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Economic cost analysis of continuous-season-long versus rotational grazing systems

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Introduction

A majority of ranchers in the Western US employ rotational grazing (movement of livestock among multiple pastures over the duration of the grazing season) (Roche et al. 2015). Furthermore, state and federal agencies often promote the use of rotational grazing for conservation purposes, such as to control the timing or distribution of grazing on certain ecological sites. However, decades of scientific evidence suggests that rotational grazing does not convey ecological or production advantages over season-long continuous grazing (livestock graze the same pasture from the start to the end of the grazing season) (Briske et al. 2008 and 2011). Moreover, diverse management strategies (including grazing systems) produce similar ecological outcomes on ranches in the Western Great Plains (Wilmer et al. 2018), and economic returns are primarily influenced by the stocking rate rather than the grazing system (Hart et al. 1988, Heitschmidt et al. 1990, Manley et al. 1997). Roche et al. (2015) suggest that there may be other motivations for ranchers which are not captured by scientific studies explaining this disconnect between grazing systems and economic returns. Nonetheless, the central question remains: Why do ranchers employ rotational grazing strategies if they are not economically advantageous? In this study we take a closer look at the costs associated with the two grazing systems to see where the greatest differences occur.

Implementation of a rotational grazing system requires additional infrastructure which can result in 1) one-time capital expenses, 2) opportunity costs in terms of time value of the money expended on the infrastructure, and 3) reoccurring maintenance costs. In addition to these direct economic costs, rotational grazing systems can be more time intensive than season-long continuous grazing systems due to the additional time

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required to move livestock among pastures and maintain the additional infrastructure (Gillespie et al. 2008). These infrastructure and time/labor costs have rarely been addressed. Thus, a key need remains to conduct economic cost analyses for rotational and season-long continuous grazing systems.

Here, we determine fencing and water infrastructure, and labor costs for five grazing management scenarios, all with the same total acreage (3,200 acres): 1) season-long continuous grazing with one large pasture, 2) rotational grazing with the one large pasture cross-fenced into ten 320-acre pastures with permanent barbed-wire fencing or 3) with temporary electric fence, 4) season-long continuous grazing with ten 320-acre pastures that are noncontiguous, and 5) rotational grazing with the ten 320-acre noncontiguous pastures (Table 1). These scenarios represent a gradient of grazing strategies representative of what ranchers are using in the Western US (Roche et al. 2015). Using scenario 1 as a baseline, we determine the conversion costs and potential labor/time differences associated with moving from season-long continuous grazing to rotational grazing with permanent (*scenario 2*) or temporary (*scenario 3*) fence. We also determine the additional costs associated with having a noncontiguous versus contiguous pastures for season-long continuous (*scenario 1 vs. scenario 4*) and rotational grazing (*scenario 2 vs. scenario 5*). This has direct application to ranchers evaluating the efficacy of renting or purchasing lands that are not adjacent to currently controlled lands. Lastly, we compare costs associated with season-long continuous versus rotational grazing on a dispersed ranch (*scenario 4 vs. scenario 5*).

Study Site and Methods

Our study system is shortgrass steppe with the primary site being the USDA-Agricultural Research Service's Central Plains Experimental Range (CPER), a Long-Term Agroecosystem Research (USDA 2017) network location, approximately 12 km northeast of Nunn, Colorado, USA (40° 50′N, 104°43′W). Mean annual precipitation is 340 mm and topography is characterized by gently undulating plains. The study site is comprised of Sandy Plains and Loamy Plains ecological sites (NRCS 2007). Two C4 perennial grasses, blue grama (*Bouteloua gracilis*) and buffalo grass (*B. dactyloides*), dominate the vegetation (typically >70% of annual net primary production). C3 perennial graminoids primarily consist of needleleaf sedge (*Carex duriuscula*), western wheatgrass (*Pascopyrum smithii*), and needle-and-thread (*Hesperostipa comata*). The most common forb is perennial scarlet globemallow (*Sphaeralcea coccinea*).

