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14. Ten Years of Vegetation Observations on Formerly Grazed Oklahoma Grassland

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ABSTRACT In summer 2003, we established a series of 40 adjacent, 10 × 10-m blocks in formerly grazed grassland in south-central Oklahoma. The blocks were allowed to rest and received no grazing, mowing, or burning. We tracked changes in the vegetation of the site over time between 2005 and 2015. Frequency sampling of prairie vegetation was performed at irregular intervals. In spring 2006 we seeded half the site with a Texas/Oklahoma prairie forb mix. We found no significant trends of change in species richness or diversity over time. However, there were subtle changes in abundance of individual species. Across fall sampling periods, Shannon diversity ranged from 1.1 to 1.3, and species richness ranged from 29 to 41, with higher richness and diversity in the sole spring sample. The percentage of nonnative species present at the site ranged from 13 to 18%. The earliest samples showed that the dominant grass species were little bluestem (*Schizachyrium scoparium* (Michx.) Nash), three-awn (*Aristida oligantha* Michx.), and Scribner's panic grass (*Dichanthelium oligosanthes* (Schult.) Gould). The dominant forb present was ragweed (*Ambrosia artemesiifolia* L.). By the end of the 10-year time period, little bluestem had declined in relative frequency and Scribner's panic grass and three-awn had increased in frequency. Among forbs, sumpweed (*Iva annua* L.) had entered the site and become a dominant forb, heath aster (*Symphyotricum ericoides* (L.) G.L. Nesom) increased in frequency, and ragweed abundance fluctuated over time. The most commonly encountered nonnative species were Bermuda grass (*Cynodon dactylon* (L.) Pers.), singletary-pea (*Lathyrus hirsutus* L.), and sericea lespedeza (*Lespedeza cuneata* (Dum. Cours.) G. Don.), but none of these species increased in abundance over time. In addition, there was anecdotal evidence of woody species encroachment on the site, mostly winged elm (*Ulmus alata* Michx.), wild plum (*Prunus* sp.), and red cedar (*Juniperus virginiana* L.). Establishment of the prairie mix appears to have been unsuccessful. In this study, cessation of grazing ("resting" a site) alone did not allow for recovery of prairie vegetation and may have permitted invasion of undesirable herbaceous and woody species.

KEY WORDS grazing, Oklahoma prairie, prairie restoration, tallgrass prairie

Central Oklahoma is at the southern boundary of the Tallgrass Prairie zone. Prairie in central Oklahoma is typically found on upland soils and within a matrix of oak–hickory forest (the so-called "cross-timbers forest"—Tyrl et al. 2008). Much of Oklahoma prairie is located on Alfisols rather than Mollisols (Tyrl et al. 2008). Oklahoma has a continental climate, with hot, often droughty summers and influences from humid Gulf of Mexico air masses (Hoagland 2000, Arndt 2003).

In general, the matrix of Oklahoma tallgrass prairie was similar to other tallgrass prairie of drier locations. Rice (1952) listed the dominant grass species for a south-central Oklahoma prairie site. They were switchgrass (*Panicum virgatum* L.), Indian-grass (*Sorghastrum nutans* (L.) Nash), and big bluestem (*Andropogon gerardi* Vitman). The most abundant forbs at the site were compass-plant (*Silphium laciniatum* L.) and Illinois bundleflower (*Desmanthus illinoensis* (Michx.) MacMill. ex B.L. Rob. & Fernald). Collins and Adams (1983), in a long-term analysis of prairie in McClain County, Oklahoma, determined that the dominant grass species were little bluestem (*Schizachyrium scoparium* (Michx.) Nash), switchgrass, and Indian-grass. They also noted that the site was experiencing population increase of western ragweed (*Ambrosia psilostachya* DC.) and invasion by woody plant species. Hoagland (2000) and Tyrl et al. (2008) noted that tallgrass prairie is found in the central part of Oklahoma and is dominated by little bluestem, big bluestem, Indian-grass, and switchgrass and include perennial grasses and forbs such as Scribner's panic grass (*Dichanthelium oligosanthes* (Schult.) Gould), heath aster (*Symphyotricum ericoides* (L.) G.L. Nesom), ashy sunflower (*Helianthus mollis* Lam.), and Missouri goldenrod (*Solidago missouriensis* Nutt.). Hoagland (2000) also noted that many areas of Oklahoma have been converted to introduced pasture grasses, such as yellow bluestem (*Bothriochloa ischaemum* L. (Keng.)) and Bermuda grass (*Cynodon dactylon* (L.) Pers.), and these species have invaded other grassland areas.

