

Mesquite-Grassland Ecotones in the Chihuahuan Desert

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Abstract—Many plains and uplands of the Chihuahuan Desert in southern New Mexico are in transition from a perennial desert grassland to a mesquite (*Prosopis glandulosa*) dominated shrubland. On the Chihuahuan Desert Rangeland Research Center north of Las Cruces, from 1982 to 1996, mesquite aerial cover increased from 1.9 to 4.5% and density increased from 123 to 176 plants ha⁻¹, with recruitment averaging 3.5 plants ha⁻¹yr⁻¹. Shrubs encroach into grasslands by individual plants becoming established and, over time, creating patches of mesquite. These patches expand into islands of mesquite with a greater biodiversity than the surrounding grasslands. The mesquite islands eventually coalesce into the mesquite "front" and biodiversity decreases. Thus the current grass-shrublands may best be considered as ecotones, both spatially and temporally.

Today the former grasslands on the uplands in the Jornada Basin in southern new Mexico are in transition to becoming desert scrublands, dominated by mesquite (*Prosopis glandulosa* Torrey). These changes are of such a magnitude that much of the plant and animal diversity associated with grasslands will be lost or at least diminished. There have been many writings and ideas put forth as to why this change is taking place. Much of the change has occurred since the start of large-scale ranching in the latter part of the 19th century (Buffington and Herbel 1965). But, there is disagreement about the actual effect of livestock grazing on the spread of shrubs into the grasslands. Overgrazing is often considered to be the primary culprit (York and Dick-Peddie 1969, Schlesinger and others 1990). Humphrey (1950), and Brown and Archer (1987) stated it was not overgrazing, but rather the encroachment resulted from livestock consuming the seeds and spreading them through their fecal droppings. Humphrey (1958) noted that there were many possible factors responsible for the increase in woody vegetation, but he proposed that fire was primarily responsible for maintaining the desert grasslands and attributed the spread of mesquite to lack of fire resulting from grazing removing the fine fuels necessary to carry fire. Reynolds (1950) found that Merriam kangaroo rats (*Dipodomys merriami merriami* Mearns) bury mesquite

seed in caches that are not all used in favorable years, and this helped the mesquite spread into grasslands.

Another idea that has been proposed is climate change. Hastings and Turner (1965) suggested that the increase in woody vegetation was because the climate was becoming warmer and drier. Neilson (1986) proposed that the increase in shrubs was because of more winter moisture favoring establishment of C₃ plants. Mayeaux and others (1991) suggested that the world-wide increase of atmospheric CO₂ in the last 150 years resulting from industrialization, automobile emissions, etc., has given competitive advantage to plants with C₃ photosynthetic pathways (shrubs) over those plants with C₄ photosynthetic pathways (desert grasses). However, Archer and others (1995) refuted rather convincingly the idea that an increase in atmospheric CO₂ was primarily responsible for woody plants moving into grasslands.

Clements (1934) considered the grasslands in the Jornada Basin to be a climax desert plains grassland. Shreve (1917) in an earlier paper considered the Jornada grasslands to be a transition between the mixed grasslands to the east and the Chihuahuan Desert to the south and west. Perhaps Shreve correctly recognized the changes taking place in the region by calling the grasslands a transition, a view point endorsed by Dick-Peddie (1993). The increase of mesquite and other woody plants in the region may reflect vegetation changes already set in motion prior to European settlement and have been hastened by livestock grazing, industrialization, etc. The grasslands may represent environmental conditions that no longer exist (Selleck 1960).

Whatever the cause, mesquite continues to invade and establish in the black grama [*Bouteloua eriopoda* (Torrey) Torrey] grasslands (Gibbens and others 1992). The purpose of this paper is to look at the process of the invasions. We propose that this ecotone between the grassland and mesquite is not a distinct line, but rather individual mesquite plants becoming established in the grasslands ahead of the "front," and often forming "patches," which allows the mesquite to spread in leaps and in uneven patterns.

