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Ecological Sites: Can they be Managed to Promote Livestock Production?

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On the Ground

- We assessed diet quality and livestock weight gains for shortgrass steppe pastures dominated by Loamy Plains or Sandy Plains ecological sites.
- When growing season precipitation is "normal," livestock gains are higher on Sandy Plains ecological sites, and diet quality is not limiting livestock production.
- Conversely, when growing season precipitation declines by 20%, digestible organic matter, but not crude protein, influences livestock gains. These negative effects on livestock gains are more pronounced for the Loamy Plains ecological site.
- Pastures with multiple ecological sites may provide range managers greater forage diversity for livestock and higher livestock gains during dry growing seasons.

Keywords: crude protein, digestible organic matter, diet quality, semiarid rangeland, shortgrass steppe.

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Ecological sites are distinct areas of land with specific soil, topographic, and climate characteristics that differ from other kinds of land in terms of ability to produce a distinctive type, kind, and amount of vegetation. Ecological sites are one of the world's largest guiding frameworks for rangeland assessment, monitoring, and management.[1] Since publication of the seminal paper on ecological sites,[2] researchers and range managers have been working to better understand vegetation dynamics and plant successional pathways. Specifically, research efforts have included defining alternate stable states,[3] emphasizing differences between pathways and transitions,[4] identifying thresholds and quantifying rangeland health,[5] developing applications for heterogeneous landscapes,[6] determining influences of small mammal grazers,[7] and quantifying temporal rates of vegetation change.[8]

Soil processes and properties distinguish ecological sites within a given climate zone.[9] For range managers, a better understanding of how different soils influence vegetation community dynamics and livestock performance could improve management decision-making in complex ecosystems.[10] Unfortunately, there is very limited empirical data on how ecological site differences influence livestock diet quality and performance. This lack of understanding limits range managers' ability to apply ecological site information when making adaptive grazing decisions on complex rangelands.[11] Though existing fence infrastructure may currently constrain spatial and temporal aspects of grazing management related to ecological sites, emerging technologies such as virtual fences[12] and monitoring animal behavior using wireless sensor networks, GPS collars, and satellite remote sensing[13] offer creative opportunities for range managers to incorporate technological innovations to more effectively exploit ecological site differences within or among pastures.

We addressed the lack of information on how ecological sites influence livestock performance by collecting seasonal gain of yearling steers in moderately stocked pastures with differing ecological sites in semiarid, shortgrass steppe. In addition, we collected fecal material from these steers over the grazing season to evaluate the quality of forage for animal health and productivity related to the USDA-Natural Resources Conservation Service (NRCS)-Conservation Stewardship Program, Conservation Enhancement Activity of "Maintaining quantity and quality of forage for animal health and productivity (E528140Z1)." This technology associated with evaluating grazing animal nutritional status provides a practical tool for range managers to use in decision-making related to grazing management and supplemental feeding

strategies (if needed) to meet animal performance goals. For example, range managers can more effectively match periods of high nutritional quality of forage with peak animal growth, alter stocking rates that may reduce grazing selectivity and resulting diet quality, and to offset declining forage quality during the grazing season or drought to implement strategic supplemental feeding to prevent negative effects on animal body condition. This assessment will provide range managers and NRCS professionals in the region with greater awareness of the contribution that contrasting ecological sites (Loamy Plains and Sandy Plains, see below) may have on optimal livestock performance, especially in dry years. It also illustrates the importance of factoring seasonal vegetation dynamics into decision-making related to grazing management strategies.

