Range Livestock Strategies Given Extended Drought and Different Price Cycles

By Christopher T. Bastian, Padmaja Ponnamaneni, Siân Mooney, John P. Ritten, W. Marshall Frasier, Steven I. Paisley, Michael A. Smith and Wendy J. Umberger

Abstract

Portions of the U. S. have recently or are currently experiencing extended periods of drought. Producers considering the purchase of breeding stock to rebuild herds while forage supplies recover could be doing so at or near the top of the current cattle price cycle. This research investigates purchasing additional hay and partial liquidation as management strategies under various scenarios of drought and price cycles. Results indicate that purchasing hay may be a more risky strategy than partial liquidation, and it only provides positive returns over a 12-year planning horizon when extended drought occurs during a trough-to-trough price cycle.

Introduction

Many areas of the United States have recently or are currently experiencing extended periods of historically severe drought (Piechota et al., 2004; Pavey, 2008). Moreover, research suggests that drier summers could become more common as the global climate changes (Hengeveld, 2000). Drought affects livestock producers through reduced range productivity and lowered irrigation water supplies. Ultimately, some ranchers are forced to reduce herd sizes, which may impact their genetic base. Bastian et al. (2006) found that Wyoming producers had experienced reduced grazing capacity, sale weights, weaning percentages and reductions in owner equity associated with drought between 2000 and 2004.







Christopher T. Bastian is assistant professor in the Department of Agricultural and Applied Economics at the University of Wyoming, Laramie, Wyoming. Padmaja Ponnamaneni is former graduate research assistant in the Department of Agricultural and Applied Economics at the University of Wyoming. Siân Mooney is associate professor in the Department of Economics at Boise State University, Boise, Idaho. John P. Ritten is assistant professor and extension specialist in the Department of Agricultural and Applied Economics at the University of Wyoming. W. Marshall Frasier is professor in the Department of Agricultural and Resource Economics at Colorado State University, Fort Collins, Colorado. Steven I. Paisley is associate professor and extension specialist in the Department of Animal Science at the University of Wyoming. Michael A. Smith is professor and extension specialist in the Department of Renewable Resources at the University of Wyoming. Wendy J. Umberger is lecturer in the School of Agriculture, Food, and Wine at the University of Adelaide, Australia. This research was funded by the University of Wyoming Agricultural Experiment Station Competitive Grants Program. Opinions expressed in this manuscript are those of the authors and not the granting agency.

Currently livestock prices are at relative highs historically, and producers considering rebuilding herds now will be doing so in an up market (Dalsted et al., 2007). Purchasing breeding livestock at relatively high prices creates the risk that they will generate negative returns throughout their productive life, even if a ranch has the available feed resources to sustain larger herds (O'Neill et al., 1999). This suggests that both cattle prices and forage availability may impact the profitability of drought management strategies. Bastian et al. (2006) survey results suggest that "there could be a great deal of value in developing research techniques that can account for the potential cumulative effects of drought, potential path dependencies and the importance of cycle dynamics in analyses of drought management strategies for livestock producers in the West (p. 8)."

Unfortunately, research literature regarding optimal drought management strategies during extended periods of drought is limited. Foran and Smith (1991) indicated that for droughts lasting two years or longer, maintaining a lower-than-average stocking rate was most profitable in the long-run. Hall et al. (2003) found that producers believed that below normal stocking of pastures, storing more hay and adjusting stocking rates to current grazing capacities were the best drought management strategies available. Bastian et al. (2006) found that Wyoming producers used a number of different strategies to mitigate the effects of drought, but the two most frequently used strategies were partial liquidation of herds and purchasing additional hay to address forage shortages. Lardy and Poland (1997) indicate that providing additional feed supplements, herd liquidation, renting additional pasture and grazing crop residues are all effective strategies for stretching tight forage supplies during periods of drought. Thurow and Taylor (1999) conclude that management and policy tools must improve the integration between the economic and ecological aspects of drought-induced destocking decisions.