Study Area

The study was conducted on a 10 km² area on the Chihuahuan Desert Rangeland Research Center located 40 km north of Las Cruces, New Mexico. This particular area was chosen because it represented an ecotone between dense mesquite and a grassland with little or no mesquite present. The climate of the region is characteristic of an arid, continental interior with summer maximum temperatures frequently exceeding 35° C and the daily minimum

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near 20° C. Daily minimum temperatures in winter are generally below freezing with daytime maximums 15° C warmer. The frost-free period is about 200 days. Spring is the driest and windiest season. Wind during the remainder of the year is generally associated with storms. Long-term (1931-1996) average annual precipitation is 234 mm (fig. 1). The primary growing season is from July through September when 125 mm (53%) of precipitation falls. Another small peak of precipitation occurs, sometimes as snow, in December-January.

The landscape of the study area is characterized by a nearly level plain about 1,400 m above sea level with slopes less than 2%. Scattered across the plain are occasional shallow depressions, varying in size from 0.5 to 2-3 ha. Soils on the plain are generally petroargids, which have a thin layer of sand deposited by wind over a moderately developed argillic horizon. Total depth to a petrocalcic horizon is less than 1 m. Within the depressions, soils generally have greater clay content with a greater depth to a petrocalcic horizon, if one exists.

Potential vegetation for the site is a black grama grassland. The aspect of the plain varies from an open, mixed grassland with an occasional single mesquite and sometimes clumps of mesquite along with other shrubs (mainly *Ephedra* spp. and *Atriplex* spp.) to dense mesquite stands. The depressions in the landform tend to support heavier stands of mesquite and soap tree yuccas (*Yucca elata* Engelm.) with a grass-forb understory (fig. 2). The general area is currently in a lower seral stage dominated by mesquite, broom snakeweed [*Gutierrezia sarothrae* (Pursh) Britton and Rusby] and several perennial grasses, including mesa dropseed [*Sporobolus flexuosus* (Thurb. Ex Vasey) Rybd.] and threeawns (*Aristida* spp.). Many other grasses and forbs are common in seasons of average or greater precipitation.

All of the study area is grazed lightly by cattle, 20 - 25% use on dominant grasses, during the year. Pronghorn antelope (*Antilocapra americana*) are frequently seen and the

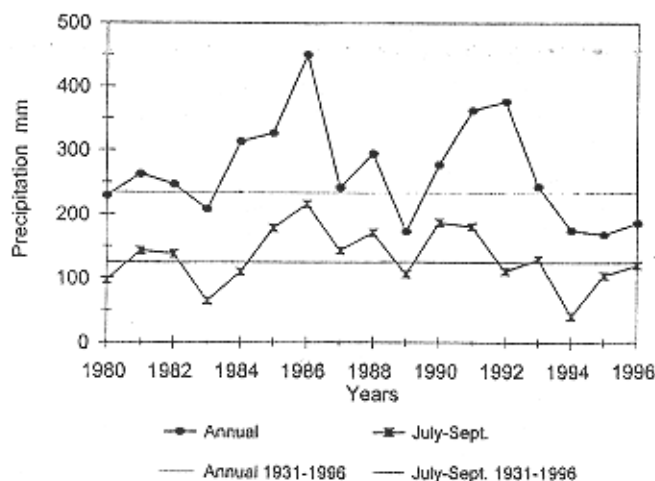


Figure 1—Annual and seasonal (July - September) precipitation from 1980 to 1996 and long-term annual and seasonal precipitation from 1931 to 1996 in the northern Chihuahuan Desert.



Figure 2—Mesquite growing in a shallow depression on the Jornada Basin. Note presence of different size of shrubs and grass clumps in the interspaces. Note also the grass aspect and individual mesquite plants growing on the hillside behind the cattle.

introduced gemsbok (*Oryx gazella*) are occasionally sighted on the study area.

