# Economic Impacts of Grazing Production Systems on Cow-Calf Ranches in Southern Idaho under Market Variability

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# Abstract

Livestock and land management decisions made by ranchers in the Mountain West have current impacts on ranch profitability as well as long-run impacts on sustainability of the operation. As a result, it is critical for ranchers to understand the economic impacts of management decisions to choose strategies that minimize economic and operational risk. Given this, the use of a multi-period mathematical optimization model to estimate the economic outcomes of two summer grazing management practices- non-irrigated rangeland and irrigated pasture grazing, given cattle price projections over a 40-year planning horizon was imperative. The model is parameterized for 150- and 300- head operations, using enterprise budgets for Lemhi County, Idaho, and grazing and animal outcome data from the Nancy M. Cummings Research, Extension and Education Center. A simulation of 40-year price trends using historical cattle price data was performed. Subsequently, the simulated operations that utilize summer grazing of range lands result in the highest overall profit, regardless of ranch size. The study also shows the average annual returns for large ranches that only utilize irrigated pasture are negative. While the average annual returns for small ranches utilizing irrigated pasture are positive, the returns are significantly lower than ranches that use rangelands for summer grazing. The results indicate the economic significance of rangeland grazing and forage production for the profitability of ranch operations and their resilience to exogenous impacts on production.

## Acknowledgments

Through the project, Dr. Lee and Dr. Tejeda were immensely helpful and always offered their advice and guidance while I navigated these topics, and without their help and encouragement I could not have completed this thesis. There were plenty of times I could have quit, but their motivational words and wisdom kept me pushing on and it helped me learn a lot about who I am as a person, and as a contributor to this paper. Through my advisors, I could not complete this project. To everyone involved, and to everyone who will read this paper, I hope this thesis has provided some educational insight on the ranching community's struggles of herd management, and I also hope it has progressively contributed to the literature established before me to further advance the conversation on livestock herd management and keep the beef industry, and agriculture, thriving for years to come.

## Dedication

First, I wanted to take time as well to thank my parents, Kim and Ed, my wonderful wife Briann Hunter, as well as my close group of friends who have supported and encouraged me through this project. Through these wonderful people, my faith, and my support group I could not have completed this paper. It has truly been a wonderful learning process about not only the subject matter at hand, but a lot of self-discoveries and learning what I am truly capable of.

Through all the difficulties of the past few years, it would have been easy to quit on this project. It truly takes a village, and for that I thank you all.

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# Chapter 1: Introduction

Over twenty-eight million acres (48 percent) of Idaho's land area is classified as rangelands which include grasslands, woodlands, shrub lands, and desert (Homer et al., 2021). Twenty million of these acres are managed as federal public lands and 7.4 million acres are privately owned. In the western United States, most privately owned rangeland is used for livestock production (Toombs et al., 2009) and millions of state and federal land acres are grazed. Cattle and calf production was the second largest contributor to Idaho's agriculture sector, generating $1.7 billion in cash receipts in 2019 (NASS). The vitality of many communities in Idaho depend on the use of rangelands for livestock production. The economic viability of livestock producers is a function of the environment and market conditions. Understanding the economic impacts of grazing management practices, as well as how livestock producers can optimally respond is critical for understanding how to adapt to changing conditions and how changes may influence their bottom line.

To understand the effects of livestock grazing management practices, this study evaluates optimal production decisions and the long-term economic impacts of utilizing non-irrigated rangelands versus irrigated pasture during summer grazing months. The long-term economic impacts of these grazing management practices to a livestock producer are assessed utilizing fluctuating market prices. This analysis is conducted using a multiperiod mathematical programming model considering regional forage production, cattle performance, and economic data to parameterize models representing multiple scenarios across a 40-year planning horizon. The model uses a similar framework (Ritten et al., 2010; Rimbey et al., 2001; Torell et al., 2014). To account for price uncertainty, the study performs 100 iterations of the model using simulated market prices.

Using this modeling methodology, the conducted simulations for the two summer grazing scenarios and tested the sensitivity of the results by parameterizing the model for two different ranch sizes. The chosen ranch sizes are representative of a large and small ranch in Lemhi County, ID, based on focus groups conducted with livestock producers in the region. The data used for the study can be adjusted to other geographical regions regarding cattle prices, and this study can be tailored to other regions to analyze operations under specific geographical regions and scenarios.

