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Simulated Analysis of Drought's Impact on Different Cow-Calf Production Systems

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Five representative, firm-level, stochastic simulation models were constructed using historical production cost, cattle prices, weather information and scientifically collected production data from the Gudmundsen Sandhills Laboratory operated by the University of Nebraska. The five hundred iterative results indicate the inclusion of crop residual grazing is a viable drought mitigation tool.

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Background

Drought is a recurring phenomenon in semi-arid regions of the western United States. Drought conditions directly impact cow-calf producers by limiting the quantity and quality of available forage. These drought events are a part of the normal climate pattern for this region. An analysis of Palmer Drought Severity Index (PDSI) values for the period from 1895 to 1995 indicates that most of the West experiences severe to extreme drought more than 10% of the time and a significant portion of the region more than 15% of the time. (Wilhite, 1997)

Drought mitigation, strategies or plans intended to reduce the effects of drought, are costly and disruptive. The traditional methods of dealing with drought include purchasing or stockpiling feed (hay), reducing cow numbers (depopulating), and early weaning. In order to minimize disruptions to the calving herd, some producers include grazing stocker calves (yearlings) as part of their operation and manipulating their number as forage varies with varying precipitation. Even with these strategies, profits are negatively impacted by drought.

The University of Nebraska has a continuing research program on cow/calf systems done at the Gudmundsen Agricultural Laboratory (GSL) in the Sandhills of Nebraska. This research has and continues to examine how different calving times impact production, input requirements, and profitability. Current research has included feeding crop residues (cornstalks) during the dormant grazing season to these cow herds that calve different times during the year. The economic analysis done on these data sets in the past has generally been performed using deterministic methods. (Carriker et. al.) To date none of the work using this information has included the effects of drought on the system. Recent work by the range specialists has made it possible to account for the impact of precipitation on forage production but capturing the effects of drought on cattle production has yet to be applied to the systems work done at GSL.

This research provides a method of addressing some of these deficiencies. It is expected that a system that is less impacted by drought would require fewer and less costly production adjustments during the dry cycles, which are a normal phenomena in this semi-arid region. Specifically, the use of corn stalk residual grazing provides a source of forage that is drought neutral, assuming full irrigation is possible. Therefore, the ranch systems that utilize cornstalk residuals are likely to be affected least during a drought period and so be more profitable overall. Furthermore, the cows that calve in the summer or fall need more feed during the rangeland dormant season, a time when cornstalks grazing is available. The cost of grazing cornstalk residual is currently lower than that for grazing rangeland.

Three-fourths of the producers in the Nebraska Sandhills calve at least part of their herd in the spring. Only ten percent calve any of their cows in the summer and 17 percent calve any of their cows in the fall. (Clark et.al.) The aforementioned percentages add up to more that 100 percent because some producers calve during more than one time during the year. Less than one-third of producers in the Nebraska Sandhills utilize cornstalk or other crop residue as winter forage. Of those that do, cornstalk and other crop residues are grazed an average of 81 days. (Clark et. al.) Current drought conditions make this research timely and of high value. Recent trends in the cattle and the corn markets further strengthen the need for this work. This research is intended as a starting point, which will hopefully lead to further improvement of techniques and information to answer question for producers, educators and policy makers.

Data and Methods

University of Nebraska researchers have been investigating several different cow-calf production systems at GSL for the past 12 years. They currently are evaluating five systems. These researchers have identified and established three primary calving herds, which calve in March, June, or August. In addition, the March and June calving herds have been each divided into two groups based on the forage source grazed during the fall and winter months. The first groups of cows graze rangeland year around and the second groups graze corn stalks in the fall and winter. The August calving cows have been maintained as a single group, which graze rangeland during the spring and summer and cornstalk residue in the fall and winter. This ongoing research provides a wealth of information with respect to production and forage utilization.

Data from the above research was combined with data from Clark et. al. and the Nebraska Agricultural Statistics Service to build five firm level models of representative ranch scenarios (RRS) for the five systems described above that are currently being studied at GSL. Two letters are added to identify each specific RRS. The first letter indicates the calving month: M for March, J for June, and A for August. The second letter indicates the winter forage source: R for range and C for cornstalk residue. The following table shows the RRS name for each system.

Table 1 – Scenarios in the Simulation

Scenario Name	Calving Month	Source of Winter Forage
RRSMR	March	Range
RRSMC	March	Cornstalks
RRSJR	June	Range
RRSJC	June	Cornstalks
RRSAC	August	Cornstalks

Each of the five models use 4,000 owned rangeland acres as their real estate base. According to Clark et.al., this is approximately the average number of owned acres, 4,365, in the Nebraska Sandhills. Each scenario consists of 400 brood cows and the associated bulls and replacement heifers. University of Nebraska livestock budgets indicate this size herd is necessary to completely support a single family. More than 4,000 acres of rangeland is required to sustain a herd of this size. The model provides the additional grazing resources through leasing. The amount of leased range and or cornstalk residual is dependent on the scenario, or system being modeled. Rent rates for rangeland were collected from the Nebraska Farm Real Estate Developments 2005-2006, a University of Nebraska Extension Circular. (Johnson et. al.) Rates for cornstalk grazing are from actual GSL records.

GSL records show that a limited amount of hay is normally fed to each of their herds except June calving cows that graze cornstalks in the winter. The model considers that all hay fed is purchased. When forage is short because of limited precipitation, the model adds enough hay to the ration to compensate for all reduced grazing, thus herd size and production do not vary.

Cattle prices used in the simulation were generated using stochastic functions. These functions were created from harmonic regression techniques. The residuals were found to have a high degree of autoregressive tendencies. Rather then try to recreate the residuals, the actual residuals were used, with the placement of the pattern of the whole string of residuals randomly choosen as a starting point. The resulting simulation had similar descriptive statistics and performed well within the limits identified from the actual historical data.

Hay prices were simulated in the same way as cattle prices, using historical data, with the exception that the residuals were draw singularly using a truncated normal distribution function.

The procedures for determining the functions for hay price simulation were as per chapter 15 of *Simulation for Applied Risk Management*. (Richardson) Prior to working with the hay price information the authors strongly believed that hay prices would be related to the amount of recent precipitation but no such relationships could be found. This may be a result of localized nature of the hay price and precipitation information. Hay prices were Nebraska only and precipitation records were from the local area near GSL.

These historic hay prices, as well as the historic cattle prices used to create the cattle and hay price simulation engines, are maintained on a University of Nebraska website that can be accessed at http://agecon.unl.edu/mark/Agprices/index.htm. All price data used to create the stochastic simulation were adjusted for inflation using the “All Urban Consumers (Old Series)” Consumer Price Index published by the US Department of Labor found http://data.bls.gov/cgi-bin/surveymost.

Simulated weaning weights of steers and heifers for each scenario were obtained using data for the corresponding GSL herd’s records in a bootstrap procedure described in chapter 11 of *Simulation for Applied Risk Management*. (Richardson). The bootstrap was necessary because of the size of the different data sets collected on the several of the five systems. The combined data set from the bootstrap was then used as an empirical base to draw random weights for each calf born for each year. Each gender and systems were draw from a unique empirical distribution.

Weaning and mortality rates were simulated using averages and variations reported by USDA’s Animal and Plant Health Inspection Service – Veterinary Services in a publication called *NAHMS Beef '97 Part IV: Changes in the U.S. Beef Cow-Calf Industry, 1993-1997* that can be found at http://permanent.access.gpo.gov/lps3025/cahm-act.htm.

Drought was simulated using precipitation data from Halsey, Nebraska, a site located within 60 miles of GSL that has been maintaining precipitation records since 1904. These records are maintained by the National Climatic Data Center and can be accessed via the Internet at http://lwf.ncdc.noaa.gov/oa/ncdc.html. Statistical analysis indicated that the data had no significant autoregressive properties so precipitation was simulated based on the historical mean and standard variation. The amount of forage from rangeland used by the model was a function of the precipitation simulation. The data used to create this function was from unpublished work by Jerry Volesky, University of Nebraska Forage Specialist located at the West Central Research and Extension facility in North Platte, Nebraska.

Each of the five models were created in Microsoft's Excel® and were designed to monitor the firm's, ranch, financial condition over a 20 year horizon. The financial condition was monitored using three coordinated financial statements: the balance sheet, income statement, and cash flow statement. Both income and F.I.C.A taxes were included in the cash flow statement. Either a cash deficit or a cash surplus was carried forward to the next year's balance sheet. Interest was either charged or paid on the resulting balance. Interest on all operating loans was 8%, and interest on surplus cash was 4%. The amount of debt carried on the land was 15%, at an interest rate of 5%, 30 year pay back. Machinery loan value started with was $128,000, 7 year pay-off at 7%. Machinery purchases were made when machinery value declined to one half its beginning worth due to depreciation. Loans were made to cover these purchases and both the loan and the new machinery were added to the balance sheet. A family draw of $35,000 was used as the labor cost; no other labor was considered an expense. As mentioned above, forage production was calculated using simulated precipitation. Hay was purchased to cover any forage deficiencies resulting from low precipitation. Rent paid for leased rangeland that could not be grazed because of drought was refunded.

Each 20 year simulation was run 500 times simultaneously using the scenario option of Simetar®, an Excel® spreadsheet add-on. (Richardson). The scenario option assures that all scenarios use the same set of random numbers, making them comparable.

Results

To summarize the substantial amount of information provided by the simulations, each of the five RSS's average 20 year accumulated earned net worth (AENW) were compared. (Table 2) This statistic was an indication of the financial success of the ranching operation, since it measured the capital accumulated as a direct result of firm earnings. It included changes in equipment value, which depreciates over time resulting in a non-cash expense, but did not include assets whose values change only because prices appreciate, such as real estate or a herd of cattle where numbers and ages remain constant through replacement. The results are reported in the subsection entitled "Group Comparison".

Table 2 – Simulated Accumulated Earned Net Worth (AENW) [500 Iterations]

	Without Drought				With Drought			
Scenario	**Mean**	**St. Dev.**	**Max.**	**Min.**	**Mean**	**St. Dev.**	**Max.**	**Min.**
March Calving Range Only	25,387	172,881	387,332	(558,353)	(125,532)	193,350	294,448	(740,336)
March Calving Fall/Winter Cornstalks	661,360	136,884	967,728	298,371	557,278	142,394	857,788	198,671
June Calving Range Only	158,570	155,048	515,252	(238,752)	1,577	173,410	410,949	(537,503)
June Calving Fall/Winter Cornstalks	924,836	126,369	1,225,717	583,910	827,469	131,863	1,137,793	424,574
August Calving Fall/Winter Cornstalks	836,804	129,828	1,149,723	453,320	742,928	135,048	1,072,268	323,609

The effect of drought on each of the individual RSS's was determined by comparing each RSS results when droughts were simulated in the model to each RSS results when the model used average precipitation. Three measures were used to compare the effect of drought on each of the systems studied: difference in annual expense (DAE), differences in accumulated earned net worth (DAENW), and differences in annual net worth (DANW).

Table 3 – Comparison of Drought to No Drought Simulated Average Annual Expenses [500 Iterations]

	Annual Expenses (DAE)			
Scenario	**Mean**	**St. Dev.**	**Max.**	**Min.**
March Calving Range Only	7,270	2,177	10,835	3,278
March Calving Fall/Winter Cornstalks	5,051	994	9,225	2,796
June Calving Range Only	7,276	2,188	17,639	3,306
June Calving Fall/Winter Cornstalks	5,113	1,250	9,850	2,288
August Calving Fall/Winter Cornstalks	4,809	886	8,660	2,695

Table 4 – Comparison of Drought to No Drought Simulated Average 20 Year Accumulated and Average Annual Net Worth [500 Iterations]

	Accumulated Earned Net Worth (DAENW)				Annual Net Worth (DANW)			
Scenario	**Mean**	**St. Dev.**	**Max.**	**Min.**	**Mean**	**St. Dev.**	**Max.**	**Min.**
March Calving Range Only	(150,919)	20,470	(92,884)	(181,984)	(7,546)	1,023	(4,644)	(9,099)
March Calving Fall/Winter Cornstalks	(104,083)	5,510	(109,940)	(99,700)	(5,204)	276	(5,497)	(4,985)
June Calving Range Only	(156,992)	18,362	(104,303)	(298,751)	(7,850)	918	(5,215)	(14,938)
June Calving Fall/Winter Cornstalks	(97,367)	5,495	(87,925)	(159,336)	(4,868)	275	(4,396)	(7,967)
August Calving Fall/Winter Cornstalks	(93,876)	5,220	(77,455)	(129,711)	(4,694)	261	(3,873)	(6,486)

Group Comparison

The group rankings of the RSS's using AENW values were unaffected by drought. Therefore the following discussion uses the AENW values simulated by the model when drought events were possible. All AENW results may be viewed in Table 2. RSSJC was ranked first with a mean AENW of $827,469 with the second through fifth ranked systems ranked as