Cattle in this study are yearling steers with cattle moved approximately every three weeks among pastures with rotational grazing. Results from this study are fairly specific to high plains grasslands and seasonal stocker steer operations. Infrastructure requirements for other terrain types and cattle operations could vary greatly from the results presented in this paper. The five scenarios presented were an attempt to make these results useful to a wider audience, but there are still restrictions to its applicability.

Scenario 1 (one large 3,200-acre pasture) with season-long grazing is used as the baseline as this presents the simplest infrastructure and management approach. Scenario 2 (permanent barbed-wire fence) and 3 (temporary electric fence) are used on many ranches that have multiple pastures in their operation for flexibility in seasonal management, and the use of permanent (*scenario 2*) versus temporary (*scenario 3*) fence provides two options for subdividing larger pastures. For scenarios 4 and 5, we use data directly from an ongoing grazing study at the CPER which is addressing socio-ecological responses of semiarid rangelands to traditional season-long continuous grazing (*scenario 4*) and adaptively-managed rotational grazing (*scenario 5*) (Wilmer et al. 2018). Here, each grazing system had ten 320-acre, noncontiguous pastures, with system-level stocking rates the same between systems each year, but stocking density is 10-fold greater in the adaptively-managed rotational grazing system. The grazing season begins in mid-May and ends in early October.

We focus on three major cost components for each scenario: 1) fencing infrastructure, 2) water infrastructure, and 3) labor. Other costs, such as veterinary expenses, mineral and supplements, transportation, utilities, taxes, and other fees are dependent on the number of animals or amount of land, and are assumed to be unaffected by the grazing system used (Gillespie et al. 2008). Fencing costs are calculated by modifying the Natural Resources Conservation Service (NRCS) fence cost calculator (NRCS, 2009) with current, local prices for the study area. For water infrastructure, well costs were based on actual costs at the CPER, and windmill and water tank costs were based on local prices for North Central Colorado. Net present value of the infrastructure includes installation costs and lifetime maintenance costs, which are based on a percentage of the initial costs and multiplied by infrastructure lifespans[6] (AAEA, 2000).

Infrastructure quantities are calculated using the minimum acceptable infrastructure to provide for a maximum herd size of 270 steers. Water infrastructure necessary is based on the suggested two days of water storage per pasture with intermittently-powered water pumps, such as windmills (Wells, 1995). Differing stocking densities among the scenarios result in two separate tank sizes: a small tank with a 1,080 gallon capacity (*scenario 4*) and a large tank with a 10,800 gallon capacity (*scenarios 1, 2, 3, and 5*). The number of watering points in the large pasture (*scenario 1*) follows the recommendation by Holechek at al. (1998) that cattle not travel more than

[6] Infrastructure lifespans are based on AAEA lifespan calculations. While it is common for fences in the Western US to be functional for upwards of a hundred years, any change in lifespan would not affect the total annual cost by much. Furthermore, given the consistency in our calculations across scenarios, a longer lifespan would change the results for both continuous and rotational grazing systems by the same percentage (i.e. a change in the lifespan of fencing infrastructure to 50 years would decrease all costs equally by 13.6%).

two miles to access water. For the other scenarios, water infrastructure was added to ensure water access by livestock in each pasture (Table 2).

The base for labor calculations comes from weekly labor inputs for the multi-pasture, noncontiguous scenarios (*scenarios 4 and 5*) at CPER. However, the numbers are also extrapolated to model the other scenarios. Size of pastures is assumed to affect labor requirements needed to check cattle. Scenario 1 had the herd in one 3,200-acre pasture; we assume the time required to check this herd would take 2.5 times as long as for a 320-acre pasture. Three of the five scenarios (*scenarios 2, 3, and 5*) have the entire herd in one 320-acre pasture, therefore taking less time to check the herd. Steers in scenario 4 are distributed across ten 320-acre pastures, which results in the largest labor requirement of 15 hours per week (Table 3). Other labor costs include time for moving cattle to pasture at the start of the grazing season, and gathering and moving cattle from pasture at the end of the grazing season. These costs were determined using actual values from CPER operations.