While the above literature suggests that grazing and stocking decisions are important during periods of drought, and that other strategies exist to extend existing forage resources, the economic consequences of those strategies are not well understood. Moreover, little is reported in the literature regarding the financial impacts of drought management strategies used by livestock producers during extended periods of drought.

The purpose of this paper is to examine the financial consequences of frequently used management strategies (partial liquidation and purchasing additional feed) during extended periods of drought coupled with price cycle dynamics.

Methodology

A multi-period, linear programming model was adapted from Torell et al. (2001) and was estimated using GAMS (Generalized Algebraic Modeling Systems) software. The model was based on a cow-calf ranch with forage resources to sustain a herd size of 600 cows. Costs and production technology represented in the model were based on data collected by Torell et al. (2001) from Fremont County, Wyoming.

The net present values (NPV) of discounted annual returns are maximized over a 12-year planning horizon subject to linear constraints that define resource limitations and resource transfers between years (Torell et al. 2001).[1] Seasonal forage supply and demand is explicitly considered and are adjusted or shocked for consecutive years of drought. Excess cash, forage or different classes of livestock can be transferred from year to year within the model so that impacts of management decisions, forage supplies as influenced by drought or management, or other pertinent resources can be transferred or adjusted between periods in the model.

An equation allowing the purchase of feed is included in the model. The timing of when purchased forage can be utilized is extended to spring and summer grazing when investigating purchasing feed as a management strategy. Excess cash from a good year is transferred to cover expenses and cash shortfalls in future years. Off-ranch income was constrained to equal family living withdrawal.

Annual borrowing is allowed to transfer from the previous year to the current year. In the original model used by Torrell et al. (2001), borrowed money is paid in full by the end of the T-year planning horizon. For our research purposes, we allowed borrowing to continue after the planning horizon, which is 12 years, as solutions obtained in some scenarios were not feasible with this terminal condition in place. For more specifics about the model as well as explicit GAMS code see Ponnamaneni (2007).

This design allows us to incorporate the dynamic inter-temporal linkages that likely exist during extended periods of drought. For example, at the ranch level, drought is expected to affect the producer's income in a given year and his savings and investment possibilities in subsequent years. Similarly, cattle prices may affect ranch income and savings for the given year. Historical data were used to run the mathematical optimization model multiple times resulting in a range of possible outcomes and responses for drought and price cycle scenarios.

Incorporating Drought into the Model

Not surprisingly, there are differing definitions of drought in the literature. Most of the definitions indicate that drought is a result of below normal moisture level or water content or precipitation. For our research purposes, we used the following definition: "A climatic excursion involving a shortage of precipitation sufficient to adversely affect crop production or range production" (Rosenberg 1979, p. 5).

Historical precipitation data were used to identify and quantify drought periods. These "representative" drought periods were then used to quantify shocks to grazing forage resources in the model. According to Smith (2007), spring precipitation is the primary influence on range forage production. In communities with primarily cool season grasses, April precipitation provides a good predictor of peak summer forage. Smith, Thurow and Legg (2005) estimated regressions related to native forage yields at three long-term research sites in Wyoming. A forage production regression equation at a site representing a relatively high elevation dominated by cool season grasses relating yield to April precipitation was used to estimate changes in range production due to changes in precipitation (see Smith, Thurow, and Legg [2005] for the actual equation).[2]

The above forage response equation was representative of conditions found in many parts of Fremont County, Wyoming, and was used to analyze April precipitation from 1949 to 2006 for consecutive years of drought. The most common frequency of consecutive years of drought in Fremont County (i.e., below average April precipitation) was for drought events lasting three or four years. A "representative" 3- and 4-year drought based on April precipitation data was then calculated and used to shock available grazing forage resources in the model to represent drought events.[3] Table 1 reports the percentage changes used to represent the three and four year drought scenarios.

