its lower elevation. An erosion slope is characterized by rills and small gullies, a cobbly and uneven soil surface, and a dominant population of shrubs, mostly established before 1972.

Livestock grazing on the grama steppe had a long but undocumented history specific to this study area.⁶ However, all livestock were withdrawn in 1972, and except for occasional but inconsequential trespass cattle, there has been no herd grazing since. No wild or prescribed fire has been known to have taken place at least for 100 years and probably even longer (Bill Miller, Sr., private oral communication to the author in 1974).

Methods

Weather

In August 1977, the National Weather Service cooperative weather station at Rodeo, New Mexico, was discontinued. The instrument shelter, min/max thermometer, and six-inch rain gauge were reestablished at the Bioresearch Ranch. National Weather Service protocols for daily reading and recording temperature and precipitation began at that time. The station was located at 1,575 m (5,170 feet) elevation in an emory oak savanna, about 300 m (1,000 feet) from the center of the grama steppe tract.

Before 1988, there were months in which daily readings were missed. When five or fewer days were missed, monthly summaries were adequate, if not exact, given the accumulative nature of the instruments. If more than five days were missed, then the month's temperatures become approximate, depending on how many days and how long the missing periods extended. Total monthly precipitation might be affected, but less so because the bucket stores water from previous events, until emptied. Most months over the 30-year period had no missing days, and about a dozen had only one or two missed daily recordings.

Vegetation

I measured vegetation using canopy coverage from three permanent transects initially established to measure soil erosion.^{4,13,14} Transects 14 and 15 were at the upper third of the alluvial fan and transect 16 near the lower edge. Each transect was 30 m in length. Canopy cover for each species was measured in 2 × 5 dm quadrats spaced at 1 m intervals. Cover of each species was averaged from the 30 quadrat frames in each transect. Plant vouchers were collected and deposited at various herbaria.¹⁵ I report measurements from August to early October in 1977, 1984, 1996, 2002, and 2007. Because there were only three transect samples in the grama steppe and only five years monitored (totaling 12 sample years), statistical trends or other comparisons were not made. However, when combined with seven other transects in other grasslands of the Bioresearch Ranch, I report relevant statistical results computed by John A. Ludwig.¹²

Plant diversity over the entire grama steppe was gradually accumulated from plants collected over the years by various botanists. I made collateral observations of termite activity in each quadrat in 2002, a wet summer, and in all years made notes of foliage clipped by wildlife and qualitative observations



Grama steppe looking downslope from alluvial fan in upper Post Office Canyon at the Bioresearch Ranch, January 2011. The stick at the end of transect 15 is banded at 1 m and 2 m above ground. The reddish grass is Texas bluestem (*Schizachyrium cirratum*).

Table 1. Mean annual temperature and total annual precipitation during two climatic periods

Years	Mean	Std dev.	t*
Temp. (°F)			
1978–1992	58.0	0.7	
1993–2007	60.6	1.0	0.00
Precip. (inches)			
1978–1992	20.1	3.7	
1993–2007	15.2	3.4	0.00
July–Sept. (monsoon)			
1978–1992	3.1	1.8	
1993–2007	2.5	1.4	0.07

* Two-sample, equal-variance Student's *t* test.

of fecal pellets of lagomorphs, deer, and otherwise unidentified small mammals.

Results

Weather Patterns

The climate summary of research natural area (Table 1) reveals two climatic periods. A two-sample, equal variance Student's *t* test indicated that mean annual temperature (MAT), total annual precipitation (TAP), and summer (monsoonal) rainfall were significantly different in each period. The first period, 1978 to 1992, was relatively wet and cool. A warming trend began in 1987 (MAT = 56.7°F) and carried into the second period of warm and dry years from 1993 to 2007. Within this period a record low TAP of 9.0 inches/year occurred in 2003 and a high year of 23.5 inches/year in 1997. Except for that high year, most other years were well below the TAPs of the first period. A cool year (58.2°F) in 1998 was the only year dipping to the levels of period 1. The warmest of the 30 years were 1994 and 2002, both with MATs at nearly 62°F. Long heat waves occurred 24 June–16 July 1994, and again 14 June–20 July 2005, both with average daily maximum temperatures of 97.5°F and numerous, consecutive days over 100°F.