Through this study, there were several conclusions surrounding the topics of producer preferences considering market variability, profitability according to producer preferences, how certain ranch sizes behave under certain price simulations and grazing methodologies, and a short analysis on how these studies impact current and future ranchers.

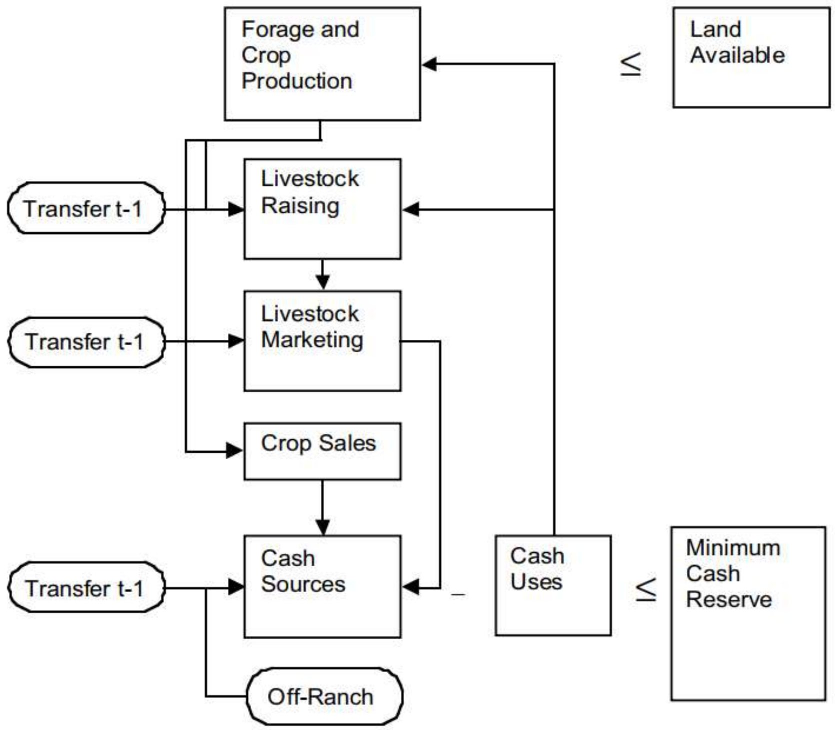
# Chapter 2: Literature Review

Previous work in agricultural economics dating back to the 1990's has assessed the impacts of market and environmental shocks on production decisions. (van Zyl et al., 2001) used a mathematical programming model (MPM) to include crucial variables such as weather conditions to quantify the effects of the change in climate given the water shortages on the Western Cape farm sector in South Africa. Others, such as (Stockton et al., 2007) have used a similar model to determine crop viability and is used as a hedging tool of negative impacts of drought on Nebraska forage production. These studies used slightly different constraints than what the study requires of the model and looked at farming operations rather than ranching operations. For example, (Stockton et al., 2007) uses fixed herd sizes and outcomes were not specifically optimal responses of drought conditions. The study required using a model that allows for variable herd sizes, to allow the rancher to sell off the herd as a profit generation strategy. It was also important to incorporate some level of dispersion in the impact variable, which in this case is prices. Both prior studies showed different environmental impacts but have not investigated based on market prices of beef cattle. To show this impact effectively, this study uses a slightly different model. The model applied, like one used in (Ritten et al., 2010) considers decisions facing forage production and output prices based on the economic impacts of developing an alternate water source to improve riparian grazing over a 40 -year planning horizon. Further evaluation and analysis of this model concluded that slight alterations of their model could be introduced for this study by simulating future prices. Doing so, the simulated prices using time series data were then put into an economic optimization model for each ranch management strategy and estimate how projected prices influence the key variables of the model while maximizing profitability.

The model used in this thesis has been used widely in the rangeland and livestock production economics literature. (Rimbey et al., 2001) used this model to analyze ranch-level impacts of alternate public land grazing policies in Owyhee County, ID. Rimbey's study concluded that purchasing hay to replace rangeland grazing created an increase of $83/head animal cost and reduced gross margin by $80/head.