Incorporating Price Cycles into the Model

Historic cattle price data were analyzed and a representative cattle price cycle was used. A smoothed price cycle then was estimated using regression. Cattle prices were collected for steer calves, heifer calves, cull cows, bulls, heifer yearlings and bred cows between the years 1972 and 2004 using Wyoming auction price data (Freeburn and Bastian, 2005; Taulealea and Bastian, 2003; Bastian, 1997; Bastian, 1992; Kearl, 1987). Price series for each class of livestock between the years 1979 to 2004 were graphed, and a common price cycle running between the years 1979 and 1996 was identified. This common price cycle was divided into a 12-year peak-to-peak price cycle (i.e., prices generally falling in the first six years and rising thereafter) running from 1979 to 1990 and a 12-year trough-to-trough price cycle (i.e., prices generally rising to a peak in the first six years and falling thereafter) running from 1985 to 1996. Regressions were estimated for these peak-to-peak and trough-to-trough price cycles. Prices were then predicted from the estimated regressions and a data file of smoothed prices by cycle and livestock class for each cycle was incorporated into the model.[4]

Hay Prices and Drought

During periods of drought, there is some concern that hay or feed prices rise if the phenomenon is widespread. If such is the case, then impacted hay prices would also be a variable that should be incorporated into the model. To investigate if hay prices increase during periods of drought, a correlation analysis between Wyoming alfalfa hay prices and the amount of April precipitation was conducted. The correlations turned out to be very small and positive.[5]

These results may seem counterintuitive. We would expect that during an extended drought, supplies of hay could be reduced at a time when demand is increased, suggesting a negative relationship between precipitation and hay prices. Our correlation results are likely related to two potential factors. First, hay production in Wyoming and much of the West depends largely on irrigation, and storage of irrigation water may very well mitigate risks associated with drought as we have defined it for rangeland conditions (i.e., spring precipitation is likely not highly correlated with hay production). Second, drought and hay markets tend to be regional in nature, and statewide markets for hay may very well show less price variability from drought than one might think initially. We concluded that there was no significant effect of drought on hay prices for the case ranch. Therefore, we did not incorporate drought impacted hay prices into the model.

Scenarios Analyzed

Continuous years of normal and below normal precipitation do not represent a realistic scenario. Cattle producers may receive an above normal amount of precipitation during some years. If we incorporate only normal and below normal precipitation (due to drought), then ranch income may be less than what could be the case and solutions could be infeasible. For this reason, we incorporated a variable precipitation profile (having similar mean and standard deviation to the precipitation for the historic April precipitation data) into the model.

The above data for precipitation, drought, and price cycles were then used to shock the model for a number of different scenarios. Precipitation and management scenarios were analyzed across the following price scenarios: 1) peak-to-peak price cycle (i.e., smoothed prices generally falling years 1 through 6 and rising thereafter); and 2) trough-to-trough price cycle (i.e., prices generally rising years 1 through 6 and falling thereafter). The above mentioned price scenarios were coupled with the following precipitation and drought scenarios: 1) base: stable precipitation; 2) variable precipitation; 3) variable precipitation with 3-year drought (drought began in year 2 of the 12-year horizon for all drought scenarios); and 4) variable precipitation with 4-year drought (drought began in year 2). For each combination of price and drought (variable precipitation with drought), the model was configured to allow either partial liquidation and/or the purchase and feeding of hay as management strategies. To model partial liquidation as a management strategy, the model was allowed to choose optimal herd size each year, given the specific precipitation and price scenario, which maximized discounted net returns. The use of purchased feed was modeled by allowing the model to utilize purchased hay year round rather than that activity being constrained to winter and early spring, as was the case for partial liquidation only. Thus, the model could choose between substituting hay and/or reducing herd size when range forage was a binding constraint. A total of 12 separate precipitation, price, and management strategy scenarios were estimated (only the price cycle scenario varied for the base without variable precipitation). These scenarios, as labeled in Figures 1 (peak-to-peak prices) and 2 (trough-to-trough prices), were: 1) Base: Stable Precipitation; 2) 3 Yr Drought (allows model to choose optimal herd size each year); 3) 4 Yr Drought (allows model to choose optimal herd size each year); 4) 3 Yr Drought – Purchase Feed Option (allows model to choose optimal herd size and feed purchased alfalfa year round); 5) 4 Yr Drought – Purchase Feed Option (allows model to choose optimal herd size and feed purchased alfalfa year round); and 6) Variable Precipitation (allows model to choose optimal herd size each year).

