RANGELANDS

THE ECONOMIC IMPORTANCE OF MAINTAINING FLEXIBLE GRAZING STRATEGIES FOR DROUGHT MANAGEMENT

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THE STORY IN BRIEF: Cow/calf production means breeding animals are kept across years. This is problematic when annual forage production is highly variable. In this paper we estimate profit maximizing stocking strategies for alternative price situations when annual grass growth is variable. Study results suggest that breeding animals should constitute no more than 50% to 70% of total grazing capacity. Average net annual ranch returns were estimated to more than double when a yearling stocker enterprise augments and adds grazing-capacity flexibility to a base cow herd.

THE PROBLEM: Range livestock producers face 2 major types of risk, prices and weather. Futures and options tools are available to help manage price risk but fluctuations in seasonal and annual forage production remain an ongoing and widespread problem. Dry periods create financial hardship and management problems for people throughout the world. Stafford Smith (1992) suggests that successful managers in Australia have coped with climate variability by pursuing some mix of two extreme management approaches. The first approach maintains a very conservative stocking rate so that destocking is rarely necessary. The second strategy aims to anticipate and follow fluctuating annual forage production levels by building stock levels during favorable years and destocking quickly during dry periods. In this paper we investigate which of these strategies is economically best.

OBJECTIVES:

15. The primary objective of this research was to evaluate the economics of following alternative livestock production and marketing strategies in the face of climate variability. We evaluate the drought management strategies recommended by the Extension Service, and other strategies, for shortgrass praire rangeland. A multi-period linear programming analysis was used. The Monte Carlo procedure simulates 4,000 different beef price and production situations and we evaluate the economics of following alternative strategies ranging from conservative stocking to flexible grazing with herd size adjusted up and down with variable annual forage conditions. The model is developed using the resources and production characteristics of the Corona Ranch and other similar ranches grazing blue grama (*Bouteloua gracilis*) rangeland on the shortgrass praires of central New Mexico. Both beef prices and herbaceous standing crop is varied annually in the 40 year analysis.
16. Because annual variation in herbaceous production is so closely tied to annual variation in rainfall a detailed analysis of weather, forage production patterns, and production variability on the Corona Ranch was required as a second objective.

HERBAGE PRODUCTION VARIABILITY AND DISTRIBUTION

As noted by Sneva and Hyder (1962), precipitation frequency distributions for semiarid and arid regions are usually not normally distributed but instead show a noticeable right skewness. Using long-term (1914 - 2006) Corona, New Mexico rainfall data, statistical models estimated for the study area indicated that rainfall probability distributions during the winter months and during the 2nd quarter of the year are substantially right-skewed. The rainfall distribution during the summer (Q_3), in contrast, was not found to be statistically different from a normal distribution.

With regard to grass yield estimation we found end-of-season standing crop during the year (Y_t) relates to key rainfall variables and amount of broom snakeweed by the equation:

$$\text{(1)} \qquad \underset{(37.18)}{Y_t = 129.88} + \underset{(0.21)}{1.75}\ WINTER_t + \underset{(0.33)}{0.86}\ Q_{2t} + \underset{(0.17)}{2.22}\ Q_{3t} - \underset{(5.73)^*}{33.96}\ LNGUSA_t$$

$R^2 = 0.31$, Root mean square error (RMSE) = 295.
* Standard error, all parameters were statistically significant at the 0.01 level or higher.

Where WINTER = quarter 4 rainfall (mm) during the previous year plus quarter 1 rainfall of the current year,
Q_{2t} = quarter 2 rainfall,
Q_{3t} = quarter 3 rainfall,
$LNGUSA_t$ = natural log of broom snakeweed (kg/ha) present on the area.

Statistical analysis indicated that end-of-season grass yields on blue grama dominated areas on the Corona Ranch are approximately normally distributed with a mean of 768 kg/ha (685 lb/acre) and with a standard deviation of 200 kg/ha (178 lb/acre). We adjusted the mean downwards to 651 kg/ha (581 lb/acre) to be consistent with levels estimated in recent years at broom snakeweed study plots located on the Corona Ranch. Thus, for the stocking rate analysis we formed expectations of forage availability as a random draw from a normal distribution with a mean of 581 lb/acre and a standard deviation of 178 lb/acre.