Hamilton discusses using the ranch level economic model to analyze the economic impacts of increasing seasonal precipitation variation on cow-calf enterprises in Southeast Wyoming (Hamilton et al., 2016). This paper discusses using the model in efforts to manage risk that includes decreasing herd numbers to accommodate lower levels of forage production in drought years, as well as cattle performance as relevant to climate changes. Hamilton utilizes the multiperiod linear programming model to estimate optimal management strategies that was previously developed as part of a regional economic effort and is widely used and adapted for evaluation of management strategies and grazing management assessments, hence previously used in (Torell et al., 2002) which utilizes the flow chart as seen in the figure below to show how the linear programming model functions.

Figure 2.1 This table reflects Recursive Multi-Period Linear Programming conceptual model shown in (Torell et al, 2002).




In this figure, Torell notes the constraints of the model, such as limited number of crop-raising alternatives are included, but only alternatives that provide forage, crop residue (aftermath), and feed for livestock production. The figure above illustrates the net present value (NPV) of discounted net annual returns, or profit margin, is maximized over a T-year planning horizon subject to linear constraints that define resource limitations and transfers between years. In this illustration, Torell explains the first block of equations sets, from top to bottom, shows a ranch has a limited availability of cropland and rangeland for harvesting and grazing. Each land type is restricted at or below a given upper limit to provide consistency in the model. The next block of equations shown above is to transfer forage and crop production to livestock-raising, and crop selling, activities. Within there are equations that define the required ratios between different animal classes, so the herd stays consistent. Specific examples are the bulls must be included based on a specified bull-to-cow ratio and specified calf crop defines the number of young animals available for sales and herd replacements (Torell et al., 2002). Torell then discusses the constraints around cash flow, meaning? the cash constraint must be maintained through the model to cover variable production expenses, fixed ranch expenses, family living expenses, and loan obligations. Excess cash is implicitly assumed to be transferred to the next year, and any funds borrowed must be repaid during the next year. Ultimately, Torell concludes the overlying production possibilities are determined by the forage resources and cash availability.

(Dyer et al., 2017) discusses how the Multi Period Linear Programming Model was used to evaluate how maximum NPV of profits earned over time changes as forage production on privately owned rangeland changes. Dyer goes on to discuss the model from their study was used to show how ranch resources are influenced by the soil health conditions as it impacts forage production. This study has a similar approach to Dyer utilizing this model, but focused on price simulation through enterprise budgets.

A previous study conducted to evaluate the forage value of public and private grazing leases (Van Tassell et al., 1997) also provided an understanding of the rancher's methodologies when it comes to private versus public grazing, and why a rancher may choose to do one or the other. Van Tassell's study found nearly all the cost categories were higher on non-irrigated grazing versus irrigated grazing.

Having this detailed literature review going forward helps to further analyze the profit maximizing objective function in understanding the external factors of a producer's operation and allows us to be more cognizant of the bigger picture.

# Chapter 3: Methodology

### *Overview*

This model simulates the optimal production choices and economic outcomes for two different grazing management practices summer grazing on non-irrigated rangeland and on irrigated pasture. This study compares the economic outcomes of a representative ranch these two summer grazing practices using a multiperiod linear programming (MLP) model that maximizes annual profits, subject to livestock resource constraints and variable market prices for a representative ranch in Idaho. In this work, the primary livestock resource constraint is summer forage availability. The model scenarios are parameterized using regional enterprise budgets and real livestock herd data from the Nancy M. Cummings Research, Extension and Education Center (NMCREEC) located in Lemhi County, Idaho. To perform a sensitivity analysis for the results around cattle price variability, the study uses historic market prices and simulate market prices for each year, which are subsequently projected on a 40-year time horizon. The outcomes of the two grazing management practices are analyzed for two scenarios, one representing a small (150 head) livestock operation and another representing a large (300 head) livestock operation. Here, first is a description of the MLP model used to estimate the economic impacts and then discussion on how the price simulations were performed.

### *Multiperiod Linear Programming Model*

(Bartlett et al., 2002) developed a MLP for livestock producers to assess the ranch-level economic impacts of changes in federal land management. Subsequently, this same model has been used for livestock producers to understand the impact of drought, grazing management, invasive species, and riparian grazing (Torell et al., 2014; Ashwell et al., 2019; Stillings et al., 2003). In this framework, the net present value of discounted annual returns is maximized over a specified time horizon subject to linear resource transfers and constraints. Seasonal forage demand and supply is explicitly modeled, making this a pertinent framework to assess the research question.