Methods

Our study location was at the USDA-Agricultural Research Service's Central Plains Experimental Range, a 6,270-ha Long-Term Agroecosystem Research network location at the northern end of the shortgrass steppe ecosystem in northeastern Colorado. Mean annual precipitation was 340 mm and the average growing season (May–September) value was 239 mm. Three 130-ha pastures were randomly selected for monitoring during 2016 to 2018. One pasture was dominated (> 90%) by the Loamy Plains ecological site (R067BY002CO) where blue grama (*Bouteloua gracilis*), a warm-season (C4) shortgrass, was the primary forage species (Figure 1). A second pasture was similarly dominated by the Sandy Plains ecological site (R067BY024CO), where needle-and-thread (*Hesperostipa comata*), a cool-season (C3) midgrass, was the primary forage species. A third pasture had a mix of these two ecological sites (henceforth, "mixed").

Although only one pasture represented each ecological site, the lack of replication is partially offset by pasture sizes (130 ha) similar to those of actual ranches in the region. Pastures were moderately stocked with yearling steers from mid-May through the end of September in each year. Stocking rates for the Loamy Plains pasture were 0.54 AUM/ha in 2016, 0.56 AUM/ha in 2017, and 0.63 AUM/ha in 2018. For the Sandy Plains pasture, the stocking rates were 0.63 AUM/ha (2016), 0.66 AUM/ha (2017), and 0.71 AUM/ha (2018). Stocking rates for the pasture containing both ecological sites were intermediate between the Loamy Plains and Sandy Plains pastures.

We collected fresh fecal samples from five individual animals in each pasture on a weekly basis. These samples were composited, frozen, and shipped to the Grazingland Animal Nutrition laboratory (https://cnrit.tamu.edu/ganlab/) for analyses. The two variables of interest were crude protein (nitrogen) percent and digestible organic matter (an indication of both energy and digestibility) percent in the diet of the cattle. These values were determined from fecal Near Infrared Reflectance Spectroscopy (NIRS) equations for predicting diet quality of free-ranging cattle, which have been field validated.[14] Arithmetic means of the weekly values for crude protein and digestible organic matter were determined for three periods in the grazing season: 1) late spring, mid-May through June, which represents the period of peak cool-season (C3) plant growth and early warm-season (C4) plant growth; 2) summer, July and August, which represents the period of peak warm-season (C4) plant growth; and 3) early fall, September, which is a time when cool-season (C3) regrowth can occur if precipitation is adequate.

Loamy Plains (R067BY002CO)	Characteristic	Sandy Plains (R067BY024CO)
Loess, Alluvium, Eolian deposits	Parent Material	Eolian sands, Alluvium
Loam, sandy loam	Surface texture	Sandy loam, loamy sand, fine sandy loam
Well drained	Drainage class	Well drained to somewhat excessively drained
Slow to moderate	Permeability class	Moderately slow to moderately rapid
Warm-season shortgrass	Plant Community	Cool-season grasses
Blue grama	Key plant species	Needleandthread
604	Plant production (2016-2018) (kg/ha)	1106

Figure 1. Soil and plant community characteristics of Loamy Plains and Sandy Plains ecological sites in the semiarid, shortgrass steppe. Upper pictures are characteristic of early summer conditions and lower pictures display late summer conditions.

Livestock weight gains during the grazing season were based on the difference between individual animal weights at the beginning and end of the grazing season for each pasture for each year. These individual animal gains were averaged for all animals in each pasture and divided by the number of days of grazing in each season to obtain average daily gains (see Figures 2–4). Livestock gain data was analyzed using a 1-way analysis of variance each year to determine the influence of pasture (ecological site) for crude protein and digestible organic matter.

Results and Discussion

Seasonal trends in diet quality of the yearling steers, as observed through the fecal analyses, showed that for both ecological sites, both crude protein and digestible organic matter, were consistently highest in the spring when vegetation was green and rapidly growing, intermediate in the summer months (July and August), and lowest in the fall (September) (Figures 2–4). Low diet quality in September resulted in limited livestock gains during this month.[15] We acknowledge that this study is limited in replication but argue that the large pasture sizes and 3-year study duration provide realistic results for range managers. Further, these results are based on widely recognized relationships between species composition and forage quality, but further specify them for two important ecological sites in the shortgrass steppe. Despite this lack of replication, the value of this study for range managers is that we have proposed a strategy for evaluating the impacts of ecological sites on livestock