We annualize the net present value of the infrastructure and add on the weekly labor costs multiplied by the number of weeks (n=21) in the grazing season. Annualizing costs break down the installation and maintenance costs of the infrastructure over the lifespan of said infrastructure, with a discount rate of 6% (AAEA, 2000). The discounting accounts for a 3% long-term real rate with a 3% additive risk adjustment. The formula for the equivalent annual cost is:

$$\frac{NPV}{\left(\frac{1-\frac{1}{1+r}^{t}}{r}\right)}$$

Where:

NPV = Net Present Value of the infrastructure (fencing or water developments) including maintenance costs for the lifespan of the infrastructure
r = discount rate (6%)
t = lifespan of the infrastructure

Results

Annualized costs for the five scenarios range from \$15,300 to \$55,300 (Figure 2). The cost of cross-fencing the single pasture (*scenario 1*) into 10 permanently fenced pastures (*scenario 2*) doubles the cost of infrastructure, which includes the addition of only one more water source as we assume existing water sources could be shared among the newly cross-fenced pastures. However, the weekly labor requirement is halved, contrary to the finding of Gillespie et al. (2008). Additional infrastructure required for this conversion increases the annual cost by $12,000 over scenario 1, despite the savings created by the decreased labor requirement. Cross-fencing scenario 1 with the temporary fencing (*scenario 3*), however, only increases infrastructure costs by 12%. This results in an annual cost increase of $1,850 over the costs of scenario 1. Scenarios 2 and 3 require approximately 10 hours of additional labor to move cattle among pastures for the rotation. Even with these additional labor requirements, total labor for the rotational grazing scenarios (*scenarios 2 and 3*) remain less than scenario 1, due to the shorter checking times associated with the smaller pasture (320-acre vs. 3,200-acre).

The noncontiguous, multi-pasture scenarios (*scenarios 4 and 5*) require more infrastructure than the contiguous scenarios (*scenarios 1, 2, and 3*), and therefore have substantially higher costs. Fencing infrastructure increases from 8.9 miles in the baseline scenario 1 to 28.3 miles for scenario 4. Water infrastructure increases differently among the scenarios. For example, water costs for scenario 4 are nearly three times higher than scenario 1, despite having five times the number of water sources, due to the smaller acceptable tank size. Weekly labor costs double due to the need to check 10 separate herds in smaller pastures rather than the single 3,200-acre pasture. Scenario 4 also has the added labor cost associated with moving the 10 herds from the central sorting location to their individual pastures (Figure 1 and Table 1). Noncontiguous pasture arrangement with a season-long continuous grazing system increases the cost of infrastructure and labor by $35,700 annually compared to scenario 1.

Fencing infrastructure is 40% greater for scenarios 4 and 5 (noncontiguous pastures) compared to scenario 2 (contiguous pastures). Furthermore, an additional seven water sources are needed in scenarios 4 and 5 which results in an additional $12,000 in annual costs. Weekly labor costs for checking livestock between scenarios 2 and 5 was identical due to the same herd density and pasture size. However, moving livestock between noncontiguous pastures results in 30 more hours of labor for scenario 5. Comparing cost differences between scenario 2 (rotational grazing with contiguous pastures) and scenario 5 (rotational grazing with noncontiguous pasture) results in savings of just under $25,000 annually for scenario 2 as lack of common water sources in scenario 5 increases costs.

Cost differences of $2,200 annually occur between scenarios 4 and 5. Scenario 5 requires larger water tanks which increases water infrastructure costs by 33%. Although, the increase in cost is offset by scenario 4 requiring 3.5-fold greater labor costs associated with increased time spent checking cattle weekly and more labor involved with moving herds to 10 different pastures at the beginning and end of the grazing season.

Fencing infrastructure costs are the largest cost for all five scenarios, accounting for 69% to 83% of total costs. Annualized costs range from $8,800 (*scenario 1*) to $29,800 for (s*cenarios 4 and 5*). Cross-fencing with electric fence (*scenario 3*) increases annual costs by $800, whereas permanent barbed-wire cross-fencing (*scenario 2*) results in nearly 14-fold greater annual costs ($11,000). Water infrastructure and labor costs account for 17% to 31% of total costs.