### *Objective Function*

The economic model is a profit maximization function. This is composed of the total revenue over a 40-year time horizon, multiplied by a discount factor to produce net present value of future net returns. More explicitly, this could be written as the following:

$$Max\ \pi = \sum_{t=0}^{40} (REV_t + K_t - FCOST_t - ACOST_t - N_t)\rho^t + TERM\_VAL$$

Where $REV_t$ is ranch revenue, $K_t$ is off-ranch income, $FCOST_t$ and $ACOST_t$ are variable costs of producing crops and livestock, $N_t$ are fixed costs of production, and $\rho^{t}$ sis a discount factor. The model assumes a discount rate of 7%. In each decision period (in this case, one year) the producer chooses land use, forage and sale crop production, herd size, animals sold, and animals purchased, i.e., fixed costs. For simplicity, the model uses the same fixed costs for each simulated ranch size from Ritten's study (Ritten et al., 2010). Total revenue is a function of sales from all livestock classes sold within a year, animal sale weights, and sale prices.

Variable costs vary with the choice variable herd size and include feed, labor costs, veterinary expenses, and animal transportation. In the model, the costs outlined previously is assumed fixed costs for simplicity (Ritten et al., 2010).

### *Grazed Land Availability*

The grazing land constraint states the chosen acreage allocated for grazing and rest across each land type cannot exceed the total number of acres available to the operation.

$$LAND_{l,t} = \sum_{i=1}^{7} \boldsymbol{Q_{i,l,t}} + \boldsymbol{U_{l,t}} = \overline{GRAZ\_ACRES_{l,t}}$$

where $Q_{i,l,t}$ is the total acre or AUMs of land used in season $i$, within the annual production cycle, on land type $l$ in year $t$. $U$ represents unused land resources indexed by land type l in each year $i$. Used and unused land acres in each year of the simulation must sum to the total acres or AUMs available by land type$TOT_ACRES_{l,t}$, which is a fixed parameter in the model (notated by the upper bar) due to the fact the model constrains the amount of land available to the rancher through the 40 year time horizon. The types of grazed land available to the ranch are summarized in Table 3.1.

### *AUM Constraint*

Ranchers and policy makers need to know approximately how many AUM of forage is available for them to graze and to manage the ground properly so there is a new crop every cycle of grazing. This measure is built for public grazing grounds to tell the rancher how many head of livestock can be on the ground at one time.

The constraint in this model states the chosen herd size cannot exceed the total number of AUMs available to the producer- both grown and purchased. In other words, this constraint says the producer cannot starve its animals- it must feed each animal in their herd their AUM requirement or reduce the herd size.

$$HERD_{i,t} = 12\sum_{k=1}^{N}(\boldsymbol{A_{k,t}} * REQ_{k,i})\, x \leq \sum_{l=1}^{N}(\boldsymbol{Q_{i,l,t}} * AUM_{l,i}) + \sum_{j=1}^{N}((\boldsymbol{F_{i,j,t}} + S_{j,t}) * AUM_{j,i})$$

The total herd AUM requirement is defined as the chosen number of animals $A_{k,t}$ in animal class k multiplied by the AUM requirement $REQ_{k,i}$ for each animal class k in season $i$ multiplied by 12 months must be less than or equal to the sum of AUMS produced on each land type $Q$ and purchased and grown feed crops. This equation can be narrowed down to analyze the amount of land needed in each land type.

This equation simplifies the above by looking at the required AUMs for the cattle and constrains the equation to say you cannot have more animal AUE, animal use equivalent, in a particular season than you have AUM available of land in a particular season. This constraint prevents overgrazing and keeps the grazing land at a sustainable level to continue to use it in the following years.

### *Forage Production and Purchase Cost*

Each type of forage, both grazed and grown, in the model has an associated cost. For example, the cost of grazing BLM acres is the per-AUM permit cost plus additional operation expenditures associated with using BLM land such as trucking animals to and from the allotment and providing animals with water and another form of supplementation.

$$FCOST_t = \sum_{l=1}^{n}\left[forcost_{l,t}\sum_{i=1}^{7}\boldsymbol{Q_{i,l,t}} + cropcost_{l,t}(\boldsymbol{S_{j,t}} + \sum_{i=1}^{7}\boldsymbol{F_{i,j,t}})\right]$$

where $forcost_{l,t}$ is the per acre or AUM cost of grazing on land type $\boldsymbol{Q_{i,l,t}}$ and $cropcost_{l,t}$ is the per- ton cost of growing and purchasing types of feed.