Vegetation

Consider 1977 as a threshold year. That year established a baseline of cover—whatever the history of vegetation cover dynamics during previous years and whatever were the climatic and other environmental influences that influenced the baseline before 1977 (Tables 2 and 3). From that threshold, vegetation entered the cool–wet period (sampled in 1984) and then the warm–dry period (sampled in 1996, 2002, 2007). The year 2007 saw an average decline (26%) in total vegetation cover from 1977. But there was no overall trend in vegetation change during the 30 years. For example,

at transects 14 and 15 total cover was about the same in 2002 (a wet summer) as in 1977. Overall, total vascular plant cover ranged from 14% to 78% over the 12 transect year measurements. Perennial grasses ranged from 47% to 93% of the total cover, and woody shrubs from 4% to 43% of the total cover. But various components of vegetation exhibited differing responses over the two climatic periods.

Grasses. From the baseline year nearly all grasses greatly declined in cover in 1984, a year within the wet–cool period. I offer no explanation for this counterintuitive decline, but see the work of Ludwig et al.⁴ for similar results at Otero Mesa, New Mexico. By 2007 total grass cover had not reached its average threshold total of 51%. The first impression is that grass cover never recovered its high threshold level; but, given the high variability of cover from year to year and place to place, that impression can be misleading. For example, in each transect there were grass species that exceeded or about equaled their 1977 cover in one or another subsequent monitoring year. Rather than a trend or real decline of grasses there may be a kind of persistence with ups and downs. These responses, including apparent declines in some monitoring years, seemed affected mostly by seasonal precipitation patterns of the monitoring year and the year before (I cannot analyze this rigorously on sparse data).

The diversity of grasses (Tables 2 and 3), each responding differently to the 30-year climate variations, may help explain the fluctuating persistence of *native* grasses through a drought.¹⁶ The leading dominant grass, side-oats grama (*Bouteloua curtipendula*), was reduced to approximately half its cover in 1977. If I include the other grassland monitoring sites at the Bioresearch Ranch into the analysis, the decline by 1996 was significant at the 5% probability level.¹² However, side-oats grama did not significantly decline at Santa Rita grasslands in southeastern Arizona during the drought years that followed.¹⁷

I could not analyze the following grasses statistically since they occurred in so few transects. Hairy grama (*Bouteloua hirsuta*) fluctuated sharply and nearly disappeared in all transects. Texas bluestem (*Schizachyrium cirratum*) more or less increased (transects 14 and 15). The cover of blue grama (*Bouteloua gracilis*, transect 16) remained about the same in 2002 and 2007 as 1977. Tanglehead (*Heteropogon contortus*) did not occur in transects in 1977, attained 7% cover in transect 15 in 1996, and disappeared from transects altogether by 2007 (it remains in the steppe). Cane bluestem (*Bothriochloa barbinodis*) had peaks in the baseline year but was generally minor thereafter, although not disappearing. Black grama (*Bouteloua eriopoda*), restricted to Typic Haplustolls of transect 16, consistently declined, another counterintuitive result since this is a grass more prevalent at lower elevations (and thus drier, hotter grasslands). Nevertheless, this grass declined as well at the Santa Rita Range.¹⁷ Lehmann lovegrass (*Eragrostis lehmanniana*) was merely present in the grama steppe but was not found within three meters of any



Grama steppe on alluvial fan at the Bioresearch Ranch, upper Post Office Canyon, January 2011. The reddish grass is Texas bluestem (*Schizachyrium cirratum*). The scale is near a sotol bush (*Dasyliirion wheeleri*).

transect. It remains abundant along the road that crosses the fan near its lower elevation.

Other collateral observations seem important. Prior to 2002, many large grass clumps had dead centers,¹² and there were only a few smaller clumps without dead centers. In 2007 there were *no* clumps with dead centers, nor *any* sign of senescent grasses with dead centers. In 2002 about 8% of the quadrats had termite castings in the aboveground dead foliage. Other quadrats may have had castings too, but they crumble easily and were not clearly noted. Unfortunately collateral termite observations within quadrats were not recorded in earlier years.