Prairie in Oklahoma, as in many other states, has experienced threats and losses in the past 150 years. Tallgrass prairie occupied 5,200,000 ha in Oklahoma (the entire state is roughly 17,800,000 ha); it is not clear how much remains (Sampson and Knopf 1994). Oklahoma prairie has been lost to agriculture (plowing, pasturage, or haying, with plowing the most severe disturbance). Additionally, some prairie land has been lost to urbanization. Fire suppression in Oklahoma has led to encroachment of woody

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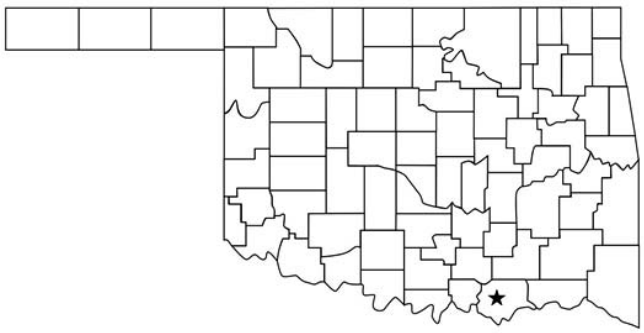

Figure 1. Location of field sampling site in Bryan County, south-central Oklahoma. Approximate location of sampling site is marked with a star.

vegetation (Collins and Adams 1983), especially *Juniperus* species (cedars; Hoagland 2000) and some nonnative species of herbaceous plants, including sericea lespedeza. Though prairie acreage in Oklahoma has declined, large tracts of prairie land still exist in the state, especially the Tallgrass Prairie Preserve in Osage County at 16,045 ha (Palmer 2007). However, restoration of prairie in areas that once supported it is a worthwhile goal because prairie maintains and builds soil, provides habitat for many native species, and can sequester carbon.

We undertook this project to examine the possibility of using low-intensity management to recover a formerly grazed site as possible habitat for native species. We lightly seeded the site with prairie forb species and monitored it periodically over 10 years. We also used the site as an example site for field labs over the years.

MATERIALS AND METHODS

Site Description

The study site was part of 32.4 ha of land (33°31′22.8″N, 96°9′0″W) near Roberta, Oklahoma (Figure 1). The upland site is relatively flat and has a known history of relatively continuous grazing with variable stocking rates, before 2000. Its soil association is the Crockett–Durant complex, a mixture of loam and sandy loam (USDA 1978). As of 2000, the site was showing evidence of overgrazing, including low aboveground biomass, erosion on some slopes, areas of exposed soil, and presence of species that increase in the presence of grazing (three-awn grass [*Aristida oligantha* Michx.], green milkweed [*Asclepias viridis* Walter], and snow-on-the-prairie [*Euphorbia bicolor* Engel. & A. Gray]). There is no plow layer in the site's soils or evidence of past plowing, but adjacent areas were historically plowed and planted with peanuts.

In 2000, the land was taken out of grazing when it changed ownership. In 2003, we began a vegetation monitoring and restoration project on the site. Forty 10 × 10-m blocks were established in five rows of eight sections each (Figure 2). These blocks were separated by 2-m-wide mowed strips. The total area of the research site was 0.4 ha and located on a part of the site with no signs of soil erosion.

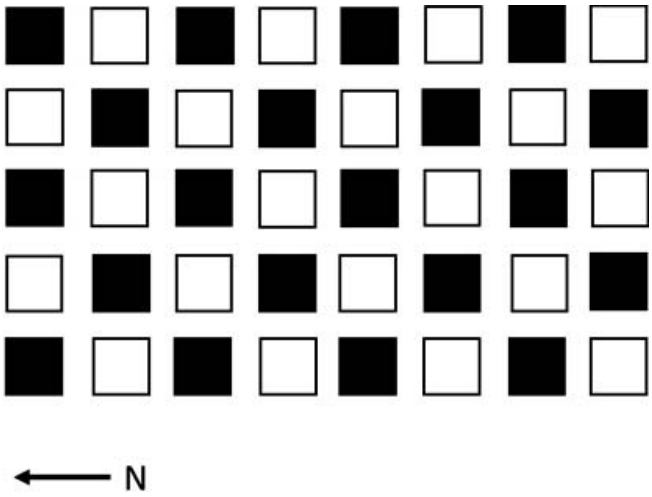

Figure 2. Diagram of arrangement of sampling blocks. Each square represents 10 × 10 m.