Analysis of Results

Variables of interest were collected from GAMS output (net discounted returns, herd size in animal units, raised meadow hay consumption, tons of purchased alfalfa and short-term borrowing). For purposes of this article, we will focus largely on discounted net returns (see Ponnamaneni [2007] for further analyses of all variables). Results were graphed, descriptive statistics estimated and multiple means comparisons tests were conducted using the Tukey-Kramer method. This test was chosen based on the conclusions of Dunnett (1980), Hayter (1984) and Hayter (1989), indicating it is a superior multiple means comparison test.

Results

Figure 1 indicates that without variation in precipitation (base: stable precipitation), returns follow the expected path given a peak-to-peak price cycle. Discounted returns generally fall as prices decline during the first half of the cycle and then rise thereafter as prices recover. Once variability in precipitation is added, returns become more variable but tend to follow the expected pattern of prices as well. This suggests potential interaction between prices and precipitation in determining profitability. Overall, Figure 1 suggests that the purchased feed option finishes with lower returns than the partial liquidation strategy for both the 3- and 4-year drought scenarios.
Table 2 confirms the graphical results. Mean discounted returns are highest for the base scenario of no variability of precipitation given a peak-to-peak price cycle. Mean returns are negative for the purchased feed option scenarios in the peak-to-peak price cycle. Moreover, the standard deviations and the range between minimums and maximums indicate that variability is highest for the purchased feed options as compared to partial liquidation only.

Mean discounted returns are generally higher during the trough-to-trough price cycles as one might expect. Figure 2 indicates that returns again follow price patterns: as prices rise first half of the price cycle, so do returns. Mean returns are lower for the purchased feed options as compared to the same drought scenarios where partial liquidation is the only management strategy allowed in the model. Overall, standard deviations are lower for the 4-year drought scenario with purchased feed option compared to the 4-year drought scenario with partial liquidation only, but the reverse is true for the 3-year drought scenarios (Table 2). Moreover, the range between the minimum and maximum return values tend to be higher for the purchased feed options compared to the other drought scenarios, suggesting more potential risk.

An interesting result of our analyses is that in like price, drought and management scenarios, mean returns are always higher for the 4-year drought scenarios as compared to the 3-year drought scenarios. Initially, this seems counterintuitive, until one investigates further the interaction between herd size, hay purchases, short-term borrowing, revenues and intensity of the drought. Annual income in our model is equal to revenues from livestock and any hay sales minus animal

costs, forage costs, and loan costs. Table 3 summarizes mean returns (in descending order) coupled with mean herd size, mean raised meadow hay use (in tons), mean alfalfa purchases (in tons) and mean short-term borrowing for each scenario. When comparing like scenarios in the peak-to-peak price cycle, the 4-year drought mean herd size is higher, purchased alfalfa is only slightly higher and mean short-term borrowing is nearly half that of the 3-year drought. Thus, the tradeoff in herd size coupled with loan costs makes the 3-year drought less profitable. The purchased feed option indicates a higher herd size for the 3-year drought, but purchased alfalfa and short-term borrowing is much higher as compared to the 4-year drought. The added costs of purchased forage and loan costs overshadow the increased revenue from having an average higher herd size of 40 animal units. In the case of the trough-to-trough prices, the 4-year drought has a much higher herd size coupled with no borrowing and only slightly more purchased alfalfa on average. These tendencies also are present in the purchased feed option for the 4-year and 3-year drought in the trough-to-trough price cycle. Mean borrowing is twenty times higher for the 3-year drought with purchased feed as compared to the same 4-year drought scenario coupled with herd size being nearly 75 animal units higher for the 4-year drought scenario.