### *Animal Production Cost*

Each animal class k has an annual cost of production.

$$ACOST_t = \sum_{k=1}^{n}\left[acost_{k,t} * \boldsymbol{A_{k,t}} + \boldsymbol{apurch_{k,t}} * pwt_{k,t}\right]$$

The total cost of the herd number of animals in each class k multiplied by the per-animal cost of raising an animal in that animal class and number of animals purchased each year $apurch_{k,t}$ , multiplied by their purchase price $pwt_{k,t}$.

### *Revenue*

Annual revenue for the operation is the total amount of cashflow coming into the ranch from sales of animals and crops.

$$REV_t = p_{k,t} \sum_{k=1}^{n} \boldsymbol{L_{k,t}} + p_{j,t} \sum_{j=1}^{n} \boldsymbol{S_{j,t}}$$

The chosen number of animals sold $L_{k,t}$ is constrained by another equation that states the number of animals sold from each animal class k cannot exceed the total number of live animals currently held in the herd.

### *Terminal Value*

Terminal value is the appropriate monetary value that must be remaining at the end of the 40-year simulation to adequately continue the operation into the future, as per the definition of this constraint, the rancher cannot completely sell out of the business in year 40.

The model accounts for the number of heads for each animal class at the last period in the model. This value makes up the total number of heads needed for each animal class in the final period.

Then, dividing by the total gross margin to get the total gross margin per head of cattle. This is then multiplied by the total slack variable of gross margin per head discounted into the infinite future to get the total terminal value.

### *Modeling Assumptions*

There are several key assumptions in the model. First, in the case of the irrigated pasture summer grazing scenario, the model assumes the rancher has enough irrigated pasture to feed the herd through the summer season. In the non-irrigated summer grazing scenario, It is assumed the rancher does not have enough irrigated pasture to feed their herd for the whole summer, therefore utilize a grazing lease on rangeland during the summer months. This decision will have two outcomes:

1. Outcome 1:
    a. If the rancher grazes irrigated pasture during the summer months, the animal weight will be higher at time of sale but may have to purchase winter feed. There is a tradeoff between higher revenues and higher input (feed) costs per head.
2. Outcome 2:
    a. If the rancher grazes non-irrigated rangeland during the summer months, the rancher can harvest the hay crop grown on irrigated pastures and use the hay crop as feed for

their own herd during the winter months or sell the hay. The rancher can also choose to graze the aftermath during early fall, and feed this during the winter months. In this case there is another trade-off between lower animal weights at the end of summer grazing, but lower winter feed costs. This could cause a lower yield and impact sale returns.

The land availability constraints are outlined in the following section, but it is crucial to understand there are specific periods when land is available to the producer in each scenario. Both scenarios are relevant to the rancher's decision making when grazing irrigated pasture or non-irrigated rangeland.

### *Model Parameterization*

The model considers cattle production in southwestern Idaho, specifically Lemhi County, which may use a mix of irrigated and non-irrigated grazing lands for grazing from May to October; and hay and alfalfa are used for feed in the winter. The producer can either grow their own hay, on cropland which can be used for post-harvest (aftermath) grazing, or conversely purchase hay. Cows are bred in the spring and calves are born in the late winter. Calves are weaned and sold in November. The average sale weight of steers and heifers is different and depends on whether animals grazed on irrigated or non-irrigated pasture during the summer grazing months. Cows are kept until they are 9 years old and 15% of heifer calves are retained. The "representative ranch" small (150 head) and large (300 head) representative ranches have a specified amount of cropland and rangeland resources available for growing and harvesting crops and grazing. Land types are defined and restricted seasonally which creates a set of constraints in the model. The land availability constraints are paired with a conversion to available AUMs that drive seasonal availability of AUMs. The data in Table 3.2, sourced from land availability data provided by the Nancy M. Cummings faculty, provides a snapshot of land availability per herd size on the representative ranch. Since there are multiple units of measure involved in land availability, the table below outlines each land resource with its corresponding unit of measure for clarity of input data visualization.

