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Original Research

Economic Impacts of Increasing Seasonal Precipitation Variation on Southeast Wyoming Cow-Calf Enterprises☆

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ABSTRACT

Knowledge regarding the economic impacts of predicted increases in seasonal precipitation variability on cow-calf enterprises, through influences of precipitation on both forage and cattle productivity, is needed by land managers for developing risk management strategies. Here we use existing forage production and cattle performance data from the northern mixed-grass prairie, coupled with spring precipitation and economic data, in a ranch-level mathematical programming model. We estimate economic impacts across a 35-yr planning period with 100 iterations of different price cycles including five levels of increasing spring precipitation variation (10%, 20%, 30%, 40%, and 50% increases), examining the impact of resulting forage production and calf gain. Annual expected profit variability increases largely due to the increase in herd number variability rather than variability in calf gains. Overall, as seasonal precipitation variation increases, higher annual expected profit variability results in greater risk of negative returns from cattle. An important implication from our results is that the positive benefits of wet years do not overcome the negative impacts of the dry years given relationships among precipitation, forage production, and calf gains used in our model. Results indicate greater profitability in generally maintaining lower herd numbers as seasonal precipitation becomes more variable. The results also illustrate the need for producers to diversify their operation and/or income sources if they are to cope with increased precipitation variability even if mean annual precipitation remains constant.

Introduction

Given the dependence of forage and cattle production on precipitation (Derner and Hart, 2007; Derner et al., 2008; Reeves et al., 2013a, 2013b), economic stability of the livestock industry could be negatively impacted by predicted increases in precipitation variability (National Research Council, 2010; Hatfield et al., 2014). Increases in precipitation variability, coupled with cattle cycle dynamics, create complexity for livestock producers trying to manage risk given positive and negative impacts on location, timing, and productivity of cattle production systems (Walsh et al., 2014). These impacts include destocking (reducing herd numbers) to accommodate lower levels of forage production in drought years (Bastian et al., 2009; Kachergis et al., 2014) and deliberately slow restocking through heifer retention or purchase of breeding stock during favorable weather years (Torell et al., 2010). These stocking and liquidation (or destocking) decisions before and during drought periods greatly impact long-term economic outcomes for cow-calf operations (Thomas et al., 2015). Increasing precipitation variability would increase the frequency and severity of drought and lead to greater occurrence of destocking decisions often made during unfavorable price levels, thereby directly reducing the economic viability of cow-calf operations (Bastian et al., 2009; Ritten et al., 2010a).

Changes in weather and climate can translate into direct and indirect effects on cattle performance (Ojima et al., 2013). Direct effects resulting from changes in precipitation on cattle include changes in the forage quantity and quality of rangeland vegetation that influence animal growth (Hatfield et al., 2008; Calvosa et al., 2009; Mader and Gaughan, 2010; Miller, 2011) through feed intake (Craine et al., 2010). Indirect effects resulting from changes in precipitation, unfortunately, are not well understood as the feedbacks from the influence of

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precipitation on forage production to cattle performance are often nonlinear with more pronounced effects in dry compared with wet years (Reeves et al. in review), as forage limitations in dry years negatively impact weight gains, whereas extra forage production in wet years does not translate to greater animal performance. Enhancing the knowledge of seasonal-weather-related decision making for land managers is necessary for adaptive management (Reeves et al., 2015).

The major objective of this study is to show the ranch-level impacts of, and optimal response to, increasing variation in growing season precipitation. We hope this knowledge will improve decision making by land managers and increase the resilience of cow-calf operations to improve economic sustainability given predicted increases in precipitation variability associated with altered climate. Specifically, we use existing forage production and cattle performance data from the northern mixed-grass prairie, coupled with precipitation and economic data, in a ranch-level mathematical programming model to estimate economic impacts for three scenarios across a 35-yr planning period. We include 100 iterations of different price cycles, as well as five levels of increasing spring precipitation variation (10%, 20%, 30%, 40%, and 50% increases). Although it is impossible to separate the impacts of climate on forage and calf performance, we also aim to determine the economic importance of these impacts separately to better understand potential management priorities in the face of altered precipitation patterns. Therefore, initially, we examine separately the impact of resulting forage production from precipitation variability (scenario 1) and the impact of precipitation variability on calf gains (scenario 2) as it relates to the likelihood of negative returns. For the remainder of the manuscript we examine the impacts of these two factors combined (scenario 3).

Methods

Representative Ranch Characteristics

Our data regarding precipitation, forage production, and cattle production are based on research conducted at the US Department of Agriculture (USDA)-Agricultural Research Service (ARS), High Plains Grasslands Research Station (HPGRS) station located in Laramie County in southeastern Wyoming (Derner and Hart, 2007; Derner et al., 2008; Reeves et al., 2013b, 2015).

Land composition for a case ranch was modeled from a six-county region (Albany, Converse, Goshen, Laramie, Niobrara, and Platte Counties) in southeastern Wyoming to simulate average resources and related operating procedures in this area. Bastian et al. (2005) indicate that while variations across counties do exist, this region is relatively homogeneous in terms of livestock production, average productivity of range resources, and average ranch carrying capacity. Average carrying capacity of ranches sold ($n = 147$) in these counties for this region ranged between 159 and 162 Animal Units during the study period of 2002 − 2004 (Bastian et al., 2005). Although average operations across the counties are similar, as expected, heterogeneity does exist. For example, operations ranged from 1 to 19 head per operation for 2012 to operations with more than 500 head in the counties for the study area for our analysis (NASS, 2012). However, given the objective of the study, we model our case ranch on the basis of average characteristics for the region of interest.

The total number of hectares of each land type according to the Bureau of Land Management (BLM, 2014) in each county coupled with the total number of operators in each county according to Wyoming 2012 Agricultural Statistics data were used to estimate a simple average of land resources for an individual operation in the region (NASS, 2012). Our case operation consists of 1 461 ha. On the basis of the above-average calculations, this land base consists of 1 114 ha of deeded rangeland, 125 ha of state land, 139 ha of federal land lease, and 83 ha of privately leased land. Ranches in Wyoming are typically characterized by multiple land ownerships/leases (Kachergis et al., 2013).

The deeded land produces just over 1 385 animal unit months (AUM), state land provides 150 AUM, federal lands provide 168 AUM, and leased land provides 100 AUM, resulting in a total of forage available for grazing on the ranch of 1 803 AUM. Again, on the basis of reported averages for the area, the representative ranching operation in the study area produces both irrigated meadow and alfalfa hay, with 70 and 91 ha of each, respectively. Hayed lands also offer the availability of grazing after harvest, incorporating alfalfa and meadow hay land aftermath grazing potential of 0.33 and 1.57 $AUM \cdot ha^{-1}$, respectively, according to previous research for the area (Torell et al., 2002; Strauch, 2008). This provides an additional 410 AUM of grazing after harvest.

On the basis of the ranch characteristics reported earlier and the ability to feed hay through winter months, the representative ranch has the potential to carry a maximum of 180 head of cows (with calves), including the required number of bulls and replacement heifers. A typical ranch in southeastern Wyoming consists of a combination of enterprises that often include cow-calf and hay enterprises. Many operations have other farming (e.g., small grains) or yearling cattle enterprises that, when combined, tend to make the whole ranch more viable than just haying or raising calves (Kachergis et al., 2013). However, because of the cow/calf production lag due to heifer development, this sector of the industry is the least flexible in terms of responses to forage supply. Our model isolates and focuses on the cow/calf enterprise to understand the impact of changes to variation in precipitation on this type of business with other enterprises or off-ranch income expected to contribute to the ranch.

A multiperiod linear programming model was used to estimate optimal management strategies for the operation. The model was originally developed as part of a regional effort and has been widely used and adapted for evaluation of management strategies and grazing management assessments (Torell et al., 2002; Rimbey et al., 2003; Taylor et al., 2004, 2005; Torell et al., 2013). The base for this model is that used in Ritten et al. (2010b). We altered the model to represent our case ranch using the previously mentioned land resources, production practices, and representative costs and represented it conceptually in Figure 1. The model was solved using the MINOS solver in Generalized Algebraic Modeling System (GAMS) (Rosenthal, 2008).

The model maximizes the net present value of future profits over a T-year planning horizon subject to a series of constraints defining the ranch resource limitations and transfer resources from one year to the next. The decision variables under the land manager's control include herd size (mainly through liquidating/restocking decision) and land use (amount and timing). For each model iteration, initial herd size was set at 180, but the model is free to adjust herd size in subsequent years. Major constraints include animal production limitations (conception/weaning rates, required bull/cow ratios, interyear transfers), and forage supply (total supply, seasonal use restrictions). A 35-yr planning horizon corresponds to available precipitation and production data from the HPGRS. The model consists of equations that transfer animals and cash from one year to the next. The model is constrained by both total annual forage supply and seasonal land constraints. The operation is also required to maintain a minimum cash reserve of $500. Although some previous applications of this model tend to use a higher amount (e.g., Torell et al., 2010 require a $10,000 cash reserve), we are interested in determining the impact of increasing precipitation variation on bankruptcy. This requirement is simply used to ensure a positive cash position (in line with the original application of this model, which also uses a $500 minimum cash reserve, Torell et al., 2002).

Forage Production and Constraints

The model consists of six seasons determined by important ranch activities (e.g., calving, marketing, weaning) (Torell et al., 2010) and land availability (federal land permit restrictions). The season dates can be seen in Table 1. Forage availability is constrained by both total annual production and seasonal availability. For example, public lands are

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