In October 2006, half the blocks were raked to clear litter and seeded with "Caddo Mix" (Native American Seeds, Junction, Texas) in an attempt to increase native forb diversity on the site. The forb seed mix included the species listed in Table 1. Site preparation included raking the blocks designated for a seeding treatment clear of litter. Seed was hand broadcast, trampled in (by foot), and litter was replaced on the site. Seeds were not tested for viability; viability values in Table 1 are those provided by Native American Seed. The site was seeded once; no other form of

Table 1. Forb species present in Caddo Mix seeded onto research site in October 2006. Planting rate was about 15 lbs. per acre. Percent viability numbers are provided by Native American Seeds, Junction, Texas.

Common Name	Scientific Name	% Viability
Clasping coneflower	*Dracopis amplexicaulis*	88.2
Lemon nint	*Monarda citridora*	96.8
Indian blanket	*Gaillardia pulchella*	75.2
Partridge pea	*Chamaecrista fasciculata*	99.9
Plains coreopsis	*Coreopsis tinctoria*	99.8
Black-eyed Susan	*Rudbeckia hirta*	99.8
Illinois bundleflower	*Desmanthus illinoensis*	99.9
Pink evening Primrose	*Oenothera speciosa*	96.8
Lazy daisy	*Aphanostephus* sp.	69.5

Table 2. Species richness (Richness), Shannon diversity (H'), percent evenness (J), and percent nonnative species of all species sampled on a formerly grazed prairie site in Bryan County, Oklahoma over a 10-year period. H' is calculated using the formula $-\Sigma p_i \log p_i$, where p_i is the proportional occurrence (n_i/N) and J is calculated as (H')/log (Richness) × 100.

Year	Richness (N)	H'	J (%)	% Nonnative
Fall sampling results				
2005	37	1.18	74	14
2008	29	1.12	73	13
2011	39	1.28	79	18
2013	29	1.13	73	17
2015	41	1.19	73	14
Spring sampling results				
2009	47	1.40	76	17

management was done after seeding. The project concluded in late 2015.

Sampling Methods

We sampled the site during September at irregular intervals for the years 2005, 2008, 2011, 2013, and 2015. A single spring sample (March) was collected in 2009 to provide a comparison of species composition and to capture the spring ephemeral species, if any. All 40 blocks were sampled during each sampling period. A 25 × 25-cm sampling frame was used to collect the samples. Five samples were collected per block in a systematic fashion: one sample near each corner and one near the center.

Data were collected on presence/absence of species in a sample. This yielded a total of 200 samples per sampling period. Relative frequency values (relative frequency = occurrences of the species/total occurrences × 100) were calculated for each species per sampling period, and these values were used to calculate a Shannon index of diversity (as $-\Sigma p_i \log p_i$, where p_i is the proportional occurrence). Additionally, evenness was calculated on the basis of the $H'/H'_{max} \times 100$ where H' is the Shannon diversity index and H'_{max} is the logarithm of the total number of species (Magurran 1988).

We also calculated some measures on the species assemblage as a whole: each set of species-richness data was separated into forb vs. graminoid. We also separated species into native vs. nonnative, and into warm-season (C4) vs. cool-season (C3) using either the Noble Foundation's Plant Image Gallery website (https://nobleapps.noble.org/plantimagegallery/) or the U.S. Department of Agriculture Plants database (plants.usda.gov).

We used SPSS Statistics version 20 (IBM 2011) to perform nonparametric correlation analyses (Spearman rank) between site diversity values and sampling period to determine if there was any trend in diversity over time. We only included the fall samples in statistical analyses; the spring sample is included for comparison of raw percentages. We also examined the percentage of native vs. introduced species, percentage of grasses that were warm season vs. percentage that were cool season, and annual species vs. perennial species. We also compiled lists of most frequently occurring grass and forb species for each sample.