Woody plants. Woody plants comprised 4–43% of the total vegetation cover over the 12 transect years. Only in transect 15 was there an increase in woody plant cover in 2007 from that of 1977, due primarily to white-thorn acacia (*Acacia constricta*). However, including other grassland monitoring sites in analysis, the fluctuations in white-thorn acacia in 1977, 1984, and 1996 were not significant.¹² In all three transects of the grama steppe the proportion of woody plants remained at about the 1977 level, and *Acacia* was more or less unimportant. However, this shrub does have invasive potential. The evidence for this is seen in the eroded section on a southeastern portion of the fan. Here the soil surface is laced with rills and shallow gullies, and check dams established in these gullies in the 1970s are back-filled with sediments from both local sheet erosion and more distant gully erosion. Judging from the size and longevity of large shrubs, this area (east of transect 16) has long been dominated by white-thorn acacia mostly established in the livestock grazing era before 1972. In some places the shrubs formed thickets with sparse grasses beneath.

Generally, however, there is slight evidence that woody shrubs are increasing elsewhere or replacing perennial grasses. Because of the few transects, however, only the

decline of snakeweed (*Gutierrezia*) was significant at the 5% probability level.¹² Snakeweed had only trace cover in the grama steppe transects and was included in the “other” category of Table 3. Velvet mesquite (*Prosopis velutina*) also declined within the steppe, and the litter remains of sotol (*Dasyliirion wheeleri*), turpentine bush (*Ericameria laricifolia*), and century plant (*Agave palmeri*) occurred along or very near one or more transects. The occurrence of burroweed (*Isocoma tenuisecta*) not far from transect 16 is interesting. This low shrub is invasive and widespread in nearby live-stock grazed lands and elsewhere.^{10,12} Individuals are common along the road through the lower elevation of the steppe fan but have not yet been found within the steppe. Similarly, turpentine bush and catclaw minosa (*Mimosa aculeaticarpa* var. *biuncifera*) are both dominant on alluvial rangelands below the fence adjoining this grama steppe. The former had much dieback throughout the region, but many shrubs whose older foliage yellowed and that otherwise displayed low vigor during the drought nevertheless recovered after good summer rains in 2002. The mimosa occurs in the above-mentioned *Acacia* area but is rare in the noneroded soils of the grama steppe. Only mariola (*Parthenium incanum*) and oreganillo bush (*Aloysia wrightii*) seem to be locally increasing from patches of soil churned by wildlife near transect 15. The widespread low shrub, bastardsage (*Eriogonum wrightii*), seldom recovered its high cover values of 1977. Its dieback can be attributed to interactions of drought, herbaceous competition (particularly shading by overtopping grasses), and occasional browsing by deer.

Forbs. Numerous forb species (broad-leafed herbs in contrast to grasslike herbs), both annuals and perennials, are found in the grassland (Table 2) and may have episodes of local abundance during one or more years (whether or not a monitoring year). Some are “winter” forbs with greatest cover around April or early May and are thus underestimated or omitted from Table 2. Forbs are a generally insignificant in cover, except for erratic and seasonal “explosions” of annuals, such as carpet weed (*Drymeria molluginosa*) during episodes of good winter moisture or summer rains. The lowest cover of forbs was, like the grasses, in 1984. The most common perennial each year was leatherleaf croton (*Croton pottsii* var. *pottsii*), whose cover fluctuated throughout the years without meaningful gains or losses. Perennials such as deervetch (*Lotus plebius* and *Lotus greenii*) were common at the end of the period. These are nitrogen fixers observed to be important to lagomorphs, rodents, and white-tailed deer that feed here (defoliated plants and the droppings of animals that feed on them were frequent in the transect areas and throughout the grassland). The diversity and ubiquity of forbs in all years suggests their ecological importance despite overall low coverage compared to grasses.^{2,18,19}

Factors of Grassland Maintenance Are Often Local

Good examples of native grasslands in the Southwest are sometimes found as isolated fragments of landscapes that

