Cattle Ranching in the "Wild Horse Desert" – Stocking Rate, Rainfall, and Forage Responses

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On The Ground

- No research involving the comparative evaluation of grazing methods has been performed in South Texas at an operational scale.
- We report initial findings from a large-scale demonstration project involving two cattle stocking rates and two grazing methods; our focus was on forage standing crop and forage utilization responses.
- Erratic, but typical, rainfall patterns and resulting forage production proved our stocking rates (though realistic for this region) to be unsustainable over the long term, regardless of grazing method.
- The "Wild Horse Desert" is a harsh but resilient environment following periods of above average rainfall.

Keywords: Cattle ranching, Forage standing crop, Forage utilization, Grazing, South Texas, Stocking rate

Introduction

Cattle ranching is a tough business. This is no truer than in the "Wild Horse Desert" of deep South Texas where frequent and reoccurring drought paired with an extended growing season of 306 frost-free days are the dominant climatic features. Drought is not a new phenomenon in this region. In 1916 Caesar Kleberg of the famed King Ranch noted, "I am up against the hardest fight I've ever had – the extreme drought is keeping me going from morn until night."[1] To be sustainable, cattle ranchers need to balance stocking rate with available forage (or standing crop) while considering uncertainty in future precipitation and markets.[2]

Additionally, ranchers must select a grazing method that accomplishes their overall objectives. In South Texas, grazing methods have historically involved continuous grazing and to a lesser extent some variation of deferred rotation grazing.[3] However, the literature is unclear as to which of these methods is superior for vegetation and animal production.[4,5] Complicating matters, no research involving the comparative evaluation of grazing methods have been performed in South Texas at an operational scale.

Herein, we report initial (March 2014–June 2018) findings from a large-scale demonstration project involving two cattle stocking rates and two grazing methods. Our focus here was on forage standing crop and forage utilization responses; however, we are also monitoring herd performance, vegetation composition and structure, and wildlife responses over the long term (>10 years).

Living Laboratory

The East Foundation is an agricultural research organization that promotes the advancement of land stewardship through ranching, science, and education. We manage our herd of approximately 3,000 breeding cows across six ranches encompassing nearly 87,817 hectares (217,000 acres) for research, educational, and production purposes. East Foundation ranches are not contiguous and occur in Jim Hogg, Starr, Kenedy, and Willacy counties of Texas (Fig. 1).

We established the Coloraditas Grazing Research and Demonstration Area (CGA) in 2014 on the East Foundation's San Antonio Viejo Ranch in Jim Hogg County, Texas (Fig. 2). Plant communities on the study areas are dominated by woody species such as honey mesquite (*Prosopis glandulosa*), huisache (*Acacia farnesiana*), brasil (*Condalia hookeri*), granjeno (*Celtis pallida*), and prickly pear (*Opuntia* spp.), as well as herbaceous species such as Seacoast bluestem (*Schizachyrium scoparium var. littorale*; Fig. 3), purple threeawn (*Aristida purpurea*), spotted beebalm (*Monarda fruticulosa*), and woolly croton (*Croton capitatus*). The CGA is on 7,502 hectares (18,538 acres) of predominantly native rangeland, which is divided into 10 pastures and four treatments (Fig. 2). As such, treatment areas were 1,875 hectares (4,635 acres); this is similar in size to most landholdings in the South Texas Brush Country Ecoregion.[6]