A Bray–Curtis ordination was performed on the data (PC-Ord v. 6.21: MjM Software, 2016). Species that could not be identified ("unknowns") were dropped from the analysis. These species were few and their relative frequency value was generally less than 1%.

RESULTS

There were few changes in the site during the 15 years postgrazing (Table 2). The values calculated for the Shannon index varied between 1.12 and 1.28 among fall samples, with the single spring sampling having a value of 1.40. Species richness (number of species observed) also showed no correlation to time of sampling; fall species richness ranged from 29 to 41, with 47 species present in the single spring sample. There were no significant correlations between time of sampling and diversity measures—i.e., no trend in site diversity over time. Additionally, there were no trends in native vs. introduced species ($\rho = -0.308$, $P = 0.614$), graminoid vs. forb ($\rho = -0.205$, $P = 0.741$), or annual vs. perennial graminoid ($\rho = -0.102$, $P = 0.870$) species.

We saw no trends over the course of the study in the percentage of native vs. nonnative species (Table 2), percent graminoid vs. forb, and percent perennials (Table 3). However, there were minor differences in these values for fall 2011, likely because summer 2011 was a period of extreme drought. Figures 3 and 4 show ordination results; the first sample (fall 2005) generally separated from the other samples. There was no clear trend in species frequency patterns over time from the ordination analysis; however, the fall 2005 and fall 2015 samples showed some separation on axis 1 and fall 2005 and fall 2013 showed the greatest separation of any two samples on axis 2. This may reflect the increase in sumpweed (*Iva annua* L.) and three-awn grass over time.

In general, the most frequently occurring graminoids were Scribner's panic grass and three-awn grass (Table 4). Little bluestem, Indian-grass, and gama-grass (*Tripsacum dactyloides* (L.)) were present, but they occurred at low frequencies (<5% overall relative frequency). Little bluestem declined over time, possibly because of competition from introduced bluestems; in the initial sampling (fall

Table 3. Percentages of graminoid vs. forb species, and percentages of annual vs. perennial species sampled on a formerly grazed prairie site in Bryan County, Oklahoma, over a 10-year period. The *N* value is the total number of species (graminoid plus forb) in the sampling period.

Year	% Graminoid	% Perennial Graminoid	% Forb	% Perennial Forb	*N*
Species results: fall					
2005	43	87	57	62	37
2008	45	77	55	68	29
2011	33	94	67	65	39
2013	45	85	55	62	29
2015	37	87	63	58	41
Species results: spring					
2009	28	77	72	59	47

2005), its relative frequency was 18%; during later samplings its frequency was closer to 2%. Among forbs, the only species exhibiting frequency >10% was common ragweed (*Ambrosia artemesiifolia* L.) (Table 4). Common ragweed is generally considered to be an agricultural weed and often comes in from existing seed banks of sites (Foster and Lovett 2003). The species frequency data for the spring sampling (in 2009) were different: beaked cornsalad (*Valerianella radiata* (L.) Dufr.) was the most frequent forb species (7.3% relative frequency), and there were two species present found in no other sampling: mock bishop-weed (*Ptilimnium nutalii* (DC.): Britton) at 1% relative frequency, and pink milkwort (*Polygala incarnata* L.) at 2% relative frequency. These are species that tend to complete their life cycle before the heat of summer.

The Bray–Curtis ordination showed few additional differences (see Figures 3 and 4). The spring 2009 sampling was distinct from the fall sampling periods, as might be expected from differences in the species present. There is a weak trend over time shown in Figure 3: the first sampling (fall 2005) received the lowest axis 2 score and scores increased with time. Similarly, axis 1 scores increased with time. (The spring sampling is distinct from the other samples.) Surprisingly, the postdrought samples (fall 2011 and to a lesser extent, fall 2013) were not distinct from those of the other sampling periods, suggesting that the drought of 2011 had little effect on species composition at this site. Ordination axis 3 (Figure 4) does not show as clear a separation of the sites, though again there is a progression along axis 1 over time. These patterns may reflect the increase in sumpweed and three-awn grass over time. In general, there was no clear trend that could be labeled "site recovery of native species."

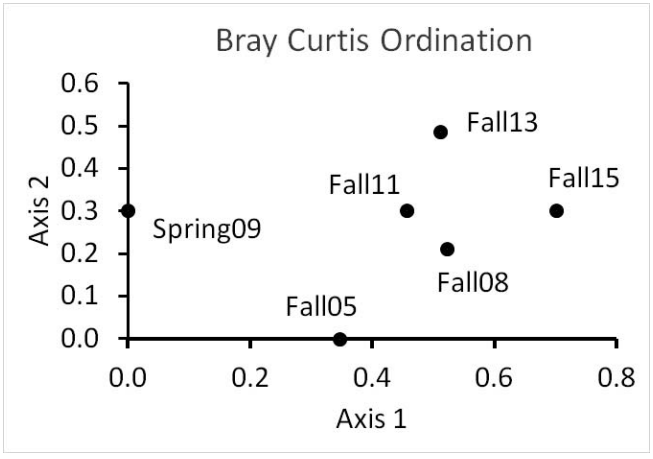

Figure 3. Bray–Curtis ordination of the sampling periods; axes 1 and 2 are shown. Prepared using data from PC-Ord for windows; graphs generated using IBM SPSS.

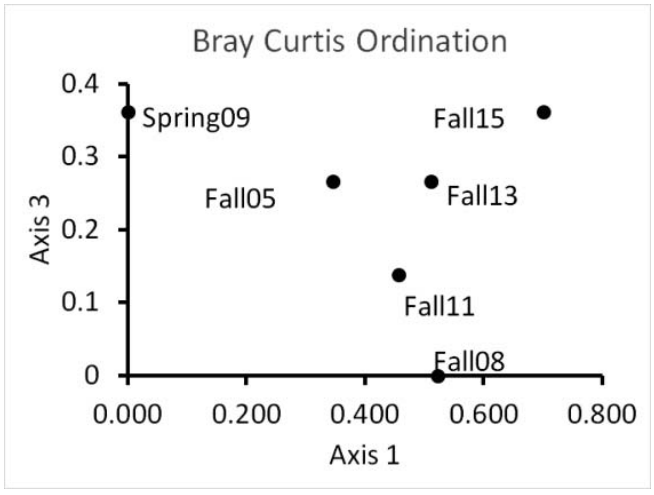

Figure 4. Bray–Curtis ordination of the sampling periods; axes 1 and 3 are shown. Prepared using data from PC-Ord for windows; graphs generated using IBM SPSS.

Table 4. Highest-relative-frequency species (graminoid and forb) sampled on a formerly grazed prairie site in Bryan County, Oklahoma, over a 10-year period.

Year	Species	% Relative Frequency
Species frequency results: fall		
2005	*Schizachyrium scoparium*	17.8
	Dichanthelium oligosanthes	12.9
	Aristida oligantha	10.8
	Ambrosia artemisiifolia	10.4
2008	*Dichanthelium oligosanthes*	16.6
	Aristida oligantha	9.9
	Iva annua	11.3
	Ambrosia artemisiifolia	11.2
2011	*Dichanthelium oligosanthes*	14.1
	Andropogon glomeratus	13.2
	Ambrosia artemisiifolia	9.3
	Iva annua	6.3
2013	*Carex* sp.	13.8
	Dichanthelium oligosanthes	13.4
	Iva annua	17.6
	Ambrosia artemisiifolia	14.7
2015	*Dichanthelium oligosanthes*	20.1
	Aristida oligantha	13.6
	Iva annua	16.0
Species frequency results: spring		
2009	*Schizachyrium scoparium*	11.0
	Dichanthelium oligosanthes	7.3
	Ambrosia artemisiifolia	16.2
	Valerianella radiata	7.3

DISCUSSION

In general, the site showed little change over 10 years of the study. For the fall sampling periods, Spearman rank correlations indicated no significant relationship between year of sampling and Shannon diversity, species evenness, percent native species, percent grass, or percent perennial vs. annual species.

Species composition (based on abundance values and species present) of the site changed relatively little over the decade of the study. Bray–Curtis ordination of the site data showed a weak trend of changes over time, though these changes did not tend to reflect "recovery" of native prairie species. The most frequently occurring graminoids across the study period were Scribner's panic grass, three-awn grass, bushy bluestem (*Andropogon glomeratus* (Walter) Britton, Sterns, and Poggenb.), and, in the first sampling, little bluestem. Members of the *Carex* genus were also abundant, but were not identified to species because of the lack of reproductive structures at the sampling times. Relative frequency values for *Carex* ranged from a low of 1% in fall 2008 to a high of 14% in fall of 2013. We do not have any clear explanation for the change in abundance; it is possibly an artifact of sampling given the patchy distribution of some species. Although anecdotal, the landowner observed an overall decline in little bluestem over the entire property, which was treated similarly to the study site (rested, with infrequent mowing). Bermuda grass was also present on the site, but in lower frequency, ranging between 2.6% and 8.5%. There was no trend over time in Bermuda grass frequency. The most frequently occurring forbs across the entire sampling period were common ragweed, sumpweed, and heath aster, respectively. Although prairie species, including pink milkwort, Kansas gayfeather (*Liatris pycnostachya* Michx.), and compass-plant occurred on the site, they were at low frequency, rarely if ever occurred in samples, and did not increase over 10 years of the study. There were also several species in the Asteraceae present in low abundance (<5% at any one sampling time) on the site: broomweed (*Amphiachyris dracunculoides* (DC.)), tall goldenrod (*Solidago* cf. *gigantea*), and golden aster (*Chrysopsis pillosa* Nutt.). The composition of the site was closest to the association that Hoagland (2000) lists as "V. A. 5. N. a."—a mesic or upland grassland dominated by big bluestem, little bluestem, and Indian-grass. Another species present in this association is Scribner's panic grass, one of the grasses that dominated this site. In general, the site resembled tallgrass prairie, but with some of the typical dominants absent and more "weedy" grasses and forbs present, i.e., degraded community composition. Three-awn grass, for example, is native, but is an annual and is generally considered to be weedy (Foster and Lovett 2003), and Kelting (1954) listed three-awn grass as a species indicative of disturbance. Most of the typical tallgrass prairie grasses of Oklahoma were extremely low in frequency when they did occur. Kelting (1954) suggested that heavy grazing reduces these species.

Over the 10 years of the study, the site experienced invasion by woody and nonnative species. Sericea lespedeza was present in the blocks, but consistently remained at a low frequency over the study period. However, other areas of the 34 ha had larger stands of it. Woody plants also invaded the site after grazing ended: the primary species present were winged elm (*Ulmus alata*, a common weedy tree in southern Oklahoma), wild plum (*Prunus americana*, most likely spread by birds), and red cedar (*Juniperus virginiana*, a major invasive native species in Oklahoma). The woody plants were rarely captured in samples but they were notably present; they tended to grow up alongside the 2.1-m posts that were used to mark the corners of the blocks (indicating likely dispersion by perching birds). Collins and Adams

(1983) also noted woody invasion of their research site; this is a common problem throughout much of the tallgrass prairie region where there is a history of fire suppression. In general, nonnative species did not increase over time; the percentage of nonnatives as a total of all species on the site ranged from 13 to 18%, which is slightly higher than the estimate of 12% made by Palmer (2007) for the Tallgrass Prairie Preserve in Osage County (northern Oklahoma).

In summary, we observed little change in the site over the 10 years of sampling. It remained a largely weedy site showing the possible after-effects of grazing. Although some prairie species were present, they were low in abundance and did not increase in abundance over the study period. There were also species (snow-on-the-prairie and green milkweed) present on the site that are known to increase on grazed land. There was also significant erosion in an area with a relatively steep slope near our study sites. Otherwise, there seemed to be few physical signs of effects of grazing on the site. Our site had a higher frequency of agricultural and pasture weeds, and a lower frequency of the typical warm-season prairie grasses than those described by Rice (1952) and Collins and Adams (1983). Our site shared some species in common with the tallgrass prairie described by Rice: Indian-grass, little bluestem, compass-plant, *Carex* sp., heath aster, and yellow-puff (*Neptunia lutea* (Leavenworth) Benth.; Rice 1952). Neither sumpweed nor common ragweed was listed as being present on the site that Rice (1952) surveyed.

The lack of observed change in the site is likely due in large part to the absence of restoration treatments such as fire, removal of woody/nonnative species, or mowing, and resting the site from overgrazing pressure was not sufficient to allow recovery of native species.

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