Table 2. List of plant taxa observed or collected in the grama steppe

Grasses and grasslike plants
<i>Aristida adscensionis</i> L.
<i>Aristida divaricata</i> Willd.
<i>Aristida ternipes</i> Cav. var <i>ternipes</i>
<i>Aristida schiedeana</i> var <i>orcuttiana</i>
<i>Bothriochloa barbinodis</i> (Lag.) Herter
<i>Bouteloua curtipendula</i> (Michx) Torr.
<i>Bouteloua eriopoda</i> (Torr.) Torr.
<i>Bouteloua gracilis</i> (Willd.) Lag. ex Griffiths
<i>Bouteloua hirsuta</i> Lag.
<i>Cyperus fendlerianus</i> Boeckl.
<i>Digitaria californica</i> (Benth.) Henr.
<i>Digitaria pubiflora</i> (Vasey ex L.H. Dewey) Wipff
<i>Eragrostis intermedia</i> Hitchc.
<i>Eragrostis lehmanniana</i> Nees.
<i>Elyonurus barbiculmus</i> Heck.
<i>Heteropogon contortus</i> (L.) Beauv. ex R&S
<i>Leptochloa dubia</i> (HBK) Nees.
<i>Lycurus phleoides</i> Kunth
<i>Muhlenbergia emersleyi</i> Vasey
<i>Panicum obtusum</i> HBK
<i>Schizachyrium cirratum</i> (Hack.) Woot. & Standley
<i>Setaria vulpiseta</i> (Lam.) Roem. & Schult.
<i>Urochloa arizonica</i> (Schrib. & Merr.) Morrone & Zuloaga
Woody plants
<i>Acacia constricta</i> Benth
<i>Aloisia wrightii</i> Heller ex Abrams
<i>Dasyllirion wheeleri</i> Wats.
<i>Ericameria laricifolia</i> (Gray) Shinnery
<i>Eriogonum wrightii</i> Torr.
<i>Gutierrezia microcephala</i> (DC) A. Gray
<i>Isocoma tenuisecta</i> Greene*
<i>Mimosa aculeaticarpa</i> var <i>biuncifera</i> (Benth) Barneby
<i>Parthenium incanum</i> HBK
<i>Prosopis velutina</i> Wooton
<i>Rhus virens</i> Lindh. ex Gray var <i>coriophylla</i> (W&S)
<i>Senecio flaccidus</i> var <i>flaccidus</i> Hack
<i>Yucca schottii</i> Engelm.

Table 2. Continued

Succulents
<i>Agave palmeri</i> Engelm.
<i>Coryphantha scheeri</i> var <i>robustispina</i> (Schott) L. Benson
<i>Echinocereus fendleri</i> (Engelm.) F. Seitz
<i>Echinocereus rigidissimus</i> (Engelm.) Haage f.
<i>Mammillaria heyderi</i> var <i>macdougalii</i> (Rose) L. Benson
<i>Opuntia</i> Mill. spp.
<i>Cylindropuntia spinosior</i> (Engelm. & Bigel) Toumey
Broad-leaved herbs (forbs)
<i>Acacia angustissima</i> (Mill.) Kuntze
<i>Amaranthus palmeri</i> Wats.
<i>Chaetopappa ericoides</i> (Torrey) Nesom
<i>Chamaecrista leptademia</i> (Greenm.) Cockerell
<i>Chamaesyce albomarginata</i> (T&G) Small
<i>Chamaesyce revoluta</i> (Engelm.) Small
<i>Chamaesyce vermiculata</i> (Raf.) House
<i>Croton pottsii</i> var <i>pottsii</i> (Klotz.) Muell.-Arg.
<i>Desmanthus cooleyi</i> (Eaton) Trel.
<i>Drymaria molluginea</i> (Lag.) Didr.
<i>Erigeron nudiflorus</i> Buckl.
<i>Euphorbia dentata</i> Michx.
<i>Euphorbia bilobata</i> Engelm.
<i>Evolvulus sericeus</i> Swartz
<i>Ipomoea</i> spp.
<i>Lotus greenei</i> Ottley ex Kearney & Peebles
<i>Lotus plebeius</i> (Brand) Barneby
<i>Machaeranthera scabrella</i> (Greene) Shinnery
<i>Pectis longipes</i> Gray
<i>Polanisia dodecandra</i> ssp <i>trachysperma</i> (T&G) Iltis
<i>Proboscidea parviflora</i> (Woot.) Woot. & Standl.
<i>Rhynchosia senna</i> var <i>texana</i> (T&G) M. C. Johnston
<i>Sanvitalia abertii</i> Gray
<i>Solanum elaeagnifolium</i> Cav.
<i>Stephanomeria thurberi</i> Gray
<i>Tetradlea coulteri</i> Gray
<i>Tragia ramosa</i> Torrey
<i>Zinnia grandiflora</i> Nutt.
* Only on disturbed soil along road.