Conclusion

Additional infrastructure costs are associated with implementing a rotational grazing system for ranchers, with these costs substantially greater (51%) if the pastures are noncontiguous. Factors offsetting these infrastructure costs are: 1) reduction in time/labor costs for checking livestock, and ecological benefits resulting from 2) increased uniformity of grazing, 3) increased utilization of forage in the smaller sub-divided pasture, and 4) rest from grazing when the livestock are moved to another pasture (e.g., Teague et al. 2013). Using scenario 1 (season-long grazing in a single 3,200-acre pasture), a rancher would need to gross $61.50 per steer on a 250-steer herd to cover the estimated infrastructure and labor costs. Note, the other costs accrued throughout the grazing season (including veterinary expenses, mineral and supplements, transportation, utilities, taxes, and other fees) are not accounted for in the equation. Converting from scenario 1 to rotational grazing with permanent cross-fence (scenario 2) or temporary electric fence (scenario 3) would require an additional increase of $48.00 and $7.45 per steer, respectively, in gross revenue to offset the additional annualized infrastructure and labor costs.

When pastures are noncontiguous (scenarios 4 and 5), substantially greater annualized costs are present for ranchers compared to the baseline scenario 1. Gross revenue increases of $204.00 (scenario 4) and $212.80 (scenario 5) per steer would be required relative to scenario 1. For comparative purposes, nearly $165 per steer is needed to cover costs in scenario 5 (noncontiguous pastures) vs. scenario 2 (contiguous pastures) with rotational grazing. For ranchers considering sub-dividing larger pastures into smaller ones (scenarios 2 and 3), the USDA-Natural Resource Conservation Service offers cost-sharing programs for fence and water infrastructure.

The substantial economic cost differences between contiguous (scenarios 2 and 3) and noncontiguous (scenarios 4 and 5) pastures has key inferences for ranchers considering expansion of their current operations, or young/new ranchers starting in the business. Understanding that economic costs of managing noncontiguous parcels of land are substantially higher provides key information for consideration when comparing alternative scenarios for purchasing/renting land. Ranchers need to be cognizant that increasing gross revenues from steers is necessary to cover these increased costs.

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Table 1. Modeling Scenarios

	Scenario	Grazing System	Number of pastures (size)
1	Single pasture	Continuous	One (3,200 acres)
2	Single pasture, cross-fenced, barbed wire	Rotational	Ten (320 acres)
3	Single pasture, cross-fenced, electric wire	Rotational	Ten (320 acres)
4	Multi-pasture, non-contiguous*	Continuous	Ten (320 acres)
5	Multi-pasture, non-contiguous*	Rotational	Ten (320 acres)

*The multi-pasture, noncontiguous grazing system is based on the pasture setup from the Central Plains Experimental Range in Colorado. Distances from the ranch headquarter to each of the 10 continuously-grazed pastures and back are used to calculate moving labor for scenario 4; the sum of these distances is 44.62 miles for the round-trip travel. The moving labor for scenario 5 is based on the average distance travelled by the rotationally-grazed herd from 2014 through 2017. The rotation is decided annually by a group of stakeholders who are involved with the ongoing socio-ecological study at CPER (Wilmer et al. 2018).

Table 2. Infrastructure Requirements

Scenario	Fencing (miles)	Useful Life	Water sources, Tank size	Useful Life
1	8.9	20 years	2, Large (11,486 gal.)	20 years
2	20.1	20 years	3, Large (11,486 gal.)	20 years
3	8.9 (perimeter) 5.4 (electric)	20 years 4 years (partial replacement)* 20 years (total replacement)	3, Large (11,486 gal.)	20 years
4	28.3	20 years	10, Small (1,100 gal.)	20 years
5	28.3	20 years	10, Large (11,486 gal.)	20 years

*Some components of the electric fence require more frequent replacement than barbed-wire fencing does. These components include wire insulators, electric wire, electric gates, and the battery for the solar power box. Additionally, this replacement uses 50% of the initial installation labor.