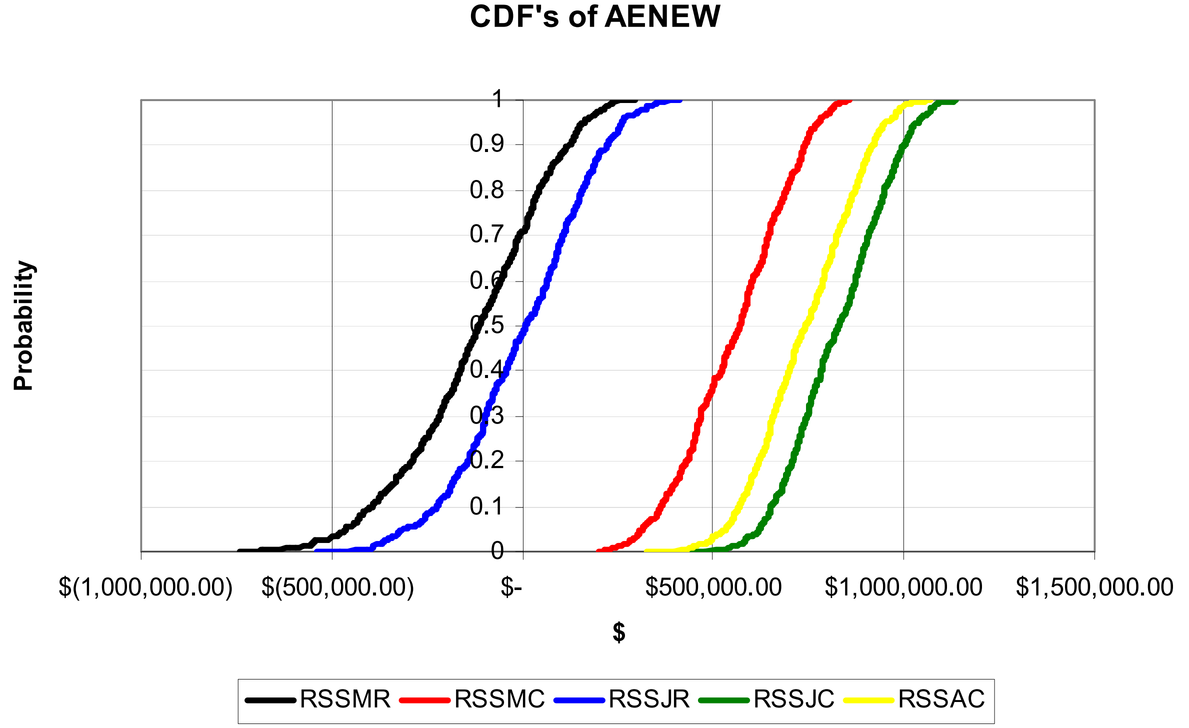
RSSAC, RSSMC, RSSJR, and RSSMR with AENW's of $742,928, $557,278, $1,577, and -$125,532 respectively.

Those systems that used rangeland as their only source of grazing were affected most by drought. With the introduction of drought into the simulation, RSSJR had the largest average decrease in AENW of $156,992, followed by RSSMR with $150,919. Those RRS's that grazed cornstalks had at least $46,000 less decrease in AENW than those systems which did not include cornstalk residual grazing. The simulated decrease in AENW for RRSJC was $97,367, RSSMC was $104,083, and RSSAC was $93,876, the least decrease of the group. The difference between the RSS with the greatest and least change in AENW, RSSJR, and RSSAC was more than $63,000. A look at chart of the cumulative distribution functions (CDFs) for all of the RSS's, Chart 1, created from the 500 simulated 20 year periods show the RSSMR had a negative AENW approximately 70% of the time, with the RSSJR having a negative AENW close to 50% of the time, none of the RSS's which used cornstalk residual grazing had a negative AENW.

Individual Comparison

The RSSMR represents the most common calving system in the Nebraska Sandhills so the fact that it had the lowest average AENW was surprising. Including drought events in the simulation increased its average DAE $7,270, the second highest increase exceeded only by the RSSJR system. It also had the greatest increase in DAE's standard deviation, $2,177, with a difference in maximum DAE averages increasing by $10,835 and a difference in minimum DAE averages increased by $2,177. (Table 3) DANW declined on average $7,546, with an average standard deviation increase of $1,023 annually. DANW's difference in average maximums decreased $10,855, with the difference in minimum averages increasing by $3,278. (Table 4)

Chart 1.



The RSSJR had the second lowest decline in the 20 year average AENW when drought was simulated. The addition of drought events in this simulation increased the average DAE $7,276, making it the RSS with the greatest DAE. The standard deviation for the average DAE increased by $2,188, with the difference in maximum DAE averages increasing by $17,639 and the difference in minimum DAE averages increasing by $3,306 (Table 3). DANW declined on average $7,850 when drought was simulated, with an average standard deviation increase of $918 annually. DANW's difference in average maximums decreased by $14,938, with a difference in DABW's minimum averages decreasing by $5,215. RSSJR exceeds RSSMR in all DANW and DAE changes, yet RSSMR has a lower AENW, which implies that annual overall receipts must be greater for the RSSMR system. Greater receipts are caused lower expenses and market timing of the calf. These results are consistent with recent work Carriker et al.

The RSSMC had the third greatest AENW. The addition of drought events in this simulation increased the average DAE $5,051 and increased the standard deviation by $994, with the difference in maximum DAE averages increasing by $9,225 and the difference in minimum DAE averages with an increase of $2,796 (Table 2).

DANW declined on average $5,204 when drought was included in the simulation, with an average standard deviation increase of $276 annually. DANW's difference in average maximums decreased by $5497, with a difference on DANW minimum averages decreasing by $4,985. RSSMC had the second smallest average DANW change in standard deviation making one of the systems less affected by drought events.

The RSSAC had the second greatest AENW. The addition of drought events in this simulation increased the average DAE $4,809, and increased the standard deviation by $886, with a difference in maximum DAE averages increasing by $8,660, and a difference in DAE minimum averages increasing by $2,695 (Table 2).

DANW declined on average $4,694 when drought was included in the simulation, with an average standard deviation increase of $261 annually. DANW's difference in average maximums decrease by $3,873, with a difference in minimum average annual DANW decreasing by $6,486. Overall RSSAC was affected least by the inclusion of drought in the simulations with the least average increase in average DAE, and decrease in average DANW. The only exceptions were the difference in average minimum DANW and the difference in average minimum DAE, which were second best.

The RSSJC had the greatest AENW. The addition of drought events in this simulation increased the average DAE $5,113 and increased the standard deviation by $1,250, with a difference in maximum averages increased in DAE by $9,850 and a difference in minimum averages increased in DAE by $2,288 (Table 3).

DANW declined on average $4,868 when drought was included in the simulation, with an average standard deviation increase of $275 annually. DANW's average difference in maximums decreased by $4,396, with a difference in minimum averages decrease by $7,967. Interestingly RSSMC does not have the smallest decrease in average DANW or DAE. It only has the smallest difference in minimum averages in DAE. The superior rank in AENW must therefore come from higher average profit.

Looking at Table 5, average annual Expenses (AE) and annual average annual receipts (AR), RSSJC has the lowest AE and the highest AR, RSSAC has the second highest AR but the third lowest AE, RSSMC has the third highest AR, and second lowest AE, RSSJR had the second highest AE, and least AR and RSSMJ had the greatest AE and the second lowest AR.

Table 5 - Average Annual Expense, Receipts and Profit

Scenario	AE (Average Annual Expense)	AR (Average Annual Receipts)	AP (Average Annual Profit)
March Calving Range Only (RSSMR)	$ 204,396.70	$ 217,080.90	$ 12,684.20
March Calving Fall/Winter Cornstalks (RSSMC)	$ 181,579.35	$ 237,141.79	$ 55,562.44
June Calving Range Only (RSSJR)	$ 194,656.77	$ 214,942.44	$ 20,285.67
June Calving Fall/Winter Cornstalks (RSSMC)	$ 182,143.46	$ 256,311.53	$ 74,168.06
August Calving Fall/Winter Cornstalks (RSSAC)	$ 183,220.24	$ 251,467.43	$ 68,247.19

Discussion

The RSS systems, which used range as a source of forage year around, were hardest hit by drought conditions. Cornstalk residual grazing benefited the March calving and the June calving systems. The RSSJC dominated the other systems with lower costs and higher receipts.

The RSSJC average AR was higher than the RSSAC average AR because of the heavier weight of weaned calves since both scenarios market at the same time. The reason the weights are greater in RSSJC system is a result of older calves, which were allowed to nurse longer. The added time on the cow was a result of the inexpensive cost for cornstalk residue grazing and practical considerations such as labor and travel resulting from seasonal considerations. The difference is easily seen when you compare the weights to other June calving system, RSSJR, where steers are sold over 88 pounds lighter and heifers over 78 pounds lighter. The RSSJR calves were weaned and sold in January.

A factor that needs to be incorporated in this simulation is the risk associated with winter storm events, which would result in a snow cover making it impossible for cattle to graze cornstalk residual. This factor might change the results. Consideration should also be given to the same weather conditions affecting range grazing.

The cost of drought for each of the five RSS's was different, but each RSS suffered a loss in average with AENW values between about $94,000.00 to $157,000.00, with a Maximum average loss in average AENW of just less than $300,000.00 making drought a costly event.

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