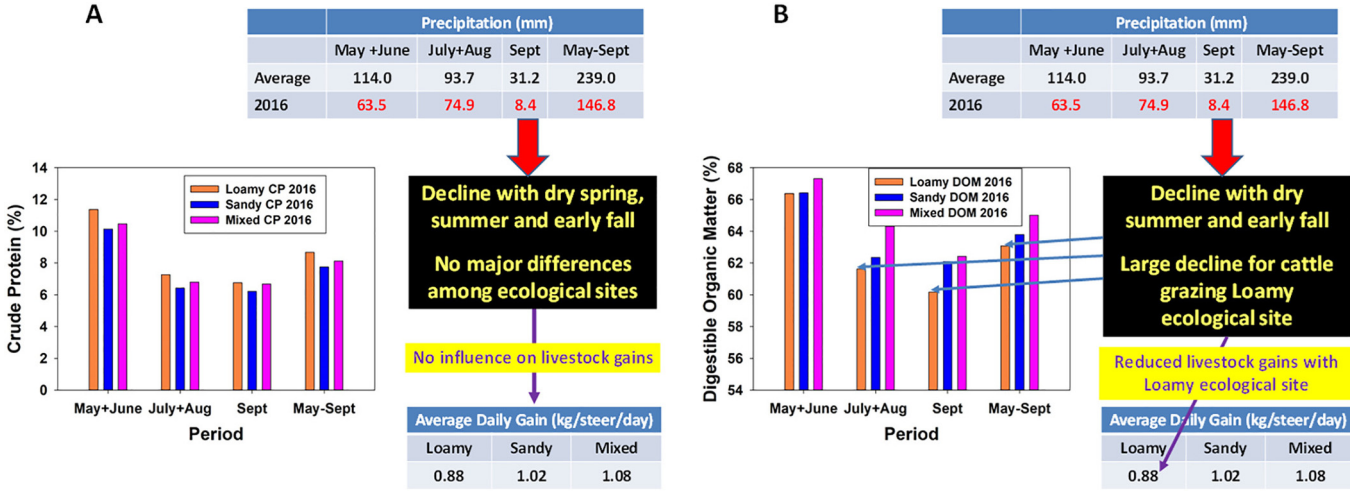

Figure 2. Crude protein (**A**) did not affect livestock gains of yearling steers grazing pastures dominated by Loamy Plains, Sandy Plains, or with both ecological sites (Mixed) during 2016, with below-normal (–39%) precipitation during the grazing season. However, the dry summer and early fall resulted in lower digestible organic matter (**B**) for the pasture dominated by Loamy Plains, and this reduced livestock gains compared to the pasture dominated by Sandy Plains or with both ecological sites (Mixed).