Table 3. Labor Requirements

Scenario	% of Herd	Acres per Pasture	# of Pastures	Weekly Checking Time
1	100%	3,200	1	7.5 hours
2	100%	320	1	3 hours
3	100%	320	1	3 hours
4	10%	320	10	15 hours
5	100%	320	1	3 hours

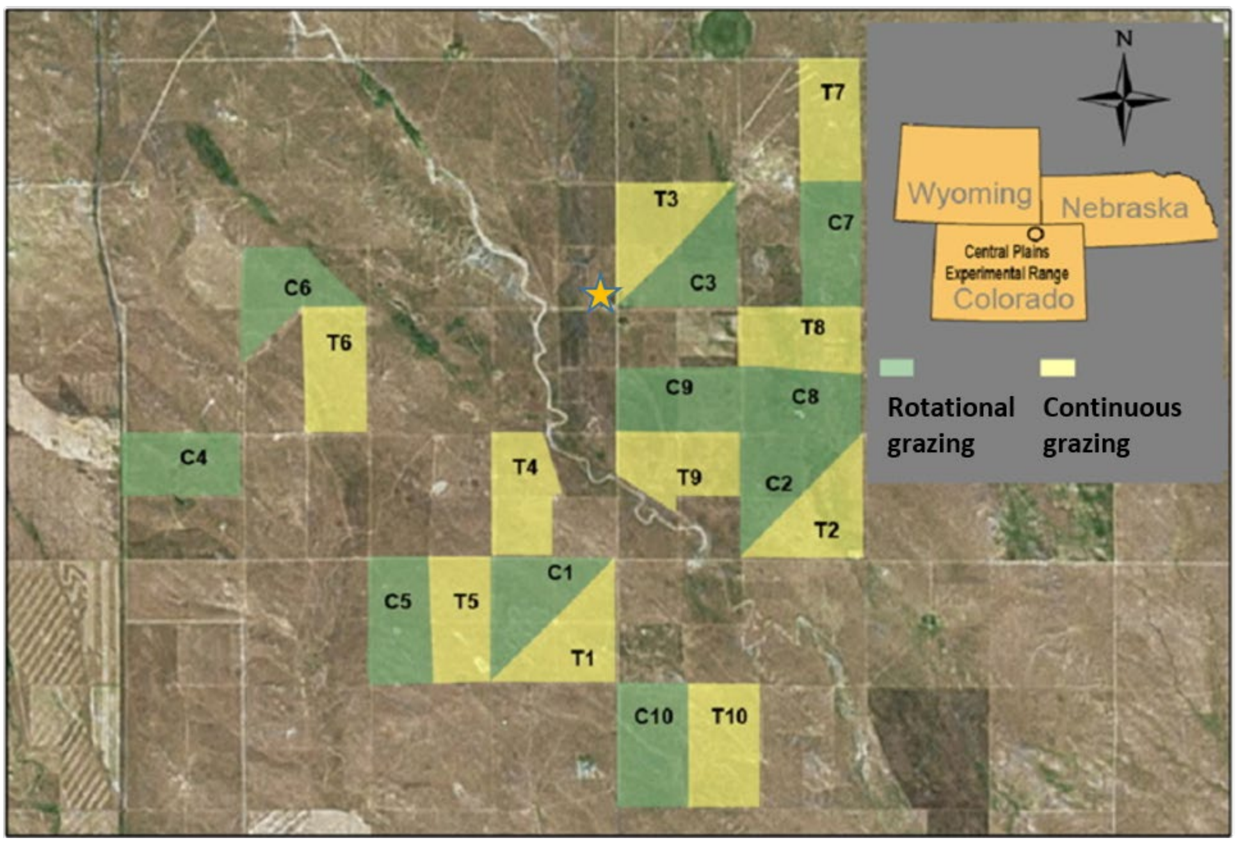

Figure 1. In the Central Plains Experimental Range's grazing study, each grazing system consists of ten separate pastures. The green squares indicate rotationally-grazed pastures and the yellow squares indicate continuously-grazed pastures, with the grazing season from mid-May to early October. The yellow star indicates the ranch headquarters, where steers are received in the spring and shipped out in the fall. This is the starting and end point for all cattle operations. (Source: USDA ARS)