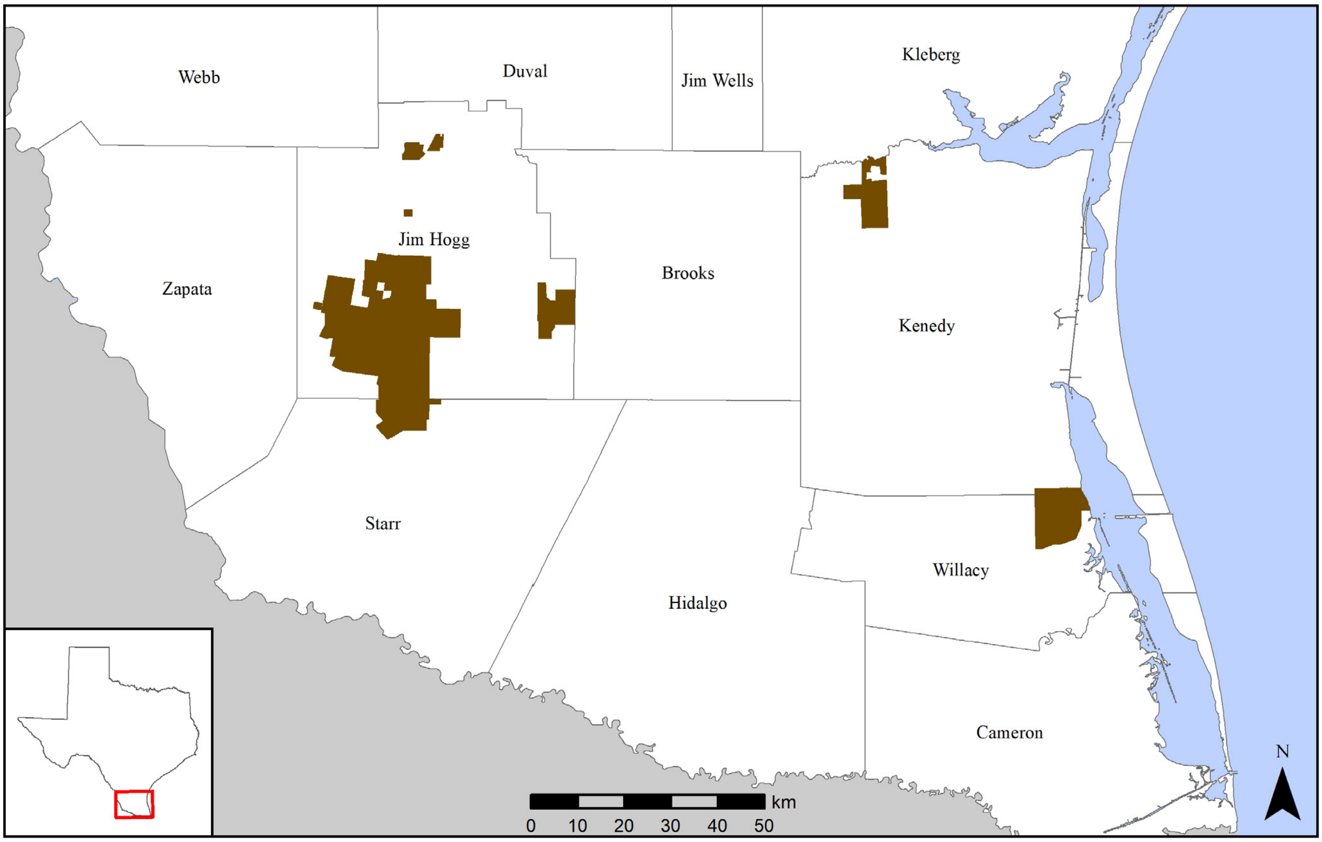

Figure 1. Location of East Foundation ranches in South Texas encompassing over 87, 817 hectares (217,000 acres) and spanning four counties.

Approach

Layout, Cattle, and Rainfall

The East Foundation implemented the CGA to test the regional grazing paradigms of a high (1 animal unit [AU]/14 ha [35 acres]) and moderate (1 AU/20 ha [50 acres]) stocking rate within commonly used grazing systems. Though often deemed unsuitable in variable environments,[7] we held stocking rates constant throughout the experiment to represent scenarios in which ranchers must either endure the financial costs of selling herds into a flooded cattle market or hold on to stock and incur the costs of supplemental feed and rangeland degradation.[8] Furthermore, traditional paradigms that rangeland degradation is the consequence of excessive stocking rates alone and that low-fixed stocking rates are appropriate through time persist.[9] Our demonstration sought to mimic real-world scenarios by holding constant multiyear stocking rates but allow flexibility in management decisions such as time of rotation, cattle workings, and the decision to provide supplemental feed. In this way, our demonstration provides insight on the benefits or consequences of an inflexible stocking rate at a high and moderate (conservative) level between a continuous and rotational grazing system at an operational scale.

We evaluated forage responses resulting from two cattle stocking rates (1 AU/14 ha and 1 AU/20 ha) and two cattle grazing methods (continuous and rotational). Grazing included four treatments applied to 10 subpastures within the CGA: 1) continuous grazing-high stocking rate (CH; two pastures-two herds); 2) continuous grazing-moderate stocking rate (CM; two pastures-two herds); 3) rotational grazing-high stocking rate (RH; three pastures-one herd); and 4) rotational grazing-moderate stocking rate (RM; three pastures-one herd; Table 1; Fig. 2). Prior to the onset of the project in 2014, the entire CGA was grazed at a stocking rate of 1 AU/12 ha (31 acres). We deferred all cattle from the CGA from March 2014 to December 2015 to allow rangelands to recover from a drought that occurred from 2011 to 2013.

We introduced 435 ranch-raised, same-aged, first-calf heifers into the CGA in December 2015. Cattle had been bred six to eight months prior to entering the experiment. We randomly assigned cattle to a treatment (RH, RM, CH, and CM) and pasture. At initial palpation and prior to experiment, we applied a color-coded and numbered ear-tag (Large Herdsman, Temple Tag, Inc, Temple, TX) that corresponded to pasture and treatment.

For rainfall estimates, we acquired daily PRISM data at 4 km resolution for the CGA from September 2011 to June 2018.[10] In addition to daily estimates of precipitation, we acquired PRISM long-term average datasets referred to as "normal." The normal are baseline datasets describing average monthly and annual conditions over the most recent three full decades. The most recent PRISM normal data were for 1981 to 2010. We summarized these data by comparing the

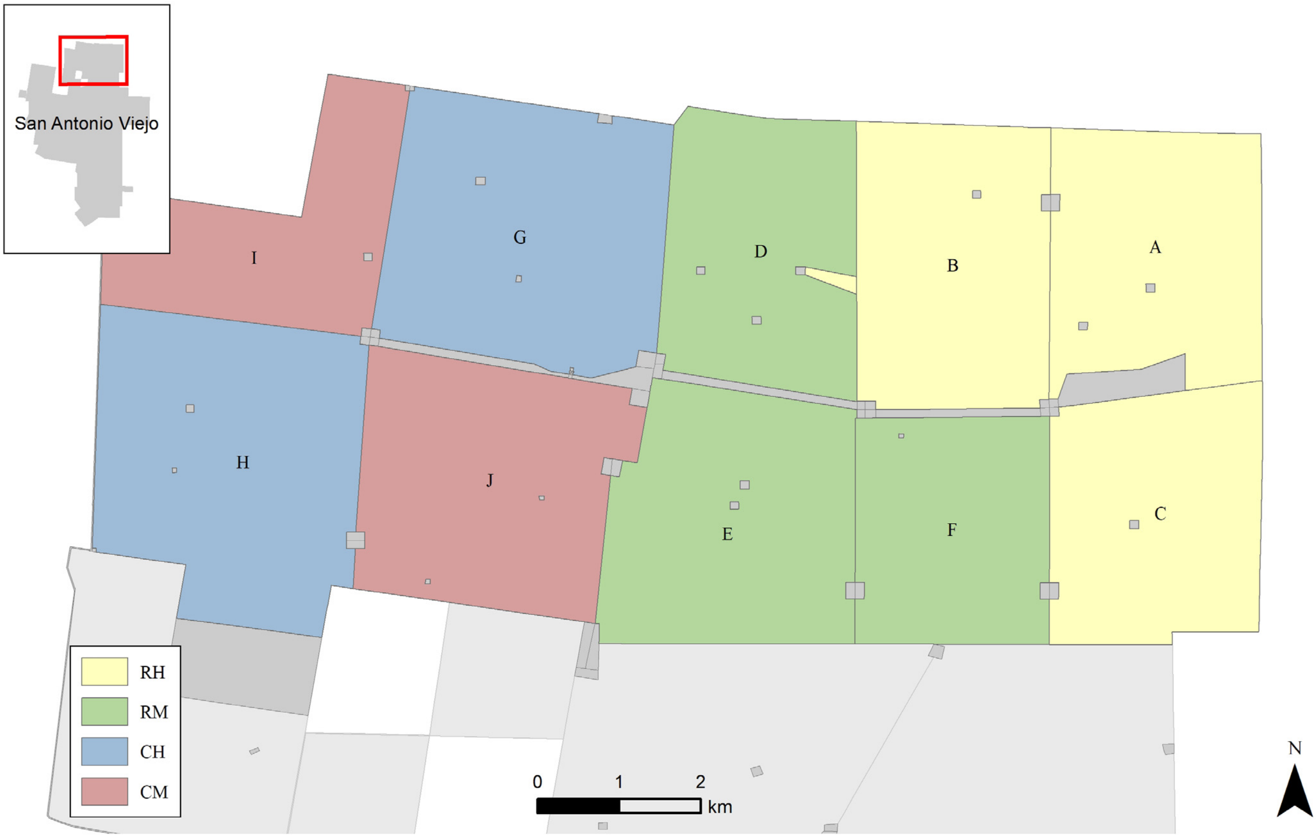

Figure 2. Study area and treatment layout of the Coloraditas Grazing Research and Demonstration Area (CGA) within the San Antonio Viejo Ranch (SAVR) in Jim Hogg County, Texas. Grey areas represent cattle and water traps, as well as pastures outside of the CGA on the SAVR. Subpasture identification corresponds to treatment assignment. CH indicates Continuous High; CM, Continuous Moderate; RH, Rotational High; and RM, Rotational Moderate.

Figure 3. Native rangelands on the Coloraditas Grazing Research and Demonstration Area, within the San Antonio Viejo Ranch in Jim Hogg County, Texas, December 2017.

Table 1. Pasture size and number of animal units for each subpasture within treatments on the Coloraditas Grazing Research and Demonstration Area within the San Antonio Viejo Ranch in Jim Hogg County, Texas

System	Rate	Pasture ID.	Area (hectares)	Animal units (AU)
Rotational	High	A	688	142
		B	737	-
		C	688	-
Rotational	Moderate	D	677	97
		E	802	-
		F	585	-
Continuous	High	G	938	63
Continuous	High	H	987	67
Continuous	Moderate	I	579	27
Continuous	Moderate	J	821	39

monthly observed precipitation to the percent of normal for the previous 3-month period (Fig. 4) from September 2011 to June 2018. We also reported rainfall descriptive statistics to compare with forage sampling periods using these data over the duration of the experiment (i.e., March 2014–June 2018).

Forage Standing Crop

We assigned 10, 1-m^2 grazing exclosures to each pasture (i.e., 100 exclosures total). Within pastures, we allocated exclosures in proportion to the area of each ecological site (≤6 ecological sites possible). Ecological sites are land types characterized by their soil and physical traits that produce distinctive vegetation and therefore respond similarly to management and disturbances.[11] Exclosures were square with 1.5 m (5 feet) sides constructed with four t-posts at the corners and cattle paneling. We marked a paired point 10 m (33 feet) from the exclosure in an area with similar vegetative characteristics as the exclosure. After sampling (destructive, see below), we moved exclosures to different random locations

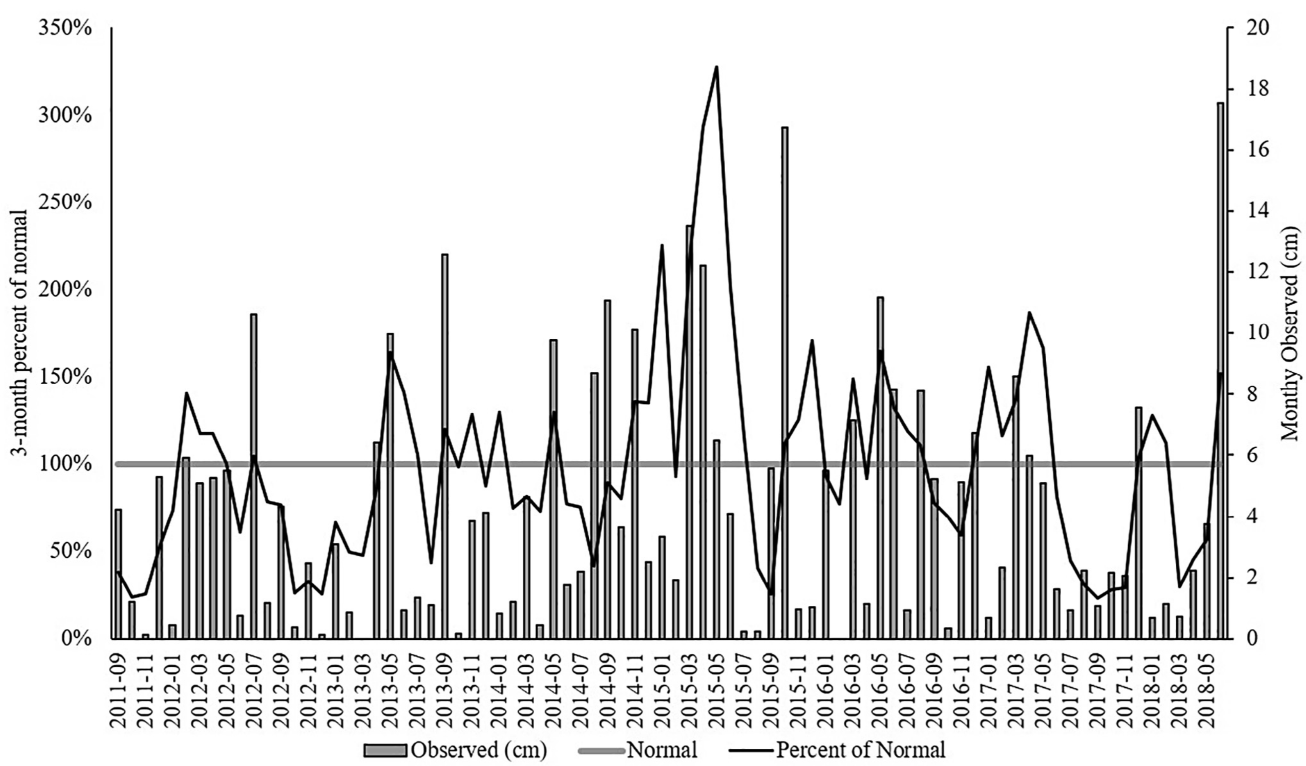

Figure 4. Observed monthly precipitation (grey bars) and the 3-month cumulative average percent of normal precipitation from 2011 to 2018 calculated from the center of the Coloraditas Grazing Research and Demonstration Area in Jim Hogg County, Texas. The 3-month cumulative average normal precipitation was calculated using the 30-year monthly normal based on PRISM data (http://www.prism.oregonstate.edu/explorer/).

within the same pasture and ecological site. We estimated forage standing crop and forage utilization at these sites. We defined forage standing crop as the above ground living and dead material attached to the plant at each sampling period.[12]

We estimated forage standing crop at the end of each growing season (i.e., June and November) from 2014 to 2018 and within 10 days from the time cattle were moved between pastures in the rotation grazing units. We sampled the vacated pastures within 2 days following rotation. Sampling at the end of each growing season was completed to capture the bimodal rainfall pattern and corresponding plant growth in South Texas.

To obtain timely estimates of residual forage at each cattle rotation, we used the comparative yield method to determine forage standing crop.[13] This method uses double sampling techniques where a small number of biomass measures from clipped samples were compared with a larger number of visual estimates of forage standing crop.[14] We used biomass measures to calculate a regression equation with visual estimates, producing a measure of pasture-wide forage standing crop.[14]

At each sampling period (i.e., growing season end or rotation period), we selected sites for clipped estimates through visual inspection of pastures. We established five categories of forage standing crop (1 = least amount of forage and 5 = greatest amount of forage). Within each pasture, we clipped one representative forage sample within 0.25 m^2 (50 × 50 cm frame) for each of the five categories at the base of the plant and collected all above ground forage material. We weighed forage samples in the field immediately after clipping using an Ohaus Navigator XT Portable Balance (Model NVT3201/1) to confirm category assignment. Within 24 hours, we placed clipped samples in a drying room at 65 °C and weighed daily until no changes in mass were observed for 72 hours. We considered this final measurement the dry weight of the sample. We converted dry weight values from g/0.25 m^2 to kg/ha.

Within each pasture, we used the 10, 1-m^2 exclosures as an initial starting point to record 25 visual forage estimates in each cardinal direction (i.e., 100 estimates per exclosure per sampling period or 1,000 estimations per pasture per sampling period). We recorded visual estimates by assigning a whole number value from one to five to an area of 0.25 m^2 that was immediately in front of our foot every other step.[14]

We used the dry weight of the forage samples collected in each pasture (categories 1–5) to develop prediction equations. For our regressions, we used the dry weights (kg/ha) for each category clipped as independent variables (y-axis) and category (1–5) as dependent variables (x-axis) for each pasture. We inserted the mean of 1,000 visual estimations for each pasture into the prediction equation to estimate forage standing crop for each pasture. These equations were linear with correlation coefficients (r^2) of 0.86 to 0.99. We reported mean forage standing crop per treatment and sampling period weighted by the number of exclosures per pasture within a treatment.

Forage Utilization

We also sampled exclosures and paired points at the end of each growing season (i.e., June and November) to calculate forage utilization. We used forage contained within exclosures and forage at the paired point to calculate percent forage utilization. We defined forage utilization as the proportion of current year forage production that was consumed or destroyed by grazing animals since the last sampling period.[15]

We sampled forage by placing a 0.25 m^2 (50 × 50 cm frame) in the center of the exclosure and at paired point on the north side of the t-post outside of the exclosure. Within each frame, we estimated percent cover for grass, litter, and bare ground. We estimated forb cover by species (≥100%) and categorized forbs as preferred or nonpreferred for white-tailed deer (*Odocoileus virginianus*) because they are similar to forbs that cattle will graze. We clipped all plant material at the base of the plant and collected all above-ground forage material. We separated plant material into grasses, preferred forbs, and not preferred forbs. Within 24 hours, we placed clipped samples in a drying room at 65 °C and weighed daily until no changes in mass were observed for 72 hours.

We calculated percent forage utilization (U) for each exclosure by grass and preferred forbs. Percent utilization was calculated by the following equation:

$$U\ (\%) = [\frac{(I - O)}{I}] \quad [1]$$

where I was the forage inside the exclosure and O was the forage outside the exclosure at the paired location. When standing crop outside the exclosure was greater than standing crop inside the exclosure, utilization resulted in a negative value. We rescaled utilization values to bound them between −100% and 0% by multiplying negative values by: 100/absolute value of the minimum negative utilization.[16] We reported mean percent forage utilization by treatment and by sampling period weighted by the number of exclosures in each pasture.

Findings

Forage Standing Crop

We obtained 15 estimates of forage standing crop for each treatment from June 2014 to June 2018. Average weighted forage standing crop by treatment fluctuated with cumulative precipitation over all sampling periods (Fig. 5). Average forage standing crop increased by 118% to 165% on all CGA treatments from June 2014 to November 2015 prior to the initiation of grazing in December 2015. The increase in forage standing crop during the deferment period demonstrated the resiliency of the rangeland in South Texas in response to increased precipitation and rest from grazing following a 3-year drought. South Texas rangelands evolved with large wild ungulates, but stabilization was facilitated by periods of rest.[17] In a semiarid environment, rest periods have a higher potential to increase range condition than destocking and restocking

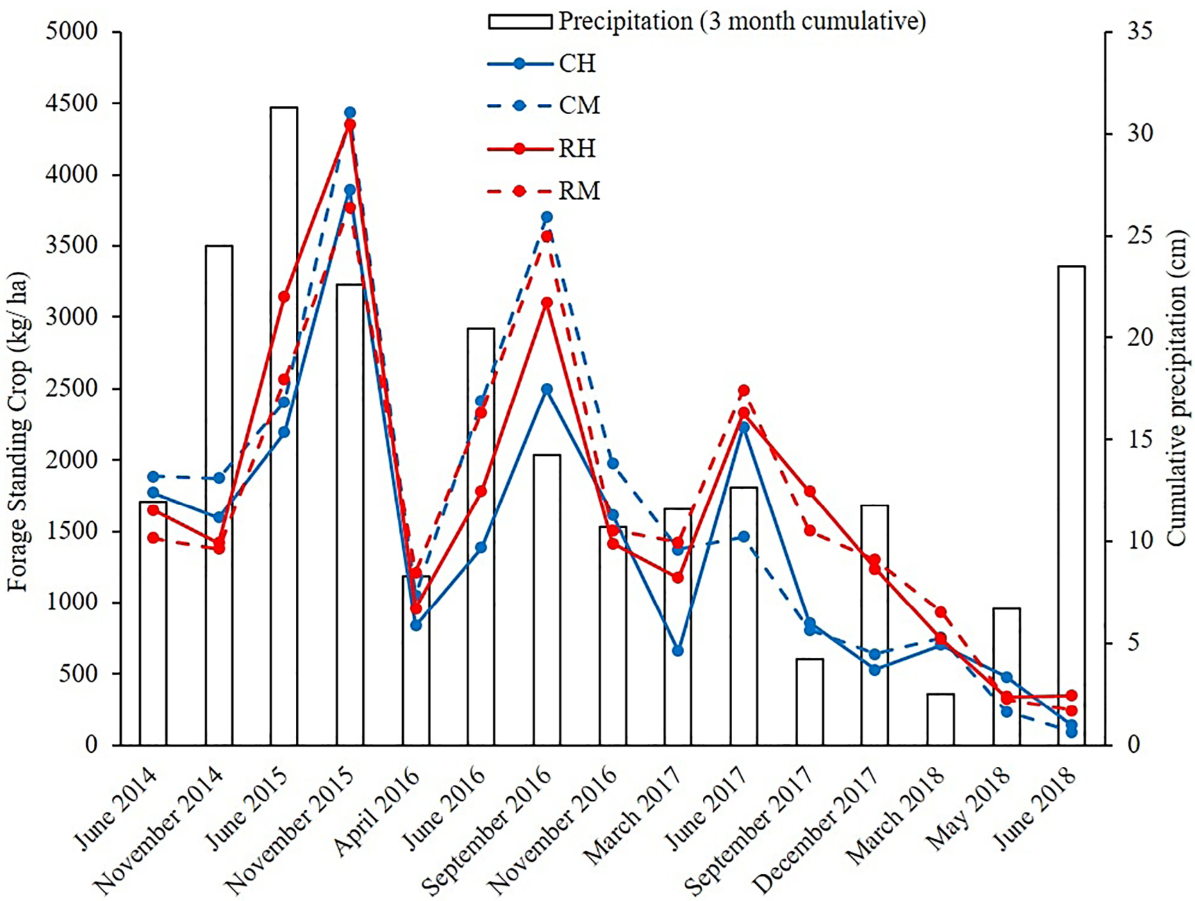

Figure 5. Weighted mean residual forage standing crop (kg/ha) by treatment collected at the end of each growing season and at each rotation from June 2014 to June 2018 on the Coloraditas Grazing Research and Demonstration Area. Cumulative precipitation for the 3 months prior to the collection period is shown in the white bars. CH indicates Continuous High; CM, Continuous Moderate; RH, Rotational High; and RM, Rotational Moderate.

without a planned rest.[9] Before the deferment period, the stocking rate was greater (1 AU/12 ha) than our "high" stocking rate (1 AU/14 ha) during this demonstration study; initiating the grazing study without deferment may have resulted in rangeland degradation. Although the removal of grazing animals entirely may cause losses in herbivore-dependent plant species and reduce nutrient cycling, overgrazing can lead to shifts in the stable state of rangelands,[18] particularly when coupled with drought conditions.[19]

From the onset of deferment to the first measurement of forage standing crop (March–June 2014), the ranch received 25% of its cumulative annual precipitation for the year and 66% of its April to August growing season precipitation. Increased precipitation left treatments with 1,457 to 1,905 kg/ha (1,300–1,700 lb/acre) of dry forage. This is above the minimum recommended residue levels of 840 to 1121 kg/ha (750–1,000 lb/acre) suggested to sustain midgrass rangelands in Texas.[20] By November 2015, 1 month before grazing implementation, peak average forage standing crop occurred on the CGA (mean = 4,115 kg/ha [3,671 lb/acre]). Subsequent peaks occurred in September 2016 and June 2017 but did not rebound to the pretreatment levels in November 2015 (Fig. 5). Minimums in forage standing crop occurred in April 2016, March 2017, and September 2017 (Fig. 5).

From November 2015 to the first rotation in April 2016, there was an 81%, 72%, 78%, and 68% decrease in forage standing crop on the CH, CM, RH, and RM treatments, respectively (Fig. 5). After 115 to 120 days since the start of the project, first year heifers produced 358 calves and weighed on average 444 kg (978 pounds). The marked drop in forage standing crop during this time period may be explained by a higher demand for protein by cattle during lactation.[21] Once rotations began in April 2016, grazing periods lasted between 60 and 120 days, and both rotational herds (moderate and high stocking) were rotated simultaneously (Tables 2 and 3). The decision to rotate was based on a visual inspection of range conditions and cattle by the CGA's cattle manager.

From April to September 2016, forage standing crop rebounded on all treatments and remained >1,121 kg/ha (>1,000 lb/acre) until March 2017. Forage standing crop declined during dormancy between November 2016 and March 2017 but rebounded on all pastures with early growing season precipitation culminating in peak forage at the end of June 2017.

From September to November of 2017, the area received <25% of normal 3-month cumulative precipitation (Fig. 4) and forage standing crop fell below 1,121 kg/ha (1,000 lb/acre) on the continuous grazing treatments (Fig. 5). In

Table 2. Estimated total forage standing crop (kg/ha) at the entry and exit dates for rotation of the cattle herd on the rotational high treatment on the Coloraditas Grazing Research and Demonstration Area, 2015–2018

Pasture	Entry date	kg/ha	Exit date	kg/ha	Days grazed	Precipitation (cm)	Change	kg/ ha/day	Utilization (%)
A	14 December 2015	4,931.8	7 April 2016	1,469.8	115	13.7	3,461.9	30.1	70.2
B	7 April 2016	760.0	29 June 2016	1,627.2	83	20.4	867.2	10.4	114.1
C	29 June 2016	2,358.8	13 September 2016	2,070.7	76	11.6	288.0	3.8	12.2
A	13 September 2016	2,925.8	15 November 2016	1,632.0	63	11.5	1,293.8	20.5	44.2
B	15 November 2016	1,127.0	1 March 2017	670.3	106	12.1	456.7	4.3	40.5
C	1 March 2017	926.5	5 July 2017	3,359.6	126	23.6	2,433.1	19.3	262.6
A	5 July 2017	2,026.8	5 October 2017	1,933.8	92	9.4	93.1	1.0	4.6
B	5 October 2017	418.4	22 December 2017	385.1	78	12.3	33.3	0.4	8
C	22 December 2017	1,790.0	1 March 2018	445.2	69	2.0	1,344.8	19.5	75.1
C*	1 March 2018	445.2	5 May 2018	326.8	65	5.8	118.4	1.8	26.6

Note: Cattle were stocked in pasture A on December 2015 and rotated through pastures A, B, and C throughout the study. Number of days of grazing, cumulative precipitation (cm) during the rotation period, change (forage standing crop at entry–exit dates), kg/ha/day, and utilization (%) of the pasture are shown for each period.

* Herd C was not rotated on 1 March 2018.

Table 3. Estimated total forage standing crop (kg/ha) at the entry and exit dates for rotation of the cattle herd on the rotational moderate treatment on the Coloraditas Grazing Research and Demonstration Area, 2015–2018									
Pasture	**Entry date**	**kg/ha**	**Exit date**	**kg/ha**	**Days grazed**	**Precipitation (cm)**	**Change**	**kg/ ha/day**	**Utilization (%)**
D	10 December 2015	3,187.5	6 April 2016	386.3	118	13.5	2,801.2	23.7	87.9
E	6 April 2016	1,228.2	28 June 2016	2,705.6	84	20.9	1,477.4	17.6	120.3
F	28 June 2016	5,682.3	7 September 2016	4,072.0	70	9.0	1,610.3	23.0	28.3
D	7 September 2016	3,384.9	15 November 2016	684.9	69	10.3	2,700.1	39.1	79.8
E	15 November 2016	2,298.9	1 March 2017	1,439.2	106	13.3	859.6	8.1	37.4
F	1 March 2017	2,327.3	5 July 2017	4,045.4	126	23.1	1,718.0	13.6	73.8
D	1 July 2017	1,279.5	5 October 2017	577.0	96	6.4	702.5	7.3	54.9
E*	5 October 2017	1,621.9	21 December 2017	1,577.4	77	12.2	44.5	0.6	2.7
E	21 December 2017	1,577.4	1 March 2018	289.4	70	2.0	1,287.9	18.4	81.7
F	1 March 2018	1,497.6	8 May 2018	506.4	68	5.8	991.3	14.6	66.2

Note: Cattle were stocked in pasture D on December 2015 and rotated through pastures D, E, and F throughout the study. Number of days of grazing, cumulative precipitation (cm) during the rotation period, change (forage standing crop at entry–exit dates), kg/ha/day, and utilization (%) of the pasture are shown for each period.

* Herd E was not rotated on 21 December 2017.

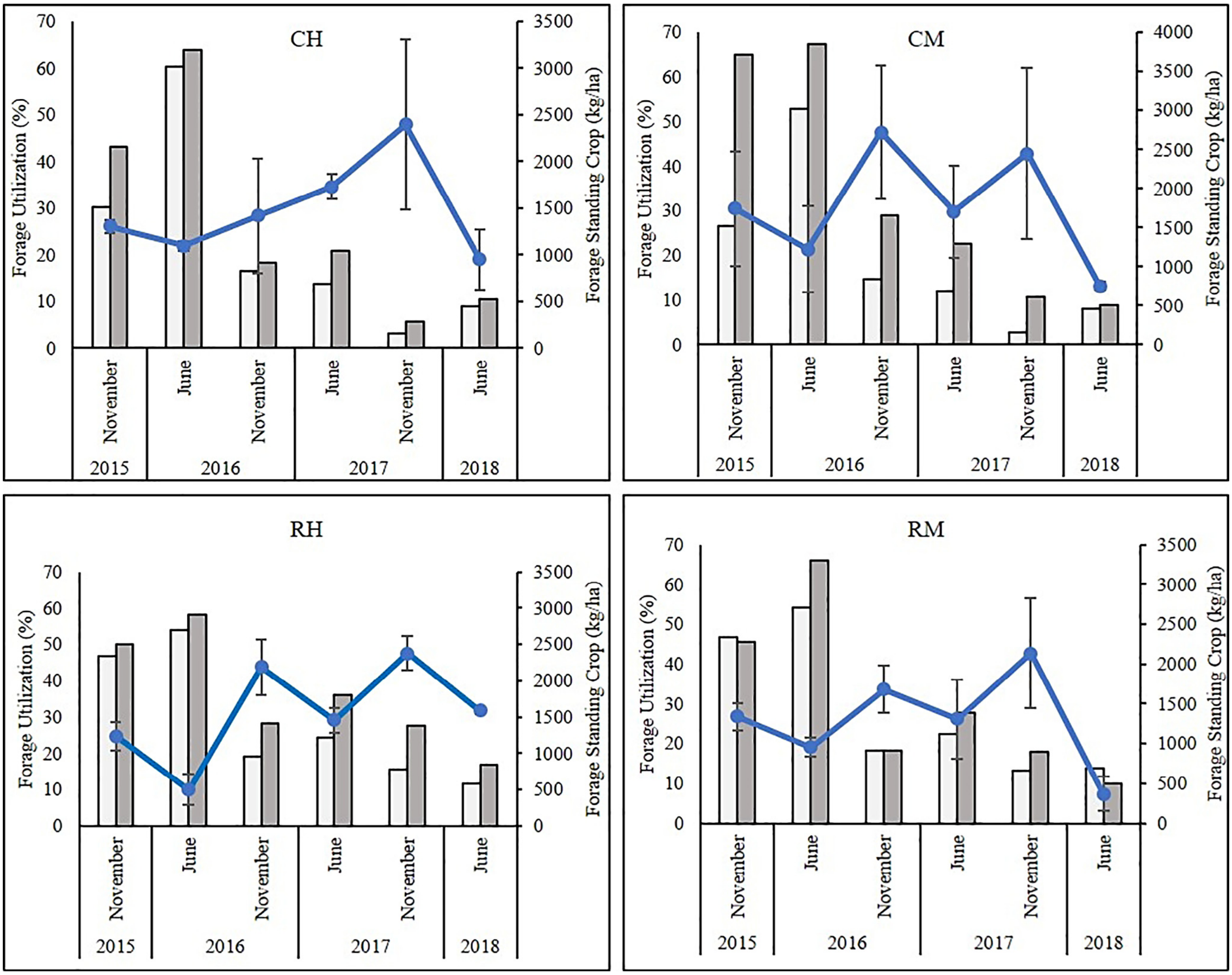

Figure 6. Mean forage utilization (% ± SE) of palatable forage (preferred forbs + grass; blue line) averaged over each treatment on the Coloraditas Grazing Research and Demonstration Area, November 2015 to June 2018. The average forage standing crop outside (white bars) and inside (grey bars) 10 1-m^2 grazing exclosures are shown on the secondary axis. CH indicates Continuous High; CM, Continuous Moderate; RH, Rotational High; and RM, Rotational Moderate.

September 2017, we began to observe a distinct separation between the continuous and rotational treatments, with the rotational treatments maintaining a greater quantity of forage (Fig. 5). Conditions worsened through early 2018 and once conditions persisted at <1,121 kg/ha (≤1,000 lb/acre) on all treatments and in the absence of meaningful rainfall, the demonstration project was put on a deferment and all cattle were vacated by June 2018. Although the rotational treatments may have been able to recover with the June precipitation received in 2018, we decided to destock all treatments at the same time to maintain the continuity of the experiment.

Year-to-date precipitation at the project's end in early May 2018 was ~8 cm (3 inches) (Fig. 4). After 6 months of deferment and receiving late September precipitation of 25.4 cm (10 inches), we completed a final estimate of forage standing crop and observed an average rebound of 310 kg/ha (277 lb/acre) on the continuous pastures and 1,060 kg/ha (946 lb/acre) on the rotational pastures. The project restart date will depend upon improved range conditions.

Forage Utilization

We sampled exclosures during six growing seasons (i.e., end of summer and end of fall) from November 2015 to June 2018. Average utilization of grass and preferred forbs prior to grazing was about 27% before the initiation of the project in November 2015 (Fig. 6). Utilization on the rotational treatments dropped as pastures with rotational herds experienced forage growth from the first rotation in April to the second rotation in June, which coincided with the start of the warm growing season and ~20 cm (8 inches) of cumulative precipitation (Fig. 6; Tables 2 and 3). For the remainder of the study, utilization on all pastures increased each November (range = 28–48%) and decreased by each June (range = 7–35%; Fig. 6). By November of 2017, each treatment reached a utilization of ≥40% (Fig. 6); this was coupled with treatment level lows in residual forage standing crop and a ranch-wide U.S. Drought Monitor classification of severe drought.[22] By the end of June of 2018, after animals had been

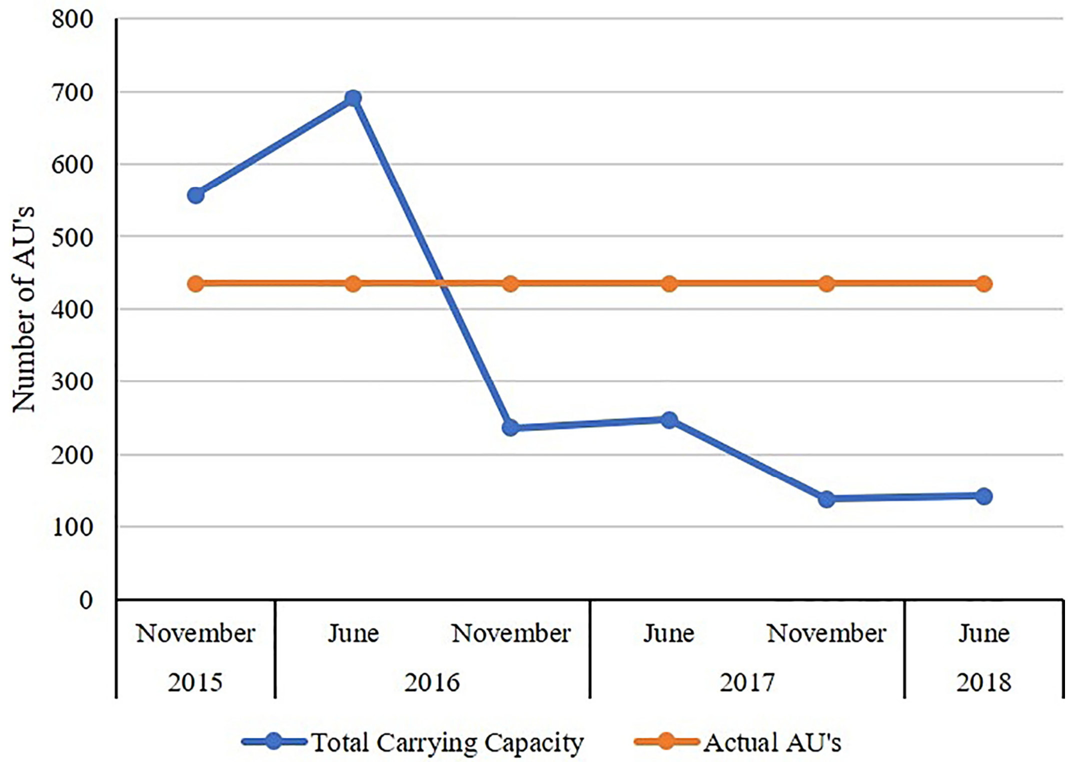

Figure 7. The estimated carrying capacity and total number of animal units (AU) on four grazing treatments combined compared with the actual number of AUs present on the Coloraditas Grazing Research and Demonstration Area from November 2015 to June 2018.

deferred from treatments for 30 to 50 days, utilization decreased in all treatment areas (Fig. 6). Overall, we observed increases in forage utilization during periods of low forage availability and decreases during periods of high forage availability. Increase in availability during these years potentially coincides with an increase in forage quality, because as forage quality increases, the amount of forage needed to acquire nutrients is met on smaller quantities.[23] However, because increases in quality often translate to higher digestibility, intake is suspected to increase with increasing quality. A closer examination of changes in species composition and diversity may be necessary to further explain our observations.

Lessons Learned

Cattle grazing using set stocking rates, in our case 1 AU/14 ha and 1 AU/20 ha, is not feasible in South Texas and likely other drought-prone regions. Our initial objectives with the CGA to evaluate operation-scale responses of vegetation, animal performance, and wildlife populations over the long term (>10 years) were unrealized because we were forced to remove cattle from the demonstration area due to lack of available forage, concerns for animal health, and risk of rangeland degradation. Erratic, but typical for this region, rainfall patterns and resulting forage production proved our stocking rates (though widely utilized for this region) to be unsustainable over the long term, regardless of grazing method. Unlike most ranchers whose purpose is to generate revenue, our purpose with this project was to demonstrate responses in vegetation composition and structure and in animal productivity. Regardless of motive, liquidation of cattle is not profitable and should be avoided when possible by periodically balancing stocking rate with forage standing crop.[3] This scenario may be avoided when flexibility in stocking is integrated into the program and careful monitoring of forage and cattle herd performance is maintained so that trigger points for destocking or relocating animals can be identified prior to the onset of a drought event.

One approach is to first establish, then regularly modify stocking rates based on estimated harvest efficiency, or the percent of the current years forage available for consumption to cattle.[2,3,24] In short, this approach involves 1) calculating grazable acreage in a pasture, 2) multiplying grazable acreage by forage production (kg/ha) to produce an estimate of total forage standing crop, 3) estimating usable forage by multiplying total forage standing crop by 25% (25% to cows; 25% lost to insects, other herbivores, trampling, and weathering; 50% left as residual[25]), and 4) determining total number of AUs by dividing usable forage by the total forage consumed by 1 AU in a year or other period of time. Stocking rate can then be determined by dividing the pasture area by the determined number of AUs (e.g., AU/number of hectares).

Retrospectively, we calculated the carrying capacity of our treatments at the end of each growing season using estimates of clipped residual forage from outside of grazing exclosures at 25% harvest efficiency and compared it to the actual number of AUs present (see Equation 1; Fig. 7). While we maintained 435 AUs on the entire treatment area from December 2015 to May 2018, our analysis shows that we were on average 243 AUs above the combined carrying capacity of all treatments from October 2016 to June 2018. This demonstrates the value of regularly adjusting stocking rates based on range conditions.

We plan to use the above approach when establishing and maintaining cattle stocking rates upon reinitiating the grazing demonstration project within the CGA. Important questions remain pertaining to vegetation composition and structure, cattle performance, and wildlife population responses to different grazing methods and stocking intensities. In the next phase, we plan to use different levels of harvest efficiency, rather than set stocking rates as treatments. We will maintain treatments under continuous and deferred rotation grazing, within which we will monitor above responses over the long term. We will use estimates of residual forage standing crop obtained through clipping each June and November to make decisions on increasing or decreasing the stocking rate, while using the preset harvest efficiencies as treatments. Using fixed stocking rates, when coupled with drought, will prompt the deferment of cattle on all experimental pastures. Building flexibility into the stocking rate by setting harvest efficiencies as treatments will allow the experiment to fulfill its long-term objectives.

We documented the impacts that inflexibility in grazing management has in South Texas. We observed that even a moderately stocked system cannot withstand a severe drought if the pasture is kept above carrying capacity for the duration. While the direct inferences of this study are specific to the regions of South Texas and northern Mexico, we recommend ranchers in other drought-prone regions across the globe carefully consider stocking rates and allow for flexibility in their cattle management systems, implementing an adaptive approach.

Lastly, we want to reiterate the point that cattle ranching is a tough business. In addition to previously mentioned challenges (e.g., uncertainty in precipitation and markets) many ranchers in South Texas are new landowners, often acquiring land for recreational purposes, and may be unaware of previous cattle management practices. This puts them at a disadvantage. However, in situations in which the landowner suspects that their land has a history of being overgrazed, we recommend a measured and conservative approach. As noted, the "Wild Horse Desert" is a harsh but resilient environment following periods of above average rainfall.

Declaration of Interests

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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