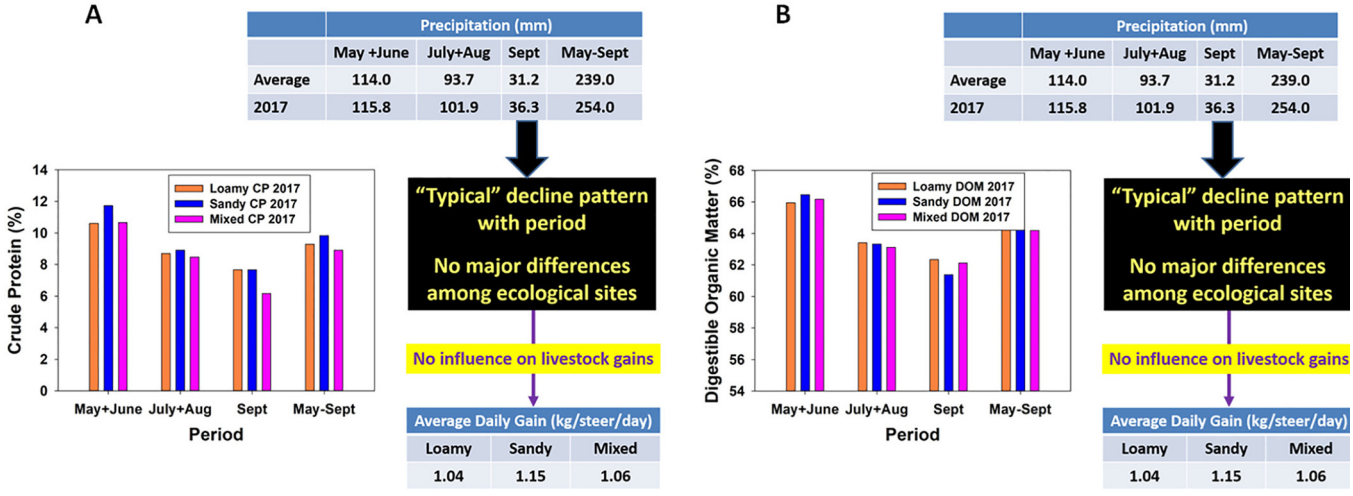

Figure 3. Neither crude protein (**A**) nor digestible organic matter (**B**) affected livestock gains of yearling steers grazing pastures dominated by Loamy Plains, Sandy Plains, or with both ecological sites (Mixed) during 2017, with normal precipitation during the grazing season

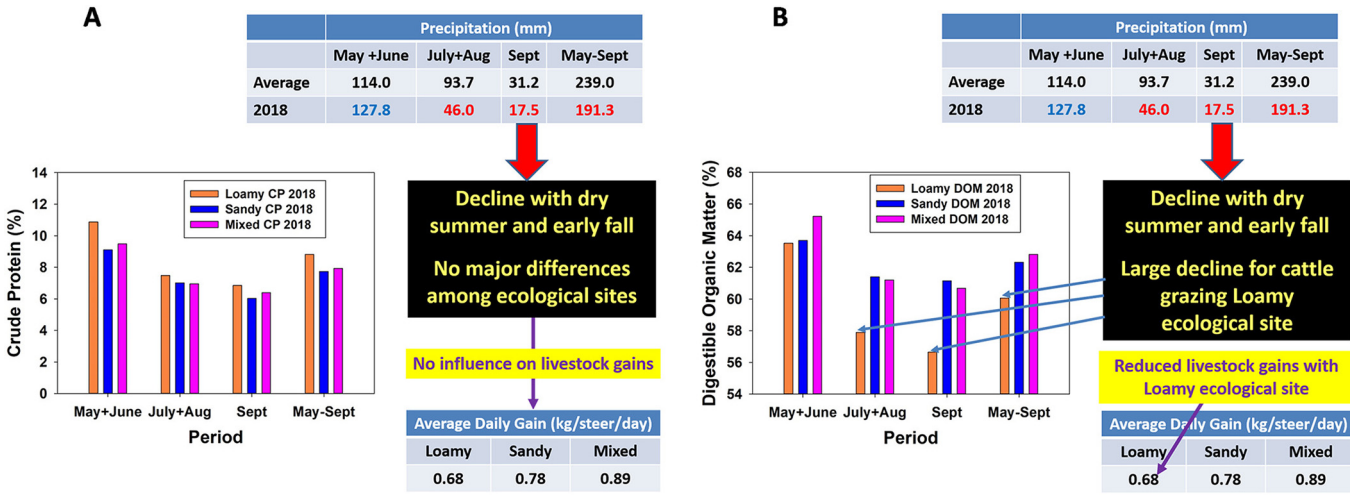

Figure 4. Crude protein (**A**) did not affect livestock gains of yearling steers grazing pastures dominated by Loamy Plains, Sandy Plains, or with both ecological sites (Mixed) during 2018, with below-normal (−20%) precipitation during the grazing season. However, the dry summer and early fall resulted in lower digestible organic matter (**B**) for the pasture dominated by Loamy Plains, and this reduced livestock gains compared to the pasture dominated by Sandy Plains or with both ecological sites (Mixed).

production and provided an initial data set that supports this idea.