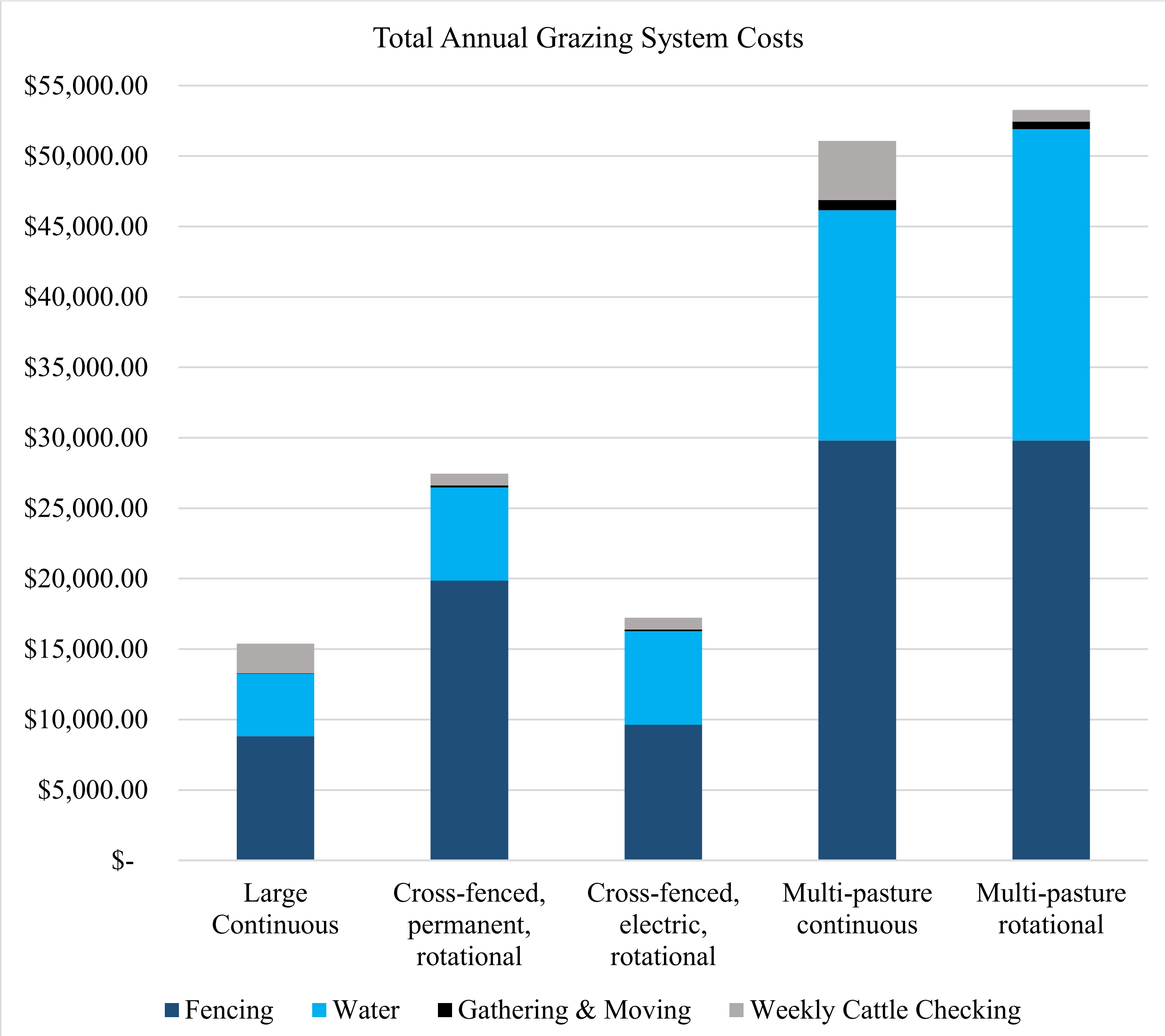

Figure 2. Total annual costs for fencing infrastructure, water infrastructure, and labor costs for each of the five scenarios.