Table 3.1 Reflects seasonal availability of forage and feed for the ranch based on Nancy M. Cummings herd management.

| Land type | Season | | | | | |
|---|---|---|---|---|---|---|
| | 1 May- 30 June | 1 July – 30 Sept | 1 Oct – 31 Oct | 1 Nov – 30 Nov | 1 Dec – 31 Dec | 1 Jan – 30 April |
| **Summer non-irrigated range grazing system** | | | | | | |
| Non-irrigated range | * | * | * | | | |
| Irrigated pasture | | | | * | | |
| Aftermath grazing | | | * | * | * | |
| Feed raised/purchased hay | | | | | * | * |
| **Summer irrigated pasture grazing system** | | | | | | |
| Irrigated pasture | * | * | * | * | * | |
| Aftermath grazing | | | * | * | * | |
| Feed raised/ purchased hay | | | | | * | * |

The producer must invest in maintaining the herd size through replacement, maintaining a bull-to-cow ratio, and as a function of other metrics such as calving success, losses after birth, and carryover of the herd between years. The model used data from the study site and two grazing treatments to parameterize these values in the model. The model tracks different animal types and age classes throughout the year: calves less than 1 year, yearlings, and mature cows and bulls.

Each animal type has a different AUM requirement, which using an animal unit equivalency (AUE) permits the model's head of animals just in terms of their AUM requirement. In this model, one animal unit is defined as a 1,000 cow and calf pair. These AUE's were assumed to be consistent with the model in (Rimbey et al., 2010) and are consistent with the representative herd size.

Table 3.2 Reflects quantity of forage and feed available for the ranch based on Nancy M. Cummings herd management.

| Land resources | Large/Small ranch land availability | Productivity Conversions | Cost Per Forage Availability Unit |
|---|---|---|---|
| Alfalfa and hay cropland | 325/105 acres | 1.5 tons/acre, 2.42 AUMs/ton | $386.70/Ton |
| Non-irrigated rangeland | 3,190/1,425 acres | 1 AUM/acre | $18/AUM |
| Irrigated pasture | 965/455 acres | 1.4 AUMs/acre | $23.40/AUM |
| Purchased alfalfa and hay | unlimited | 2.42 AUMs/ton | $191.86/Ton |
| Alfalfa and hay cropland aftermath | 325/105 acres | 2.3 AUMs/acre | $23.40/AUM |

In the table below, the brood cows, commonly known as “mother cows” are the animal class that can bear calves. The bulls are male cattle kept for breeding stock. The Weaned Calves are the cattle that are old enough to be on their own and not requiring direct feeding from Brood Cows. Yearlings are cattle that are between 1 and 2 years of age, able to sell if needed and can be used as breeding stock.

Table 3.3 Reflects Animal Unit Equivalencies for forage requirements.

| Animal class | Animal unit equivalency (AUE) |
|---|---|
| Brood cows | 1.25 |
| Bulls | 1.87 |
| Weaned calves | 0.60 |
| Yearlings | 0.75 |

In the model, annual operation of the ranch produces income from livestock and possibly crop (hay and alfalfa) sales. These annual earnings are used to pay expenditures in operating the ranch. The model requires the cash reserve from revenues must cover variable and fixed expenses. In this model, annual profits are allowed to run negative, which requires short-term borrowing at a certain interest rate. Cash surpluses can also be used to pay short-term loan obligations. The ranch also has income from off- ranch sources (off-ranch employment, investments, etc.). Excess cash can be transferred year to year. Now that there is a good understanding of the model, the following will specifically discuss the key equations in its setup.

The model permits separating the following animal classes for different types of animals included in this study that provide impact to the model, while noting not all these animal types will drive profitability.

Table 3.4 Reflects Animal Unit Equivalencies for forage requirements.

| | |
|---|---|
| Steer calf | 700-799# |
| Heifer calf | 600-699# |
| Steer yearling | 800-899# |
| Heifer yearling | 700-799# |

The operational parameters for a representative ranch in southern Idaho are incorporated from (Ritten et al., 2010) regarding other animal herd sizes serves for consistency across model usage, and in case of lack of data. The most consistent price data obtained was related to steers and heifers of all weight classes. Due to the Nancy M. