Forage Performance in Crop–Livestock Systems Designed to Reduce Water Withdrawals From a Declining Aquifer

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On the Ground

- In the semiarid Texas High Plains, integrating crops with grazing systems could conserve irrigation water and increase perennial grassland.
- We combined irrigated and nonirrigated exotic and native grasses with cotton production.
- We grazed and hayed the grasses, harvested grass seed, and harvested cotton.
- Strategically combining different forages, fertilizer, and water inputs can extend the grazing season, improve the quality of available forage, and provide a buffer against moderate drought.
- Nonirrigated, seeded native grass mixtures can provide valuable grazing and decrease total water use of an integrated crop-livestock system.

Keywords: water conservation, grazing, forage, irrigation, Ogallala Aquifer, crude protein, fiber.

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As water in the Ogallala Aquifer declines and pumping restrictions are enacted, farmers and researchers in the Texas High Plains of the United States seek alternative cropping systems to conserve water.[1,2] Integrating crop and livestock production could address water conservation and other agricultural concerns, including pest control, soil quality deterioration, nutrient concentration, energy efficiency, ecological capital, system resilience, and economic performance.[1,3–6] Additionally, integrated systems that use perennial forages could improve wildlife habitat by revegetating cropland that was previously farmed.[7] Using native plant species can have the added benefit of improving habitat for some wildlife species.[8]

In the Texas High Plains, we previously described and evaluated productivity of two integrated crop–livestock systems based on perennial forages.[9] Both systems reduced irrigation needs below levels typically used for irrigated crops in the region[9] and the perennial forages in these systems improved soil aggregate stability and soil organic C accumulation potential relative to cotton, the dominant regional crop.[10] We previously evaluated animal performance,[9] but because stocker steers (*Bos taurus*) in these systems grazed multiple forages in sequence, the contribution of individual forages to stocker performance could not be determined from animal performance alone. Better understanding of how each component of the systems functioned within the systems could help fine-tune overall performance.

Clipping forage samples from system paddocks and subjecting samples to laboratory analysis to determine nutritive value and quantity is one method of obtaining information on the contribution of individual paddocks in a grazing system. Such information allows grazing managers to match forage to animal needs. This is essential to efficient production for young ruminants with rapid growth rates because of their high requirements for digestible energy and crude protein (CP)[11]. Nutritive value of the individual grasses in our previous experiment[9] has not been previously evaluated in grazing systems subject to the weather extremes of the Texas High Plains. During this experiment, precipitation ranged from the driest year on record (2011; 96 mm precipitation) to a year 44% above mean annual precipitation (2010; 680 mm). Here, we report the nutritive value of the grazed forages in these two integrated crop–livestock systems under these weather extremes, and provide suggestions for optimizing their use in future grazing systems.

Site Description

We conducted research at the Texas Tech Agricultural Field Research Laboratory, 24 km northeast of Lubbock, TX (101°47' W, 33°45' N; 993-m elevation). The predominant soil was Pullman clay loam (fine, mixed, superactive, thermic Torrertic Pauleustolls[12]) on 0% to 1% slopes. Soil properties at 0 cm to 5 cm and 5 cm to 20 cm depths were as follows: bulk density 1.09 g/cm^{3}and 1.43 g/cm^3; pH 7.7 and 7.9; organic matter 2.2% and 1.8%; and total soil nitrogen 0.06% and 0.05%. Long-term mean annual precipitation was 471 mm, with more than 75% falling between April and October.[13]

Description of Agricultural Systems

Beginning in 2002, we established two integrated crop–livestock systems in a randomized block design with three blocks. The focus of this article is from 2009 to 2011, when we determined selected measures of forage nutritive value in the systems. We designed systems to decrease irrigation relative to typical irrigated crops in the region[9]; thus, we did not irrigate to maximize production, but rather to strategically supplement precipitation to produce more consistent growth and to meet needs of forages and grazing stocker steers.