These results are, at least in part, related to intensity of the drought coupled with timing of the intensity of drought in the given price cycle. Note that the forage shock in the three year drought has a much higher forage reduction in the first year of the drought followed by two years of relatively moderate forage reductions (Table 1). Compare this with the 4-year drought scenario which had relatively modest forage reductions in the first year, fairly severe forage reductions in the next two years, and the final year had the most severe forage reduction of all. The ranch is forced to liquidate much deeper and/or borrow much more money to purchase feed initially in the first year of the three year drought, and this puts the case ranch at a larger disadvantage earlier in the drought particularly when prices are falling during the drought in the peak-to-peak price cycle. Given the severity of the drought intensifies over time in the four year drought scenario, the optimal strategy tends to be to liquidate more deeply in the later years of the drought as compared to the three year drought scenarios. Moreover comparing the results across drought scenarios is somewhat complicated by the fact that the returns are discounted more heavily in the severest part of the drought in the four year drought scenario as compared to the three year drought scenario where the severest part of the drought occurs in the first year of the drought. These results suggest that timing of drought intensity certainly impacts the viability of ranching operations and can be exacerbated by price cycle dynamics.

Means comparisons tests indicate that the means between price cycles are statistically different, and means are different when comparing the 3- and 4-year drought scenarios (both partial liquidation only and purchase feed option) by price cycle. Overall, these results seem to suggest that partial liquidation generally provides better returns than purchasing additional hay when forage is constrained. Purchasing feed tends to be a more risky strategy overall given the variability in returns (i.e., larger standard deviations and ranges), and this strategy provides the best returns when prices follow a trough-to-trough price cycle. Moreover, these results suggest that the intensity and timing of a drought can greatly impact returns, particularly when complicated with price cycle dynamics.

Conclusions

Livestock producers in different regions of the country have recently or are currently facing extended periods of drought at a time when cattle prices are near their cyclical and or historical highs. It is interesting to note that, given the prevalence of drought throughout our history, relatively little research focusing on the potential financial outcomes associated with drought management strategies for livestock producers has been published. Moreover, research dealing with the potential interaction between drought, management strategies, and livestock price cycles seems to be lacking.

This research used a multi-period mathematical programming approach to model 3- and 4-year droughts using partial liquidation and/or purchase of additional hay as management strategies, given either peak-to-peak or trough-to-trough price cycles. Given the assumptions in our analyses, our research indicated that, at least in the short run, partial liquidation of livestock tended to provide better returns than purchasing feed to overcome constrained forage supplies. Moreover, partial liquidation tended to be less risky and create potentially less financial stress than purchasing feed. The scenarios where purchasing additional feed was allowed only provided positive returns when prices were stronger overall during a trough-to-trough price cycle as compared to peak to peak price cycle scenarios. Overall, these results indicated that management during extended periods of drought is complicated by the intensity and duration of drought, as well as price cycle dynamics.

These results are subject to the assumptions made in the analysis, but they do suggest that producers considering purchasing additional feed to address forage shortages need to consider the potential riskiness of that strategy. Moreover, our results suggest that financial stress is more likely to occur with this strategy when producers face prices in a peak-to-peak price cycle pattern (i.e., when drought occurs when prices are trending downward before trending upward again).

It should also be noted that our results never indicated that full liquidation of the herd was an optimal strategy. This result addresses, at least in part, concerns by producers that liquidating cattle may hurt the future genetic potential of their herds. Our results suggest that a genetic base likely can be maintained for a herd even under extended periods of drought and across varying price environments.

While we believe this research makes an important contribution, it is important to recognize several limitations. First, our analysis assumed that range forage tended to be comprised of cool season grasses and therefore dependent on spring precipitation for growth. Drought may affect rangelands differently if the species composition differs greatly from that assumed in this analysis. Second, we assumed linear production relationships in this model. Admittedly, some variables such as sales weight may not behave linearly. Partial liquidation and purchasing additional feed were the two strategies analyzed in the research, but other strategies such as early weaning could potentially be incorporated into the model and analyzed. Moreover, our analyses were estimated over a relatively short time horizon of 12 years. Research investigating the financial consequences of drought management strategies over longer planning horizons could be useful.