Key findings to inform range manager decision-making for ecological sites differed between growing seasons that were "normal" (2017) and "dry" (2016: precipitation 39% below normal; and 2018: precipitation 20% below normal).[16] For the growing season with mean annual precipitation (Figure 3) livestock weight gains in the pasture dominated by the Sandy Plains ecological site were 10.6% greater than gains in the Loamy Plains ecological site pasture or the pasture containing both ecological sites. This result may reflect the greater site productivity potential of Sandy Plains ecological site (Figure 1). In contrast, livestock weight gains were greater in the pasture containing both ecological sites, than in either of the pastures dominated by a single ecological site for both growing seasons (2016 and 2018) with below normal rainfall (Figures 2 and 4). This suggests that pastures with multiple ecological sites can provide greater forage diversity for livestock, resulting in higher livestock gains during dry growing seasons. Livestock weight gains were also 13% to 14% lower in the Loamy Plains than the Sandy Plains pasture during these dry growing seasons.

Metrics of diet quality also differed between normal and dry growing seasons. Diet quality did not appear to limit livestock production in the growing season with long-term average rainfall (2017, Figure 3). Conversely, during growing seasons with low average annual rainfall (2016 and 2018), patterns of digestible organic matter, but not crude protein, were correlated with differences in livestock gains (Figures 2 and 4). The negative effects of low diet quality on livestock gains were more pronounced for the Loamy Plains ecological site. These findings provide a novel and specific application of well-established relationships regarding forage quality at the plant part, plant species, and plant community levels of vegetation organization and forage intake.[17] For example, grass leaves are of a higher quality than stems (culms), such that plant architecture and growth stage are important variables determining forage intake and livestock weight gains. With plant maturity and senescence influenced by dry environmental conditions, this reduces both forage quantity and quality to create nutritional stress for cattle.[18] Moreover, increasing carbon dioxide concentration in the atmosphere reduces forage quality with consequences for livestock weight gains.[19]

Whereas prior livestock gain experiments on rangelands have largely either used a single ecological site for the study or not considered the impact of these different soil/vegetation communities, our findings provide insight into the utility of knowing the spatial distribution of ecological sites within and across pastures for range managers to optimize livestock production. Future research needs for advancing precision livestock grazing management to achieve optimized livestock production include combining: 1) advances in virtual fencing to strategically use ecological sites, 2) new technological advances in automated weighing scales for measuring within grazing season livestock weights, 3) GPS devices for determining grazing animal locations and grazing/resting activities, 4) novel equipment to measure jaw movements on grazing animals to differentiate between grazing and rumination, 5) new information on bite rates and sizes to determine daily intake rates, and 6) rumen microbiome knowledge.

Conclusions and Implications

Our research demonstrates that the relationship between livestock performance and ecological sites depends upon growing season precipitation variability. When growing season precipitation was near normal, neither forage quantity nor quality was limiting for livestock weight gains. Thus,

cattle grazing in the pasture dominated by the most productive ecological site (Sandy Plains) exhibited the greatest weight gains. In contrast, when growing season precipitation was below normal, both forage quality and quantity were lower, and both energy availability and forage digestibility limited steer weight gain. This constraint was especially evident in the pasture containing the Loamy Plains ecological site, and the pasture with both ecological sites exhibited the highest livestock performance in dry years. Greater awareness of the importance of ecological sites, in combination with growing season precipitation, can benefit livestock production at the ranch scale. It is important that range managers and NRCS professionals in the region recognize the importance of both vegetation heterogeneity and interannual precipitation variability in grazing management strategies.

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