Proper Grazing

To allow for proper grazing we modified slightly the recommendation of Hart and Carpenter (2005) and required that during favorable production years 336 kg/ha (300 lb/acre) of herbaceous production must remain at the end of the grazing period, whereas during unfavorable years the required residual can be reduced to 224 kg/ha (200 lb/acre). This recommendation is consistent with the well known stocking guideline of Bement (1969). Bement based his grazing recommendation for blue-grama rangelands largely on animal performance. It was determined that when 300 lb/acre of herbage was left ungrazed, animal production per acre was at a maximum. Reducing residual amounts below this level diminished animal gain per acre and per head.

In the modeling analysis we required a 300 lb/acre herbaceous residual when annual production was above 402 lb/acre (one standard deviation below the mean) but reduced the residual to 200 lb/acre when production was below this level. In this second case, an

11% reduction in sale weights was included and we also considered next year's calf crop to be reduced by 5% based on research by Hart et al. (1988) and Wikse et al. (1995).

With an average end-of-season standing crop of 581 lb/acre, rangeland carrying capacity on the relatively productive blue grama areas of the Corona Ranch would average 18.7 AUY/Section following the Bement (1969) stocking guide and assuming an 800 pound AUM. Some pastures on the Corona Ranch with pinyon-juniper invasion and shallow soils are not as productive as blue grama dominated areas. An index of relative productivity for each of 9 pasture units on the ranch was determined based on historically observed forage productivity differences. Annual grass yield estimates were scaled for each pasture by the productivity index and these production differences were incorporated into the economic model. Average carrying capacity was estimated to be 15 AUY/section or 660 AUY across all pastures on the ranch.

THE MULTI_PERIOD LINEAR PROGRAMMING MODEL

From the perspective of a ranch manager, the stocking rate problem can be viewed as a dynamic constrained optimization problem. The objective of the manager is to select a mix of range management practices and grazing strategies that will maximize ranch profits, subject to various resource constraints. The linear programming (LP) objective function is defined to maximize the net present value (NPV) of discounted net annual returns over a 40 year planning horizon subject to linear constraints that describe resource limitations and resource transfers between years. Variable seasonal and annual forage supply and demand is explicitly considered. A 7 percent discount rate was used to discount future economic returns.

The Corona Ranch and most other New Mexico ranches typically sell most calves in the fall at a weight of 400 to 600 pounds. Carrying calves over for sale as yearlings was considered to be an option in the LP model, as was the option of purchasing yearling stocker cattle. Forage could also be leased to an outside yearling operator. The cow-calf and cow-yearling enterprise options require other animal classes such as bulls, cull cows and replacement heifers be produced at a fixed ratio, and a number of equations are included to define these ratios.

The model was initialized to start production in year 1 fully stocked as a cow/calf ranch (90% of average grazing capacity). From this initial year, cow numbers can only increase by raising replacements or by purchasing cows, and the dynamic equation system determines the potential growth rate. The minimum number of replacement heifers raised, or cows purchased, must be greater than or equal to a required herd replacement rate. Retained replacements and cow purchases can exceed this ratio, implying a growth in the cow herd.

Forage production was considered to be variable each year. For each forage production situation a random draw from a normal curve was made and harvestable forage was computed using procedures described above. Harvesting rangeland forage allows the transfer of AUMs to cattle raising and forage leasing activities. Forage can be harvested from pastures in any of 6 defined seasons as forage demand dictates. Forage harvested before June 1 when warm season grasses substantially begin to grow is transferred from the previous year. An estimated 13 percent of the transferred forage is assumed to be lost over the late dormant season from natural decay.

Forage demands are computed using standard animal unit equivalencies for various animal classes. Cull cows are sold November 1 and do not have forage demand during the winter. Replacement heifers have an increasing forage demand as they mature. It was assumed that if forage leasing is economically optimal, outside yearlings and purchased stocker animals will be on the ranch May through October.

Economic data used in the LP model was primarily from a Standardized Performance Analysis (SPA) financial analysis conducted for the Corona Ranch during 2005 and 2006. The SPA analysis provided an annual itemized accounting of production costs and production rates by enterprise and provided a comparison to other New Mexico ranches also conducting the SPA analysis (McGrann 1995). Production costs and production rates for the NMSU research ranch were similar to other New Mexico ranches once research-related expenses were subtracted. Yearling enterprise budgets were also used to define selected cost items (Marousek 2005, Smathers and Rimbey 2006).

Cash flow is a potential limitation in the model. Livestock sales, wildlife leases and forage leases are considered as sources of income from the ranch. Forage and livestock raising activities use cash. The included restrictions recognize that each year, net returns from the ranch, off ranch income and accumulated wealth must be greater than or equal to calculated production expenses, loan obligations and a required cash residual ($10,000). A frugal and profit maximizing ranch business is considered. It is assumed that half of excess cash from a good year will be transferred forward to cover expenses and cash shortfalls in future years. The 50 percent level was chosen without strong justification. Funds can be borrowed if a cash shortfall situation arises at a 9 percent annual interest rate. Any funds borrowed must be repaid during the next year, though repeat borrowing can occur for a number of years. In the model, borrowing is not allowed during the last year, and all loan obligations must be paid in full by the end of the 40-year planning horizon. Wildlife income on the Corona Ranch has recently averaged $35,000/year and this amount was included as the first source of cash used to meet cash shortfalls.

Annual fixed expenses which do not vary with the number of animals produced included fixed labor ($14,868), ranch maintenance ($20,000), and public and state land grazing fees ($9,053) for a total annual amount of $43,921. Some costs are also incurred because livestock reside on rangeland. These forage harvest costs include brush and weed control, fence and water maintenance, moving cattle between pastures and other activities related to providing and harvesting forage. Forage harvest costs were estimated to total $3.38/ha ($1.37/acre).

Annual ranch income and optimal production strategies are greatly influenced by livestock prices. To consider the effect of beef price variation on ranch returns and optimal production strategies, a Monte Carlo analysis was used. Different beef prices were generated for each of 100 model iterations. The real beef prices (constant 2005 prices) used in the model fluctuated randomly but explicitly consider the linkage in prices between years and the relationship in prices between livestock classes. The random prices were generated using equations developed from Cattle-Fax™ price data. The peaks and valleys of the price series were different for each 40-year price scenario with an approximate 12-year cycle from peak to peak. Brood cows were assumed to be sold at cull prices whereas purchases were made at the considerably higher bred cow price.

Model Specification

The economic comparison of stocking rate strategies were evaluated as alternative model scenarios that impose different levels of grazing use restrictions and different sets of forage replacement alternatives and costs. Analyzing various specifications of the model provided insight about profit maximizing strategies for adjusting to and managing variability in annual forage production and beef prices. It also provided a way to evaluate the economic importance of maintaining grazing flexibility.

It is recognized that for many livestock producers few opportunities exist to continually purchase outside forage on an as needed basis, because drought and forage shortages are generally widespread. Without forage leasing or supplemental feeding, drought would force livestock producers out of business, or they would be forced to overgraze. As such, we initially considered two different cost situations for leased forage, \$20 and \$50/AUM. We always included forage leasing as an option. The lower price situation reflects a normal full-price lease where local forage can be leased from an adjoining ranch with full care provided for displaced animals or when economically optimal for herd expansion. The higher lease rate reflects the situation where displaced cattle must be shipped considerable distance or stood in a corral and fed roughage. Because few leasing alternatives exist for the Corona Ranch results for the \$20/AUM forage leasing option are not reported here. The answer, though, was relatively straight forward. If one has outside forage available at a reasonable price, outside leased forage would be used to offset any forage shortages. The economic consequences of forage shortages would then be minimized.

The LP model solution for each scenario defines optimal (profit maximizing) levels of resource use, annual herd size by animal class for each year, and economic measures including annual livestock sales, production costs, net returns and the maximum objective function value (NPV of discounted net returns). Optimal levels are chosen based on profitability of a particular activity given the annual cost/price situation. This includes the cost of destocking and restocking as compared to replacing forage shortages. The dynamics of inter-year herd transfers are also considered.

RESULTS

Conservative Stocking with Cow/Calf Only

Holechek et al. (2004) suggests that on arid and semi-arid rangelands herbaceous grazing use rates should be about 35% and base stocking rates should be set at least 10% below the rate that would yield proper use in an average year. Yet, as noted by Robinson (1982), the opportunity cost of conservative stocking may exceed the benefits that occur when a drought does come. Riechers et al. (1989) found average annual net returns increased as stocking rate increased. Similarly, Martin (1975) budgeted net annual livestock returns for desert ranches in southern Arizona over the 1941 – 1970 period and concluded that profits continued to increase with increases in stocking rate over a range from 20% below the long-term average up to the average level. Our results were similar. Imposing a conservative maximum stocking rate that was 70% of average (10.5 AUY/section) resulted in average net annual livestock returns of $30,104. Significant amounts of residual forage would exist in most years. Relatively expensive ($50/AUM) forage would be leased in 17% of the years and the optimal herd size would be reduced below the maximum allowed level in 67% of the years. For the most part, the number of animal units on the ranch would remain near the 10.5 AUY/section maximum with leasing of expensive forage during short-duration dry periods. Periods of extended drought meant large reductions in herd size was most economical.

Average net annual returns increased as the imposed maximum stocking rate was relaxed. If the maximum were removed so that the model could freely choose annual herd size, average net annual returns as a cow/calf ranch would increase to $40,689. The average herd size would be 502 AUY (11 AUY/Section) but herd size would exceed the 15 AUY/section average 15% of the time. Outside forage would be leased 22% of the time.

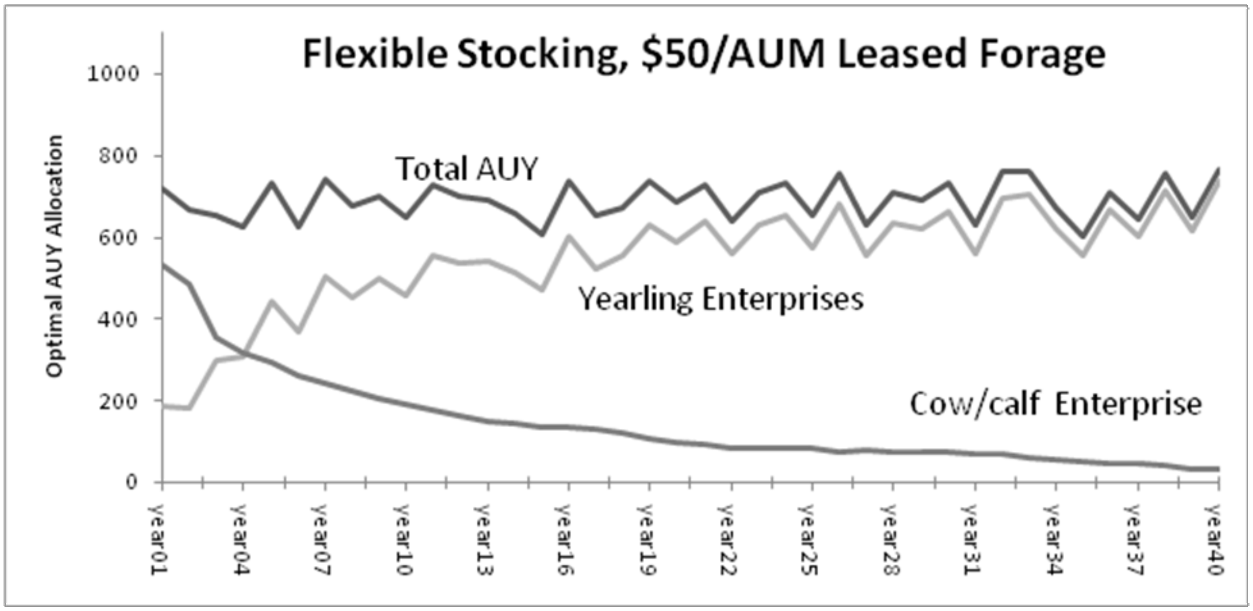
Some results were similar across all scenarios. Beef prices and yearling price margins were different across years and iterations. As such, given that the optimization model was defined to know the beef price history in advance, some brood cows would be purchased when prices were relatively low, but for the most part the cow herd was optimally replaced and brood cow numbers built by retaining replacement heifers.

Flexible Stocking with Multiple Enterprises

With flexibility from adding yearling enterprises to the ranch, the average optimal stocking rate would be near the average capacity at 688 total AUY (15.7 AUY/section). Across all years, 64% of grazing capacity would be allocated to yearlings, but optimal yearling numbers increase over the planning period. Within 10 years the average size of the cow herd would be reduced to < 200 AUY (Figure 1). This occurred because as time progresses the future earning potential from maintaining the cow herd versus switching to a flexible yearling enterprise diminishes. Beef price and forage situations eventually arise where switching to a purchased yearling operation is economically better and at this point the cow herd or part of the cow herd is sold. Most destocking occurred, as would be expected, during times of drought. It was never profitable to switch back to brood cows. The timing of the switch to yearlings was different for each price situation.

Purchasing yearlings and leasing forage to an outside yearling operator never occurred together in the same year. Leasing forage to someone else occurred when the price spread for purchased yearlings was wide and raising yearlings occurred when the price margin was relatively narrow. This is because the profitability of purchasing yearlings decreases as the price spread increases. Letting someone else harvest your forage is more economical in these years. When yearlings were purchased it was most profitable to purchase steers about 88% of the time.

Adding flexibility from an enterprise that does not need to be sustained across years has the potential to more than double ranch returns. The flexible stocking scenario had an average annual net return of $89,471 which is 2.2 times more than the returns realized from cow/calf



Note: The figure presents the average herd size allocation between cow/calf and yearlings by year, averaged over 100 different beef price and forage situations for each year. The forage allocation was unique for any particular model iteration. Sometimes prices and forage conditions were such that the cow herd was sold early in the planning horizon while other times cows were maintained for the whole 40-year period. The number of yearlings purchased for any particular iteration varied from over 2,000 head for the 6-month season to none.

Figure 2. Optimal average stocking rate allocation between cow/calf and yearling enterprises with flexible stocking and enterprises.

production only ($40,689). A limitation is that the analysis was conducted assuming perfect foresight about forage conditions and beef prices. To apply flexible stocking would require an accurate 4 to 6 month weather (forage) forecast that may never be available. The analysis demonstrates, however, the economic potential and value of a perfect weather forecast. Further, it highlights that maintaining grazing flexibility when forage conditions are variable is economically important. Across all years the optimal forage allocation between a cow/calf enterprise versus purchased yearlings was about 2/3 to yearlings and 1/3 to cow/calf. This allocation is consistent if not more restrictive than the recommendation of the Texas Extension Service that “permanent breeding animals should constitute no more than 50 to 70 percent of the total ranch carrying capacity” (Hart and Carpenter 2005).

The deterministic nature of the linear programming model is a limitation. A Monte Carlo analysis considered 4,000 different price and forage situations and optimal production strategies were formulated from the average solution values. A logical production strategy would be to follow the grazing prescription of the model; that is, follow the average production scheme. One would stock near the average carrying capacity of the ranch with both yearlings and cows, paying special attention to not get attached to the cow herd. When dry conditions arise stand ready to reduce the cow herd if reductions in the flexible yearling herd is not adequate. When favorable forage conditions return fill in with a more flexible purchased yearling animal. Recognizing forage production uncertainty favors an even more flexible enterprise mix than what we estimate here.

POTENTIAL APPLICATION: The analysis of forage production variability on the Corona Ranch is useful for improved stocking rate decisions and risk assessment. The economic analysis provides insight as to the economic value and consequences of following alternative livestock production strategies. Further, the linear programming model developed for the Corona Ranch can be used to assess the economics of new technologies developed on the research ranch including range improvements, grazing systems and new range and livestock production technologies.

EDUCATIONAL PLAN: Journal articles will be written about the research reported here.

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