Methods

The data used for this paper were collected from 14 permanent, randomly located transects in 1982, 1988, 1993, and 1996. Each transect was 61 m long. An estimate of perennial grass production was obtained by clipping 5 linear plots, 6 m by 5 cm, along each transect. Only the current year's growth was clipped from plants rooted in the plots. The plant material was separated by species, oven dried, and weighed. Each transect was moved to the side a minimum of 30 cm each year to avoid previously clipped areas.

Aerial cover and density of mesquite were determined at each transect in an oval plot, 860 m² (40.4 by 73.2 m). On each mesquite plant, the long canopy diameter and the canopy diameter perpendicular to the long diameter were measured. From these measurements the percentage aerial canopy cover was calculated. Correlation analyses were used to measure relationships among mesquite attributes and grass production.

Results and Discussion

Total annual and growing season precipitation from 1980 to 1993 was near long-term average or greater, except in 1983 and 1989 (fig. 1). Total precipitation measured during the summer growing season (July through September) was also generally average or higher. A drought started in late 1993 and continued through 1996.

Total perennial grass production was 324 kg/ha in 1988 (table 1), resulting from above average precipitation in the late 1980's, and dropped to 83 kg/ha in 1996 after 3 years of below average precipitation. Annual plant production indicated no clear pattern in relation to seasonal or annual precipitation, which is not unexpected because germination

Table 1—Mean (\pm SE) production (kg/ha^{-1}) for perennial grasses and annuals (%) for 4 different years in the Jornada Basin.

Species	1982		1988		1993		1996	
	\bar{X}	SE	\bar{X}	SE	\bar{X}	SE	\bar{X}	SE
Black grama	50	20	133	50	94	38	52	24
Mesa dropseed	80	26	161	19	72	21	29	13
Threeawns	2	1	30	9	7	2	2	1
Total perennial grass	132	33	324	51	174	40	83	24
Annual grasses and forbs	78	22	24	14	26	14	52	16

and growth of annual plants is often related to one or two critical precipitation events during the year.

Mean mesquite density increased from 123 plants/ha in 1982 to 175 plants/ha in 1996 (table 2). Percent canopy cover increased from 1.9% in 1982 to 4.6% in 1993. No change in canopy cover was noted between 1993 and 1996, indicating drought may have restricted canopy growth, although, density increased as some new, small plants became established. Mesquite canopy cover was highly correlated with density ($r = 0.90$, $df = 12$; table 3).

Mesquite canopy cover in 1982 varied from 0 to about 11%. By 1993 the densest sites had increased to over 21% cover (table 2) and the total area with no mesquite decreased. The changes in mesquite density are not as pronounced as for canopy cover, but mesquite during this time period encroached into areas with little or no prior mesquite present. Herbaceous plant production was generally not well correlated with mesquite cover or mesquite density (table 3). One of the stronger relations ($r = -0.64$) is between total perennial grass production and mesquite density. Figure 3 indicates the general pattern of how mesquite advances across the landscape with patches of little or no

mesquite being passed by and later becoming filled in with mesquite through time. Other areas with established mesquite stands become more dense. Most mesquite patches at the ecotone between the grassland and mesquite stand are relatively small.

We believe the deposition of the mesquite seeds across the rangeland away from stands of mesquite is by fecal deposits of grazing animals, primarily cattle. Brown and Archer (1989) support this idea and state further that the deposition of seeds away from parent plants reduces host-specific seed predators. However, the deposition of feces is not equal across the site, but rather occurs at preferred grazing sites and where animals congregate, drink water, and bed down. One of the preferred sites for grazing is the small depressions in the plain (fig. 2). These areas are frequently heavily grazed because of their small size, and these areas often have forage plants that are different species, sometimes being green, as compared to the dry or dormant plants on the surrounding plain.

Once a seed is deposited on the ground, there are many things (predation, disease, unfavorable site, etc.) that might happen to it to keep it from germinating (Bahre and Shelton

Table 2—Percent cover and density for mesquite in a mesquite-grassland ecotone on the Jornada Basin for 4 different years.