Each block of the low-irrigation system (LOW; 10.1 ha per block) consisted of four paddocks. Three paddocks were nonirrigated: 4.5 ha of a native perennial grass mixture (1.12 kg pure live seed [PLS]/ha blue grama [*Bouteloua gracilis*], 2.24 kg PLS/ha sideoats grama [*Bouteloua curtipendula*], 2.24 kg PLS/ha buffalograss [*Buchloe dactyloides*], and 0.56 kg PLS/ha green sprangletop [*Leptochloa dubia*]), 1.7 ha of foxtail millet (*Setaria italica*), and 1.7 ha of cotton (*Gossypium hirsutum*). Foxtail millet and cotton rotated annually. The fourth paddock was under subsurface drip-irrigation (mean: 215-mm water per year) and consisted of 2.1 ha of "WW-B. Dahl" old world bluestem (*Bothriochloa bladhii*). Old world bluestem was deferred from grazing in late summer to permit a grass seed harvest each autumn. Cotton was not grazed. Mean annual rates of N fertilizer application in kg/ha were: native grass 20; foxtail millet 60; cotton 67; and old world bluestem 67.

The moderate-irrigation system (MOD; 3.8 ha per block) consisted of three subsurface drip-irrigated paddocks: 2.1 ha of old world bluestem (mean: 224-mm water per year), and two, 0.9-ha paddocks of "Tifton 85" bermudagrass (*Cynodon dactylon*; mean: 275 mm water per year). Management of old world bluestem in MOD was similar to LOW. Mean annual rates of N fertilizer application in kg/ha were bermudagrass 178; old world bluestem 67.

Grazing Description

Angus and Angus-cross stocker steers (mean initial body weight 260 ± 24 kg) grazed within each system from May to September or October each year, except in 2011, when no grazing occurred as a result of severe drought. The LOW system was stocked with 8 steers in 2009 and 10 in 2010. The MOD system was stocked with 15 steers per year. Based on grazed area (excluding cotton) for each system, stocking rates were 1.1 and 0.85 ha per steer for LOW in the two respective years and 0.26 ha per steer for MOD in both years. We vaccinated and implanted steers with Revalor G (Merck, Summit, NJ, USA) before grazing and reimplanted and weighed them at 90-day to100-day intervals. Salt and mineral supplements were available ad libitum. In 2009, we provided cottonseed cake (38% CP) supplement when forage CP did not meet requirements for daily gains of at least 0.45 kg.[11]

Our general grazing strategy for both systems was to always provide forage quantity sufficient to meet steers' demands, and for quality to be as high as possible over the course of the grazing season, subject to several limiting criteria. In years and seasons of abundant forage, this required moving cattle from one paddock to the next relatively quickly to maintain introduced forages in a vegetative growth stage. When forage in the MOD system exceeded that required by steers to the degree that grazing could not keep it in a vegetative state, we hayed bermudagrass. Hay cutting had two benefits: first, it gave us a valuable product, and second, it enabled grazing the higher-quality regrowth that followed hay cutting. The first of the limiting criterion was to leave sufficient standing mass so that the perennial grass longevity would not be damaged. The second limiting criterion was that grazing must not interfere with farming operations. For old world bluestem, this meant that paddocks were deferred from grazing in late summer to allow a seed harvest. Actual dates when steers grazed each paddock are shown in Fig. 1. Based on previous research with the experimental forages at this site,[1,9] we set initial stocking rates at the maximum levels we expected to be able to maintain throughout the growing season in most years. Further details on the site, systems, and field layout were reported elsewhere.[9,14]

Sample Collection and Analyses

We collected samples for forage mass and nutritive value at 28-day intervals from each pasture block from May to October from 2009 to 2011. For chemical analysis, we composited 15 to 25 subsamples collected from diagonal transects within each pasture. We collected forage mass samples from the same transects within six quadrats (0.24 m^2 each) in each pasture. Mean coefficients of variation for pasture subsamples were native grass 0.39; old world bluestem 0.50; bermudagrass 0.33; foxtail millet before grazing 0.26; and foxtail millet after grazing 1.3. Clipping height represented heavy grazing pressure. We clipped sod-forming grasses slightly above the mat of stolons, young bunch grasses at 2 cm, and older bunchgrasses at 8 cm for native grasses and 15 cm for old world bluestem, to stay above the dense and decadent crown material. We included live and dead plant material in nutritive value samples, but species that we observed to be consumed very little relative to their abundance were excluded. The most common species excluded were silverleaf nightshade (*Solanum elaeagnifolium*) and ground cherry (*Physalis* spp.). We did not exclude any species from estimates of forage mass. We dried samples at 55°C for 48 hours or longer if required to reach a constant weight and ground in a Wiley mill to pass a 1-mm screen for chemical analysis.

We used conventional laboratory procedures to estimate acid detergent fiber (ADF)[15] and CP for all native grasses and foxtail millet, and for a subset of bermudagrass and old world bluestem. Percentage CP was determined by combustion. For