Endnotes

[1] Annual returns were discounted using the standard discounting formula, i.e., returns multiplied by (1+r)^-t; where r equaled a discount factor of 0.07, and t equal time or year (1 to 12).

[2] It should be noted that while the case ranch model is meant to be generally representative of cow-calf production systems, ranches in different geographic areas may have range forage bases that could be affected by precipitation in months other than and including April. Thus, drought shocks to forage bases, both in terms of magnitude and timing, would likely vary geographically.

[3] We calculated drought periods based on total April precipitation as weekly data were not available. Note that the equation from Smith, Thurow, and Legg (2005) is based on precipitation for certain dates within the month of April. For our purposes, it is expected that the relative percentage change in forage response would not change greatly given the use of monthly rather than weekly precipitation data.

[4] It is important to note that during severe drought, more cattle could be sold at depressed prices. This could likely be a very short-term phenomenon. As such cyclical cattle price behavior is assumed and seasonal variation caused by drought is not analyzed.

[5] Wyoming alfalfa hay prices for the years 1949 to 2006 were collected and deflated (Wyoming Agricultural Statistics 1949-2006). Correlation coefficients were estimated between the following: 1) deflated hay prices versus amount of April precipitation (0.23); 2) difference from mean of deflated hay prices versus difference from mean of April precipitation (0.23); and 3) percentage change from mean of hay prices versus percentage change from mean of precipitation for all drought periods (0.1). An analysis also was run for hay prices lagged one year, which yielded similar results.

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Table 1. Percentage forage response calculated given April precipitation for the representative or average 3-year drought period and 4-year drought period in Fremont County, Wyoming

Year of Average or Representative 3-Year Drought	**Deviation from Mean April Precipitation (inches)**	**Average Percentage Change in Forage Response**
Year 1	-1.29	-40.56
Year 2	-0.26	-8.45
Year 3	-0.24	-7.82
Year of 4-Year Drought	Deviation from Mean April Precipitation	Average Percentage Change in Forage Response
Year 1	-0.33	-10.54
Year 2	-0.97	-30.36
Year 3	-0.77	-24.35
Year 4	-1.16	-36.59

Table 2. Descriptive statistics of net discounted returns by price, precipitation and management scenario

		Price Cycle: Peak-to-Peak		
Scenario	Mean	Minimum	Maximum	Std. Deviation
Base: Stable Precipitation	34092.20	9449.39	95221.34	26699.47
Variable Precipitation	14757.14	-16506.61	115679.55	37093.38
3-Year Drought	8621.97	-23989.30	113924.80	36138.23
4-Year Drought	15933.42	-13101.37	110528.01	33850.99
3-Year Drought – Purchase Feed Option	-12244.16	-63434.26	108583.80	47202.89
4-Year Drought – Purchase Feed Option	-3921.57	-52068.63	107767.50	44990.39
		Price Cycle: Trough-to-Trough		
Base: Stable Precipitation	40818.61	5310.27	70589.24	18462.22
Variable Precipitation	27276.55	1162.23	42724.76	12827.35
3-Year Drought	23559.87	1162.23	39147.30	9594.97
4-Year Drought	30868.79	1162.23	48600.06	12587.97
3-Year Drought – Purchase Feed Option	19087.62	-2756.88	36656.15	10919.12
4-Year Drought – Purchase Feed Option	25966.25	-1100.10	35610.81	9660.89

Table 3. Summary of means of net discounted annual returns (arranged in descending order), herd size, amount of raised meadow hay, amount of purchased alfalfa and amount of short-term borrowing by precipitation, management and price cycle scenario

Precipitation and Management Scenario: Price Cycle	Mean of Net Discounted Returns	Mean of Herd Size (AU)	Mean of Raised Meadow Hay Used	Mean of Purchased Alfalfa	Mean of Short-term Borrowing
Base - Stable Precipitation: trough-to-trough	40818.61	672.57	893.07	71.94	237.74
Base - Stable Precipitation: peak-to-peak	34092.20	691.69	917.13	77.23	0
4 Yr Drought: trough-to-trough	30868.79	486.38	645.51	51.61	0
Variable Precipitation: trough-to-trough	27276.55	420.03	557.70	43.79	0
4 Yr Drought - Purchased Feed Option: trough-to-trough	25966.25	501.48	668.24	106.86	426.50
3 Yr Drought: trough-to-trough	23559.87	426.46	568.91	37.37	1662.81
3 Yr Drought - Purchased Feed Option: trough-to-trough	19087.62	427.55	571.97	76.78	8414.58
4 Yr Drought: peak-to-peak	15933.42	494.99	658.55	48.24	17708.45
Variable Precipitation: peak-to-peak	14757.14	451.38	598.56	49.55	20455.75
3 Yr Drought: peak-to-peak	8621.97	444.72	591.33	44.32	31418.69
4 Yr Drought - Purchased Feed Option: peak-to-peak	-3921.57	455.22	604.49	109.49	55925.62
3 Yr Drought – Purchased Feed Option: peak-to-peak	-12244.16	495.23	656.89	131.27	69396.97

Figure 1. Discounted net returns for peak-to-peak price cycle scenarios

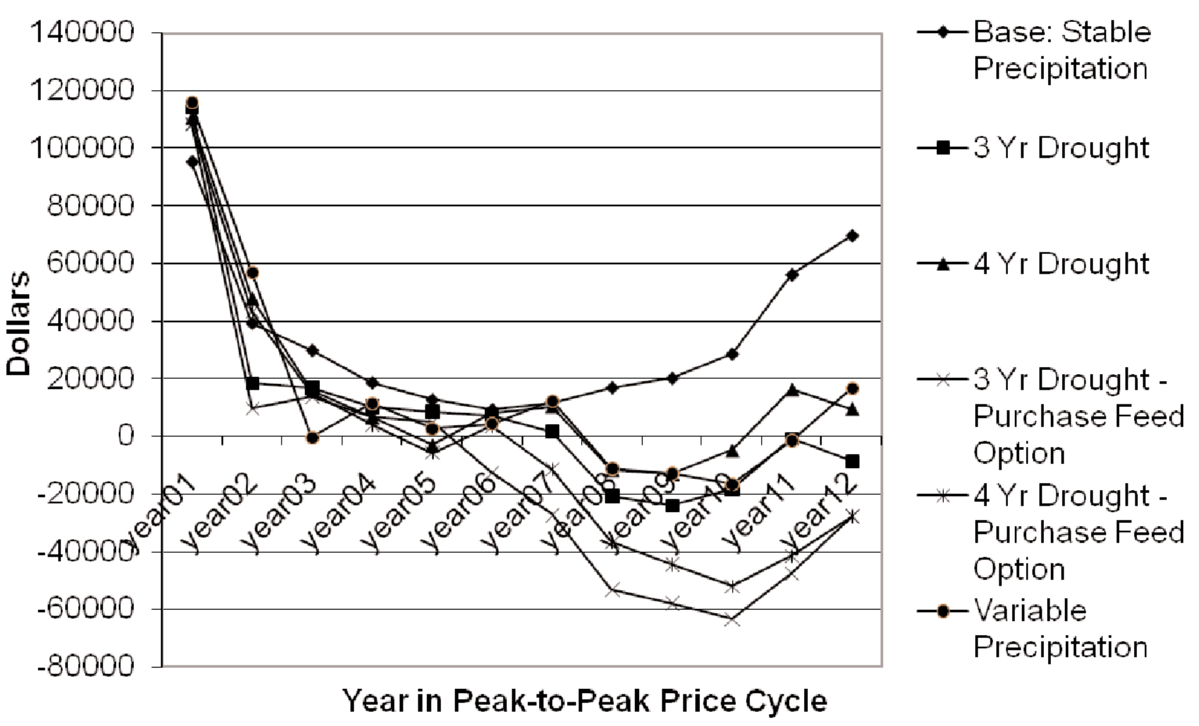

Figure 2. Discounted net returns for trough-to-trough price cycle scenarios