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Profitability of a Dryland Grazing System Suitable for the Texas High Plains

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ABSTRACT

The declining availability of groundwater will eventually force farmers and ranchers on the Texas High Plains to move to dryland production practices. Dryland production is inherently risky, and farmers need estimates of risk to effectively choose production practices and systems. We determine the profitability of a specific dryland ranching system in this paper by simulating production and profits for a wide range of rainfall and price values drawn from historic record. We find that the tobosagrass-WW-B.Dahl grazing system is profitable, but recognize that data limitations make this estimate an upper bound for the true expected profit for this system. We identify research that is needed on forage grass renewal to make more realistic risk estimates of dryland production; research that can be incorporated directly into the economic assessment presented. Specifically, we recognize the need for more estimates of dryland production practices at very low and very high precipitation levels.

KEY WORDS: old world bluestem, *Bothriochloa bladhii*, Tobosagrass, dryland production alternatives, simulating production

INTRODUCTION

The Ogallala Aquifer, one of the largest water tables in the world, lies beneath the Great Plains in the United States. It covers eight states: South Dakota, Wyoming, Nebraska, Colorado, Kansas, Oklahoma, New Mexico, and Texas, and underlies an area of approximately 174,000 square miles, 12% of which is located under Texas (High Plains Water District #1, 2009). Left undisturbed, the natural discharge rate of the Ogallala would approximately equal its natural recharge rate; but currently the Ogallala has been overdrawn by irrigation, largely for agriculture, which has caused declining

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water levels. Over 90% of water pumped from Ogallala is used for agricultural activities in the Southern High Plains. Cotton, corn, alfalfa, soybeans and wheat are the major crops in this region, as well as cattle feeding (Guru and Horne, 2000).

While Kansas had pumped 38% of its system reserves by 1980, depletions in Texas are worse: the water tables had dropped 200 feet (Lewis, 1990) and about 70% of Texas's underground water has been depleted (Weeks and Gutentag, 1984). This decline is especially serious on the Ogallala aquifer beneath the Southern High Plains of Texas given its low recharge rate. This southern portion of the aquifer formed as a deep confined overlay, and is characterized by low recharge and low hydroconductivity. This means sustained irrigation is not a feasible option in the long-run. Ranchers face the problem similarly to row crop farmers: extensive pumping of fresh water from the Ogallala to irrigate their pastures has increased pump lift (i.e. the water table has declined), escalating the costs of cattle ranching such that irrigated pastures have become less competitive. The inevitable shift to dryland production, an ostensibly system that include more range and pasture lands, appears the likely response to declining water availability in the region (Ortega-Ochoa et al., 2007b).

In order for a dryland ranching production system to be profitable on the Southern High Plains, forages need to be productive and adapted to the local climate. One proposed system combines a native grass (tobosagrass) with an introduced grass (WW-B.Dahl). In this system, cattle graze on native grassland during the March to mid-July growing season and then move to the introduced grassland from mid-July through fall, after which they are sold to market. This system has the advantage of reducing both water and pesticide use but also of maintaining sustainable forage production for cattle grazing. Together, use of these grasses reduces ranching cost and increases profits. This system also promises often under-identified ecological benefits, especially in comparison to current row cropping options (Ortega-Ochoa et al., 2007b).

At some time in the future, the agricultural economy of the Southern High Plains will depend on robust and adaptable production dryland alternatives, such as this grazing system. This study has three objectives: (1) to determine the profitability and the distribution of profits for this grazing system; (2)to evaluate the suitability of this system for inclusion in the suite of emerging dryland production alternatives; and (3) to identify key areas of study still needed to better assess these objectives.

Because of the uncertain level of precipitation in a given year, dryland production is inherently risky. In this paper, we consider the profitability of the tobosagrass-WW-B.Dahl rotation as a dryland grazing system. Because of the risk involved, determining an average-year's profit is inadequate; therefore we develop its distribution of profits under local precipitation variability to better describe the risk associated with this system. We assume that precipitation (and the resulting forage availability) and prices are the main sources of uncertainty in this production system; therefore, to determine the profit distribution, we develop a model of producer responses to available forage at differing levels of precipitation and responses to cattle delivery prices at feed yards. We then simulate the producer response, and resulting profit values, over a large set of simulated rainfall and price values to simulate profit distribution. Finally we comment on the common concerns that the forage growth response function to precipitation is poorly understood, and that, for a realistic decision tool to be forwarded to ranchers, such studies are needed for grasses not only on the Southern High Plains but across the Great Plains generally.