Year	% Cover			Density (#/ha)		
	\bar{X}	SE	Range	\bar{X}	SE	Range
1982	1.9	0.8	0.02 - 11	123	32	12 - 465
1988	3.2	1.1	0 - 15	143	35	0 - 418
1993	4.6	1.5	0.2 - 21	161	33	35 - 418
1996	4.5	1.4	0.2 - 21	175	37	58 - 465

Table 3—Correlation coefficients ($df = 12$) for mesquite cover and density with production of perennial grass species and annual plants in the Jornada Basin in southern New Mexico.

Species/ attribute	Perennial grasses				All annuals	Mesquite	
	Black grama	Mesa dropseed	Threeawns	Total		% Cover	Density
Black grama	1.00						
Mesa dropseed	-0.31	1.00					
Threeawns	-0.15	-0.04	1.00				
Total grass	0.92	0.07	-0.09	1.00			
Annuals	-0.15	0.38	-0.15	-0.02	1.00		
% Mesquite cover	-0.42	-0.1	0.07	-0.49	-0.35	1.00	
Mesquite density	-0.58	-0.1	0.15	-0.64	-0.29	0.90	1.00

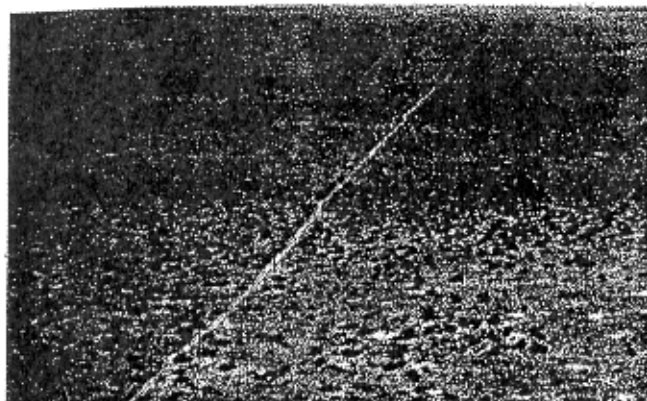


Figure 3—Aerial view (~ 250 M elevation) of part of study area on Jornada Basin showing transition between a dense mesquite stand and the grassland. Note clumping patches of mesquite in grasslands. White spots are kangaroo rat dens.

1993). After germination, establishment is uncertain due to disease, insects, drought, and herbivory. Gibbens and others (1992) reported that 70% of marked mesquite seedlings in the Jornada Basin were dead a year later, presumably by lagamorph herbivory. If the mesquite seedling survives through the first season, then adequate rainfall in subsequent seasons is important for establishment. New mesquite plants are frequently found growing close to established perennial grasses and forbs as well as in areas void of plants. Brown and Archer (1989) noted that mesquite seedlings growing near grass tussocks and on bare interspaces survived equally well after 2 years. Once the root system is developed, the small mesquite plants appear to compete successfully with herbaceous plants (Gile and others 1997). Growth for the mesquite is generally slow, and these small plants, while growing in and among grass plants, rarely produce seed.

Establishment of mesquite is a long, slow process. With occasional drought, the herbaceous plants lose vigor and basal area, and sometimes die. Mesquite, because of large established root systems compared to the above ground part, usually survives the drought and responds to the occasional rain shower during the drought, while the herbaceous plants may or may not be able to respond. Through several growing seasons, depending on the length of the drought, the shrubs slowly start to dominate the site. After drought, there is often little competition from herbaceous species. The mesquite responds quickly to the rains, and seed production becomes important for the continued spread of the mesquite.

As a result of the individual mesquite plant becoming established and producing seed that germinates nearby, patches of mesquite occur in the grasslands. These patches appear better developed in the small depressions across the area (fig. 2). Patchiness may also occur when many mesquite seeds in close proximity germinate and establish at the same time. The result is a mosaic of plants scattered across the desert grasslands with mesquite being in patches varying from a few small shrubs to several large plants,

each 2 m or so tall, and the patch being 10 - 50 m and sometimes larger in diameter.