Table 3. Canopy coverage (%) by date and transect of vascular plants in the grama steppe. Subtotals are rounded to the nearest percent. Blanks indicate the plant was not sampled (or missed) in the 30 quadrat frames along each transect

Plant taxa	Transect 14				Transect 15					Transect 16			Avg. (%)	Const. (%)
	Aug. 1977	Aug. 1984	Sept. 1996	Oct. 2007	Aug. 1977	Aug. 1984	Sept. 1996	Sept. 2002	Oct. 2007	Aug. 1977	Sept. 2002	Oct. 2007		
Graminoids														
<i>Bouteloua curtipendula</i>	27.0	8.9	2.0	8.7	32.0	3.2	3.9	8.4	13.5	18.0	11.2	8.2	12	100
<i>Bouteloua hirsute</i>	18.0	7.2	34.7	0.1	11.0	3.5	10.7	0.5	0.1	8.0	0.1	0.0	8	100
<i>Schizachyrium cirratum</i>	4.0	4.1	8.8	8.9	4.0	0.6	14.9	9.6	6.9	0.0	0.1	0.0	5	100
<i>Bothriochloa barbinodis</i>	1.0	0.4	0.5	5.1	14.0	2.2	0.1	0.1	0.5	11.0	0.0	0.0	3	100
<i>Aristida</i> spp.	0.6	0.4	0.1	4.1	3.5	0.1	0.2	0.7	0.7	4.3	2.1	1.1	1	100
<i>Bouteloua gracilis</i>				0.0	0.0		0.1	0.1		17.0	15.3	21.9	5	58
<i>Urochloa arizonica</i>	0.1		1.5	0.6			1.3	31.3	0.2		1.0	1.4	3	50
<i>Bouteloua eriopoda</i>										7.0	2.0	0.5	1	25
<i>Heteropogon contortus</i>							7.3	0.1					1	17
Other graminoids*	0.4	0.2	0.0	0.0	0.9	0.0	0.0	0.0		0.8	1.0	0.1	0	
Graminoids subtotal	51	21	48	28	65	10	39	51	22	66	33	33	39	
Succulents*														
Succulents subtotal	1		0	0	0		0	0	0		0	0	0	
Woody plants														
<i>Eriogonum wrightii</i>	9.0	3.6	11.5	1.1	6.0	3.3	6.0	1.2	0.6	3.0	0.0	0.0	4	100
<i>Ericameria laricifolia</i>	0.0		0.5		0.0		0.1	0.0	0.0	0.0	0.0		0	67
<i>Acacia constricta</i>				2.2	0.0		3.1	6.3	13.2		0.0	0.5	2	58
<i>Parthenium incanum</i>	0.0		0.0	0.0	0.0		0.0	1.3	2.1				0	58
<i>Aloysia wrightii</i>			0.0	0.5	0.0		0.0	0.0	8.0				1	50
<i>Prosopis velutina</i>							0.0			0.0	7.3	1.3	2	33
Others*	0.1		0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0	
Woody plants subtotal	9	4	12	4	6	3	9	9	24	3	7	2	8	
Forbs														
<i>Croton pottsii</i> var. <i>pottsii</i>	10.0	1.5	1.7	9.1	6.0	0.4	4.8	1.7	4.0	1.0	9.6	6.6	5	100
<i>Tragia ramose</i>	0.0		0.0		0.1	0.1	0.5	0.6	0.5	0.0	0.1	0.1	0	83
<i>Lotus</i> spp.				5.2	0.1	0.0	0.1		5.5			0.9	1	50
<i>Solanum elaeagnifolium</i>	0.1		0.0	0.0							0.5	0.0	0	42
<i>Drymaria molluginea</i>								5.4			17.5	0.0	2	25
Others*	0.8		1.7	0.2	0.3	0.1		1.5		0.6	1.7	0.0	1	
Forbs subtotal	11	2	3	15	7	1	5	9	10	2	29	8	8	
Total (all vascular plants)	72	26	63	46	78	14	53	69	56	71	70	43	55	
% graminoids	71	81	76	60	84	71	72	74	39	93	47	78	71	
% woody plants	13	14	19	8	8	24	17	13	43	4	11	4	15	

* For lists of other graminoids, succulents, woody plants, and forbs, see Table 2.

somehow escaped or recovered from regionwide excesses of livestock and wildlife grazing of the last 150 years.¹⁶ Such is the case in this study. Usually the floras of these fragments differ from floras described from much-published examples of grasslands at research and experimental ranges or areas withdrawn from livestock grazing such as the Jornada del Muerto, Santa Rita Experimental Range, Otero Mesa, Big Bend National Park, or the Appleton-Whitell Research Ranch. Certainly the environments and historical uses differed in all these areas and so too the ecosystem dynamics. What is to be learned from *this* grama steppe?