DATA AND METHODS

In order to determine profit distribution, there are several intermediate steps. We first explain our choice of forage and grazing system and then estimate yield response functions to rainfall. Second, we determine cattle gain with respect to per-hectare yield of WW-B.Dahl and tobosagrass, and then simulate cattle weight gain by applying the forage response functions to a simulated set of rainfall values and then calculating the resulting weight gain values. Third, we develop a set of simulated cattle prices (purchase and sale prices – which are uncorrelated with the rainfall distribution) and simulated costs of grazing cattle. Finally, we use the sets of simulated production, prices and costs to produce a set of simulated profit and calculate the profit distribution.

Forage system. Multiple old world bluestem grazing systems have been suggested and studied (Benzanilla, 2002; Ortega-Ochoa et al., 2007a; and Ortega-Ochoa et al., 2007b). These studies have shown that irrigated old world bluestem grazing is likely to be more profitable under dryland production due to the high cost of irrigation and the relative drought tolerance of the grasses (Ortega-Ochoa et al., 2007a). In this paper, we consider a single system developed by Ortega-Ochoa et al. (2007b) that keeps weaned stockers on native rangeland during winter and spring, and then moves them to WW-B.Dahl for summer after which they will be sent to the feedlot.

Found in West Texas and Arizona and southern New Mexico, tobosa (*Hilaria mutica* Buckl.) is a native and warm season perennial grass, and is a slightly spreading range grass of the family Poaceae (Magness et al., 1971). Tobosagrass is less palatable than blue grama (*Bouteloua gracilis*) and sideoats grama (*Bouteloua curtipendula*) (USDA, Plant Fact Sheet), but palatable when succulent (Magness et al., 1971). It is very drought resistant but responds readily to extra moisture during the growing season.

WW-B.Dahl ([*Bothriochloa bladhii* (Retz) S.T. Blake]) is a warm-season grass that originated near Manali, India. Initial tests began in Oklahoma, around 1965, and in 1994, this grass was named WW-B.Dahl, and released by USDA-ARS, USDA-SCS, Texas Tech University and Texas Agricultural Experiment Station (Texas Coalition for Sustainable Integrated Systems, Technical Notes). It is a late maturing grass and is drought tolerant, and potentially yields a maximum of 9 to 12 tons per acre. B.Dahl is highly palatable, compared to most other grasses with crude protein ranging from 10 to 12 %. B.Dahl also has a very small fertility requirement. Only 50 lbs. of nitrogen per acre per year is required to achieve high yields (Lyssy & Eckel Feeds, 2010).

WW-B.Dahl usually begins growing in early May, and is available for grazing by mid-May. It responds better to water and fertilizer during the first part of growing season. The forage quality is also higher at the first half of the growing season. Research has shown the crude protein in Dahl is 1% to 2% higher than other old world bluestem. Additional research has shown the average daily gain of steers is about 2.5 lbs/day from May to June. The daily gain would decrease without the protein supplement after July (Texas Coalition for Sustainable Integrated Systems, Technical Notes).

Forage yield response. Precipitation is the only water source available in this production system. In order to simulate producer response and profitability, we require a functional relationship between precipitation and forage yield. According to Sneva and Britton (1983), the relationship between precipitation and yield can provide reliable and effective information for forecasting and adjusting the range forage estimate.

Olson et al. (1985) investigated the quantitative changes in the basal cover of forage vegetation in response to variation in precipitation and grazing intensity. They recorded 142 species throughout 25 years, and developed equations via several regressions that were used to analyze the relationships between basal cover and precipitation. They concluded that the reactions to precipitation regimes and grazing treatments may vary by species. A species may respond differently to the same precipitation regime when subjected to different grazing intensities and the species favored and disfavored will change in accordance with prevailing precipitation. The critical finding for this paper is that moderate grazing was more conducive to optimum basal cover for more of the species than other grazing intensities and that the stocking rate could be adjusted to coincide with the forage available in order to achieve optimal basal cover.

For our forage response function, we use a log quadratic functional form:

$$logY_i = \beta_1 + \beta_2 * \log r + \beta_3 * (\log r)^2 \quad (1)$$

where, Y_i is seasonal forage production in lbs (Y_1 is tobosagrass production; Y_2 is the WW-B.Dahl production) and r is seasonal rainfall in inches. We choose the log quadratic function because of its predictive ability. We fit equation (1) using datasets of forage production and rainfall and a Bayesian estimation method to account for the issues associated with the small sample sizes of the available data. Ordinary least squares regression gives wide distributions of parameter estimates when sample sizes are small; this Bayesian method gives a slightly tighter distribution.

Cattle stocking rate. Given the choice of grasses, and a function that can estimate forage amount from given rainfall, we now consider the optimal use of forage for this system. Stocking rates (i.e. the number of animals on a given amount of area over a period of time) are critical in rangeland management since the long-term health of plants is determined by the amount of forage consumed by livestock in relation to the supply of forage available (Hanselka et al., 2001). No other management practices can affect the profitability of livestock more than stocking rate (Daren and Terrence, 2004). A proper stocking rate is therefore one that allows forage plants to withstand grazing during a particular time period but without permanent damage to plant welfare and without causing deterioration of rangeland productivity (Sims et al., 1976).

Grazing pressure is partially determined by the stocking rate and is defined as the ratio of forage demand (forage needed by livestock) to forage supply. As the grazing pressure increases, less forage is available on a per-animal basis, so the individual animal performance will suffer. Reduced performance is measured by decreased weight gain and reproductive capability, and then translated to lower economic returns per animal (Hanselka et al., 2001). Reduction in desirable grasses and invasion of weeds and undesirable grasses occurs when livestock are overstocked on the rangeland. As the undesirable species is more prevalent than the desirable species, animal performance and the carrying capacity of the land are all reduced (Daren and Terrence, 2004). Lower grazing pressure can preserve the forage and allow the ranch to weather crises such as drought. Because of better nutrition, higher weaning weights, fewer deaths, and lower supplement feed costs, livestock productivity and financial returns are higher over the long term under moderate or conservative grazing rather than stocking at carrying capacity (Hanselka et al., 2001).

We therefore constrain the producer in our model to stock rangeland so that only 25% of forage will be consumed. Of the total forage amount produced during a specific year, 50% is ungrazed to keep plant population healthy and to provide cover for the soil surface, and we assume that 25% will be destroyed by insects, leaving only 25% available for livestock (Hanselka et al., 2001). This strategy follows the "half consumed-half remained" rule for sustainable grazing. The rule is based on moderate utilization of annual forage standing crop, assuming uniform grazing distribution, and states that 50% of the annual peak standing crop can be removed without hurting the community relative to the species abundance or beef production (Daren and Terrence, 2004).

Cattle weight gain. Cattle production, that is, seasonal weight gain, is a function of forage production and a chosen stocking rate. We use the platform and results from three separate studies to determine our cattle weight gain function. Hart et al. (1988) compared continuous grazing on mixed-grass range near Cheyenne, Wyoming from 1982 to 1987 and determined the response of average daily gain (kg/day) to grazing pressure (steer days/ton of forage). Specifically, they fit the function,

$$ADG = a - b * GP \tag{2}$$

where, *a* and *b* are parameters to be estimated, for different grazing strategies. In a similar study, Sims et al. (1976) investigated vegetation and livestock response on sandhill rangeland in eastern Colorado, and used average daily gain and average seasonal gain per head to measure the livestock response to differential grazing pressure.

Using data from Sims et al. (1976), Torell et al. (1991) estimated equation (2) and determined the following average daily gain function,

$$ADG = 0.82 - 0.0029 * GP \tag{3}$$

where, *ADG* is in kg/day and *GP* is grazing pressure (steer-days/ton of forage). Equation (3) gives gain per hectare by multiplying *ADG* and the stocking rate. To determine grazing pressure (GP), we apply the definition from Hart et al. (1988),

$$GP = SR * v \;/\; F \tag{4}$$

where SR is stocking rate (animals/ha·day), v is the number of grazing days (which we fix at 120) and F is forage production (in kg/ha). The stocking rate is defined as

$$SR = {}^{F}\!/_{\text{cattle intake}} = {}^{F}\!/_{(W_{st} * .03 * v)} \tag{5}$$

where, W_{st} is starting weight of the cattle, which we assume to be 200 kg in the spring, when the cattle start on the native grassland. The starting weight when the cattle are moved to the WW-B.Dahl is then 200 kg plus the gain from the spring grazing. Note that, when equations (5) and (4) are substituted into equation (3) the term for total forage cancels out, thus the *ADG* (weight gain per head of cattle) is the same regardless of available forage. As forage increases, however, the stocking rate increases, and the resulting average gain per hectare increases.

As explained above, since the stocking rate on the tobosagrass is less than the stocking rate on the WW-B.Dahl, the operator of the integrated system would purchase more cattle in June to raise more cattle on the WW-B.Dahl grassland, in order to make more profit. Cattle purchased in spring are grazed on tobosagrass for 120 day from March to late June, and then new cattle purchased in late June together with the cattle grazed on tobosagrass were moved to WW-B.Dahl grassland and they will be raised for 120 days until being sold in the market in late October. The starting weight of these cattle is determined by the gain on the native grassland – for simplicity, we assume that the purchased cattle are the same weight as those grazed on the tobosagrass.

Profit calculation. For the profit analysis, we use the following profit function

$$\pi = P_{fl} * W_{fl} - P_{sp} * W_{sp} - P_{su} * W_{su} - C \quad (6)$$

where, π is the net profit per hectare; P_{fl} is the sale price in the fall; W_{fl} is the animal total weight per hectare in fall; P_{sp} is the cattle purchase price in February; W_{sp} is the cattle initial purchase weight per hectare in February, and is equal to 200 kg times the stocking rate; P_{su} is the cattle purchase price in June; W_{su} is the initial weight per hectare in June, and is equal to the initial spring weight plus the gain per animal in the spring, times the stocking rate; C is the cost including labor cost, land cost, supplement cost, equipment cost on tobosa grassland and WW-B.Dahl grassland. In this model, the producer perfectly predicts forage availability when making the initial stocking-rate decision, so this cost does not include the need to purchase supplemental forage in low rainfall years.

The cattle weight values in equation (6) are determined by our stocking rate which is determined by the simulated forage amount (which is, in turn, determined by the rainfall simulation). For prices, we assume that cattle prices are log-normally distributed and sample from a distribution using observed mean and variance from a dataset of monthly prices from 1979 to 2008. We also implicitly assume that prices are independent of the individual producer's production and rainfall (correlated price and forage simulations are not possible since the forage response rate away from the mean rainfall level is poorly calibrated, since those observational data do not exist). In the integrated system, cattle are purchased in February, more cattle are purchased in the summer, and then all of the cattle are sold in the market in late October. Using the 30 years of observed data, we determine the average and variance of cattle price for February, June, and October, and we simulate a set of prices for February, June and October for the purchase and sale prices to match up with the forage simulation in determining profit. Cattle production cost on native grassland is $195/head (Texas AgriLife extension), and the cost on WW-B.Dahl grassland is $64/ha (Ortega-Ochoa et al., 2007a).

Data. To estimate the forage response functions, tobosagrass forage data are collected from Post, Garza County, TX (Villalobos, 1995). The data were collected for five years of production between 1985 and 1991. The WW-B.Dahl forage production data were collected for each year from 1999 to 2004 in northeast Lubbock County, TX (Ortega-Ochoa et al., 2007a). We collect seasonal rainfall data for Garza County and Lubbock County from the National Oceanic and Atmospheric Administration (NOAA) for the years corresponding to the collected forage data. More years of rainfall data were included to test which year has the greatest impact on the current year's grass production. Given that the data are limited, we use a Bayesian estimation method that can overcome some of the issues caused by small sample sizes.

Once we have estimated a forage response function, we use a set of simulated rainfall data to generate a set of simulated forage data that will, in turn, be used to determine cattle production values and then generate a set of simulated profit data. We use a dataset of rainfall previously generated by using a Markov Chain Monte Carlo (MCMC) simulation method, using a standard approach recommended by Hastings (1970) and Gelman et al. (2008). The rainfall dataset is comprised of 35,000 rainfall observations that were simulated from 92 years rainfall of observed rainfall in Post, TX. Figure 1 shows the distribution of the simulated rainfall data. Compared to a normal distribution, the histogram of rainfall is a little left skewed, with the average rainfall of 21 inches per year.

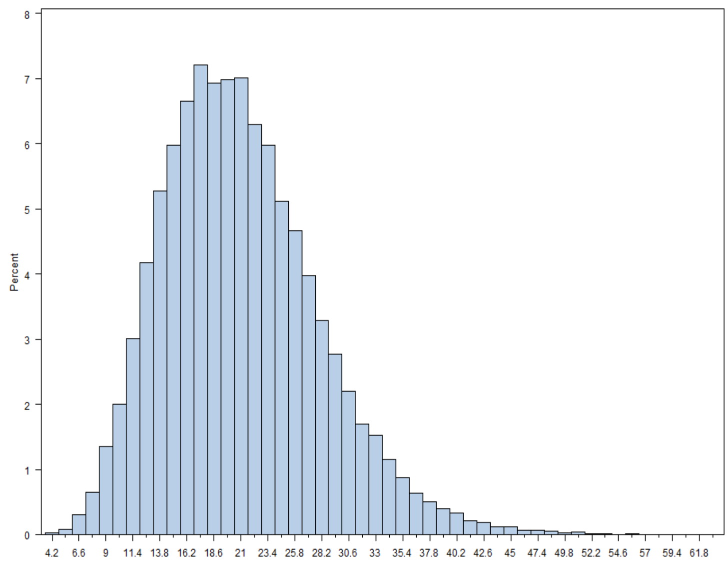


Figure 1. Simulated rainfall distribution.

RESULTS

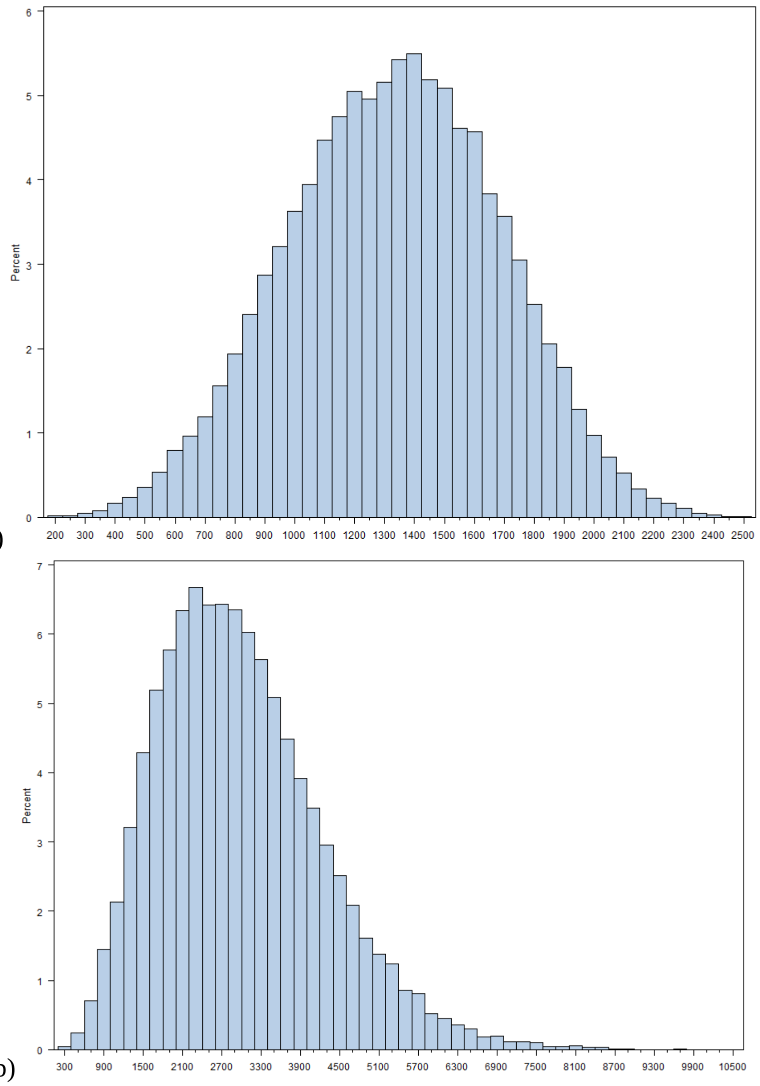
In this section, we present the distribution of the profitability of the dryland grazing system. We first provide the forage response function estimation results, along with a histogram of the simulated forage production.

Forage response estimation results. We estimate equation (1), using a Bayesian MCMC estimation method as implemented in the WinBUGS software package. We choose a Bayesian method to compensate for the small sample size of the available data. We estimate equation (1) with three different specifications of the rainfall variable for each of the two forage species: we use the current-year total rainfall (Jan-Dec), the previous-year rainfall (Jan-Dec) and rainfall from January to August of the current year. For each of these specifications we obtain the parameter estimates (β_1, β_2 and β_3 in equation 1), and use the resulting function and the rainfall data to simulate a forage production distribution. The results of these simulations are reported in Table 1.

Table 1. Forage production simulations for different specifications of the rainfall variable in the forage-rainfall function.

Model	Obs	Mean(lbs/ac)	Std Dev	Min	Max
Tobosagrass					
Previous-year rainfall	35000	1051.16	187.85	236.61	1265.41
Current-year rainfall	35000	1098.65	124.49	372.83	1212.95
Jan-Aug rainfall	35000	1333.7	354	186.94	2522.82
WW-B.Dahl					
Previous-year rainfall	35000	2984.53	1257.3	244.1	10557.8
Current-year rainfall	35000	1915.23	353.42	320.75	2275.49
Jan-Aug rainfall	35000	1957.01	166.11	529.74	2088.12

We choose among these specifications by identifying the distribution that best reflects the expected production of the two grasses. For tobosagrass, the rainfall specification that produced the best simulated distribution was rainfall from January to August. For WW-B.Dahl, we choose the distribution that was generated using the previous year's rainfall. The resulting distributions are displayed in Figure 2.



(a)

(b)

Figure 2. Simulated distribution of (a) tobosagrass production and (b) WW-B.Dahl production in kg/ha, using parameter estimates from estimation of forage production from Jan-Aug and previous-year rainfall, respectively.

The rejected rainfall specification variables all generated distributions similar to that of Figure 3, which displays the distribution of tobosagrass when the tobosa forage production function was estimated using previous-year rainfall, and does not conform to expectations of grass production, which should take on a shape similar to a normal distribution.

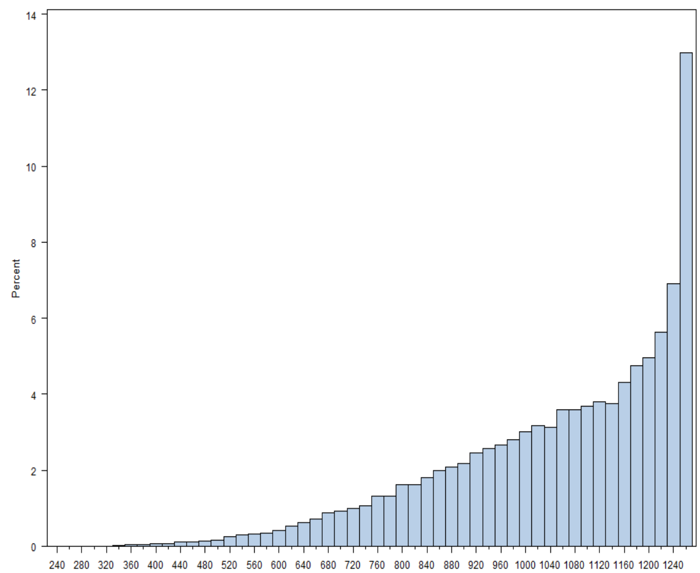


Figure 3. A "rejected" sample distribution of tobosagrass production simulation using parameter estimates generated using previous-year rainfall.

Cattle weight gain simulation. Now, for a given rainfall amount, we generate forage available on tobosagrass and WW-B.Dahl pasture, which we substitute into the weight gain functions (equations 3-5) to generate a pair of simulated weight gain observations for a single year. We then generate a distribution of weight gain by calculating simulated weight gain for each of the 35,000 simulated rainfall observations, which is reported in Table 2. The average weight gain on native grassland is 83.816 kg/ha, and 193.701 kg/ha on WW-B.Dahl grassland. The weight gain on the tobosa grassland varies from 12kg/ha to 158 kg/ha, while 90% of the weight gain lies between 47kg/ha and 120 kg/ha. Weight gain on WW-B.Dahl ranges from 16 kg/ha to 686 kg/ha, and 90% of the weight gain lies between 80kg/ha and 342 kg/ha. The weight gain distributions closely mirror their respective forage production simulations.

Table 2. Summary of cattle weight gain simulations.

Variable	Obs.	Mean(kg/ha)	Std	Min	Max
Gain on native grassland	35000	83.816	22.247	11.748	158.545
Gain on WW-B.Dahl grassland	35000	193.701	81.601	15.842	686.513

Profit simulation. We evaluate equation (6) at each of the weight gain observations and a corresponding set of simulated prices. A distribution of simulated profits is shown in Figure 4. The average profit of this integrated system is $121.2/ha, with a minimum profit of -$94/ha and maximum of $773/ha. 90% of the profit values fall between $2/ha and $298/ha. Critically, we find that the farmer has a 4% chance of loss in this dryland grazing system. In their experiment, Ortega-Ochoa et al. (2007b) reported a profit of $262/ha in 2003 and $244/ha in 2004 under non-irrigation with supplement conditions on the WW-B.Dahl pastures.

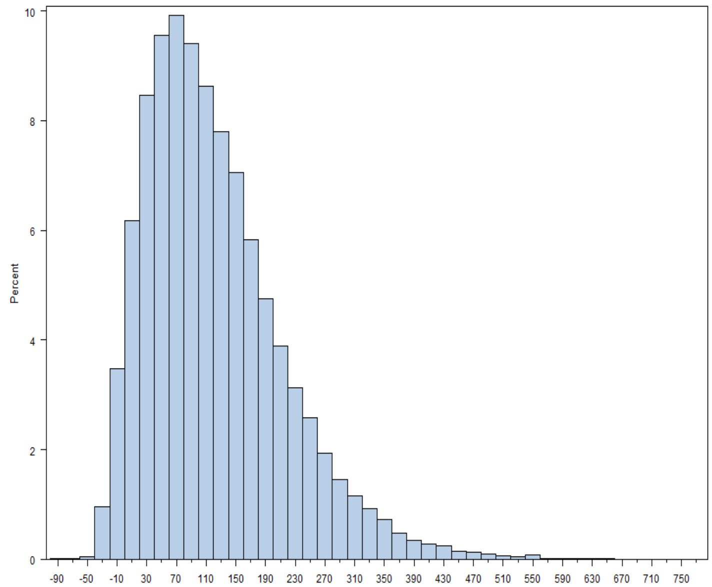


Figure 4. Distribution of simulated profit in $/ha.

DISCUSSION AND CONCLUSION

The observation that variation in forage production resulting from precipitation has an impact on cattle weight gain in dryland cattle production systems suggests that ranchers will need estimates of risk before adopting dryland production practices. In constructing a risk estimate for a specific ranching system (see section 2.1, above) we make the following observations. First, the data for dryland production of forage is scarce, limiting the reliability of any estimate or forecast of forage production. Second, even with the only somewhat reliable estimates of forage response to precipitation, we were able to produce a simulation of forage distribution that conforms to expectations of shape and placement. Third, while our estimates of average profitability were lower than some (specifically, Ortega-Ochoa et al., 2007b), they are much higher than average ranching profits per hectare observed in practice. Some of this over-estimate in profits is due to the perfect-response of the producer that we assume in this model, where the rancher perfectly predicts rainfall in a given year and adjusts stocking rate accordingly. Some of the over-estimate in profits is likely due to the forage distributions, which include forage amounts in very high rainfall and very low rainfall years which are unrealistically large, shifting the distribution to the right somewhat. Use of crop growth simulators would not have resulted in a great improvement over the simulations we derived as described above, since those simulators are calibrated with the same sparse data that are often too clustered about the mean to properly simulate production in the tails of the distribution. Better observations of dryland yield in very low and very high precipitation years will help to center the distribution of forage closer to reality. Because of these shortcomings, this estimate can be considered an upper-bound for profitability of this grazing system.

The common focus of management models on the average year or the mean profit might explain why forage growth functions have not been completed by range scientists. The primary benefit of this model is to illustrate the critical importance of recurrent drought and low precipitation stress toward a more real-world characterization of the economic strains working ranches face in semi-arid regions. Hopefully, the utility of good and detailed field work on rangelands can induce the necessary resources to answer economic questions that derive from weather stress in the short term and over time. Eventually the model presented could accommodate the inter-annual effects of protracted drought or low rainfall stress if carry-over forage response data and initial soil moisture were available.

In light of the above observations, the main contribution of this research is the platform for employing information to analyze new dryland production technologies, as well as identifying the information requirements to adequately determine risk of these new technologies. As the Ogallala aquifer draws down and farmers are forced to consider alternative dryland production technologies, their transition from irrigated agriculture will be facilitated by clearer understanding of the risk of the choices they face. In order to correctly assess that risk for specific production practices, the development of these production practices need to include observations of the technology in a wide range of climatic outcomes. Simply identifying production in an average rainfall year will not allow an accurate estimation of risk.

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