The size of the patch influences surrounding plant and associated animal life. When the plants are few and diminutive, biodiversity of the area is little affected, other than the presence of mesquite and its associated microbes and insects. As the mesquite increases in stature, it provides more habitat niches for plants, insects, and small animals that originally did not occur on the grasslands. As the patches grow together and become more dense, interspaces are affected by wind and water erosion, and herbaceous species become less abundant and some eventually die. As the grasslands are changed from grass dominants to patchiness with shrubs to shrub dominated, biodiversity increases and then declines. These former grassland dominated areas are best described as ecotones as suggested by Shreve (1917) and supported by Dick-Peddie (1993) because they possess greater diversity than they once had or will have in the future.

References

- Archer, Steve; Schimel, David S.; Holland, Elisabeth A. 1995. Mechanisms of shrubland expansion; land use, climate or CO₂? *Climatic Change*. 29: 91-99.
- Bahre, Conrad J.; Shelton, M. L. 1993. Historic vegetation change, mesquite increases, and climate in southeastern Arizona. *J. Biogeography*. 20: 489-504.
- Brown, J. R.; Archer, Steve. 1989. Woody plant invasions of grasslands: establishment of honey mesquite (*Prosopis glandulosa* var. *glandulosa*) on sites differing in herbaceous biomass and grazing history. *Oecologia*. 80: 19-26.
- Buffington, Lee C.; Herbel, Carlton H. 1965. Vegetational changes on a semidesert grassland range. *Ecological Monographs*. 35: 139-164.
- Clements, F. E. 1934. The relict method in dynamic ecology. *J. Ecology*. 22: 39-68.
- Dick-Peddie, William A. 1993. *New Mexico vegetation: past, present and future*. Albuquerque, NM: University of New Mexico Press: 244 p.
- Gibbens, R. P.; Beck, R. F.; McNeely, R. P.; Herbel, C. H. 1992. Recent rates of mesquite establishment in the northern Chihuahuan Desert. *J. Range Management*. 45: 585-588.
- Gile, L. H.; Gibbens, R. P.; Lenz, J. M. 1997. The near-ubiquitous pedogenic world of mesquite roots in an arid basin floor. *J. Arid Environments*. 35: 39-53.
- Hastings, J. R.; Turner, R. M. 1965. *The changing mile*. Tucson, AZ: University of Arizona Press. 317 p.
- Humphrey, R. R. 1958. The desert grassland: a history of vegetational change and an analysis of causes. *Botanical Review*. 24: 193-252.
- Neilson, Ronald P. 1986. High-resolution climatic analysis and southwest biogeography. *Science*. 232: 27-34.
- Mayeux, H. S.; Johnson, H. B.; Polley, H. W. 1991. Global change and vegetation dynamics. In: James, L. F.; Evans, J. O.; Ralphs, M. H.; Sigler B. J., eds. *Noxious Range Weeds*. Boulder, CO: Westview Press: 62-74.
- Reynolds, Hudson G. 1950. Relation of Merriam kangaroo rats to range vegetation in southern Arizona. *Ecology*. 31: 456-463.
- Schlesinger, William H.; Reynolds, James F.; Cunningham, Gary L.; Huenneke, Laura F.; Jarrell, Wesley M.; Virginia, Ross A.; Whitford, Walter G. 1990. Biological feedbacks in global desertification. *Science*. 1043-1048.
- Selleck, G. W. 1960. The climax concept. *Botanical Review*. 26: 534-546.
- Shreve, F. 1917. A map of the vegetation of the United States. *Geol. Rev.* 3: 119-125.
- York, John C.; Dick-Peddie, W. A. 1969. Vegetation changes in southern New Mexico during the past hundred years. In: McGinnis, W. G.; Goldman, B. J., eds. *Arid lands in perspective*. Tucson AZ: University of Arizona Press: 157-166.