A partial answer is that sometimes very little is learned, especially if borrowed conclusions are from poorly designed studies or biases against livestock grazing practices in general.⁷ However, livestock management was not an issue in locating the monitoring plots. Neither “overgrazing” nor “undergrazing”—epithets usually assigned to livestock management—accounted for plant cover or vigor over the 30 years. Another partial answer is that we can learn little if the fragments are so small and isolated that their genetic complement is compromised by inbreeding, genetic drift, and strong environmental variations (stochasticity). The grama steppe is neither that small nor isolated to that degree. All the vascular plants are widely distributed at the CPRNA, on adjoining ranches, and throughout the Borderlands. I suspect that most connective routes to and from this tract are porous to local and distant movements of most plants and animals. As for environmental stochasticity, this study shows recent climatic variations, although perhaps not the extremes possible upon longer-term regional or global warming. However, it is clear from nearby soils and landforms that plant composition and structure would change rapidly should soils erode at rates faster than past geophysical erosion¹²—a possible by-product of long-term climate change should weather extremes intensify.

I now turn to more concrete conclusions. It is clear that fire was not required to maintain this grama grassland from shrub invasion or to invigorate grass production. The senescent grass clumps were gone in 2007. Biomass turnover, nutrient cycling, and microsuccession were facilitated to some extent by termites¹⁹ and by large and small wildlife as herbivores.

Livestock herd grazing can be beneficial to grasslands,³ but examples of grassland maintenance without *any* history of domestic livestock are also reported. A grassland with minimal soil erosion, high floristic diversity, and locations never apparently grazed by domestic livestock was described from Otero Mesa, New Mexico.⁴ Perhaps the most similar example is Dutchwoman Butte on the Tonto National Forest, Arizona.¹³ That grassland, dominated by side-oats and hairy grammas and plains lovegrass (*Eragrostis intermedia*), occurred on noneroded, well-drained Aridic Argiustoll soils near the lower woodland region at 1,220–1,525 m (4,000–5,000 feet) elevation. The vegetation structure and canopy cover of grasses were within the measured range

of the grama steppe. According to the authors the most striking aspects of Dutchwoman Butte were the diversity, density, and vigor of the grasses. What the grama steppe and these other examples have in common are noneroded soils with minimum soil surface disturbance, high floristic diversity, few nonnative or invasive plants, and in situ processes for maintaining plant vigor.

Invasive and other plants considered “undesirable” to range managers are not advancing into the grama steppe. Perhaps white-thorn acacia is restrained only so long as soils remain uneroded. Similarly, other undesirable plants discussed above did not “invade” in either climate period. And no management action was needed to improve the grassland for whatever purpose. Along with high plant diversity the other factors in sustainability are soil stability and biomass turnover via the guts of native animals both large and small.

Persistence and the Future

In this article, I show that the grama steppe thrived from a relatively wet-cool climatic period into and through a warm, droughty period. Given the overall sensitivity of grassland ecosystems to such variability and the continuing “natural area” management of the Bioresearch Ranch, climate will continue to be the overall determinant of grassland expression from year to year. In the near future if climate variability remains in the ballpark of the figures in Table 1, the grassland will probably look much as described here. However, grassland ecosystems have a dynamic influenced by a large degree of uncertainty.⁸ One cannot be complacent looking more than a few decades ahead. Distant prospects of future conditions are already expressed nearby. Most important, I feel, is the uncertainty of climate change itself, extending beyond the parameters of the last 30 years. Of course, this grassland will respond, but not in ways one might anticipate. Something might trigger a spread of white-thorn acacia, Lehmann lovegrass, burrow weed, or some unsuspected introduced plant lying in wait at the threshold. An abundance of small mammals might be attracted by future vegetation cover and plentiful food here.¹⁸ A wildfire could introduce new plants from the soil seed bank. An episode of accelerated soil erosion might be in the roll of the dice. Or we may find unforeseen effects of human activity on lands that adjoin the steppe, including land ownerships on other sides of fences where major changes of management will doubtless occur.

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Author is Research Ecologist (retired), USDA Forest Service, Box 253, Trinidad, CA 95570, USA.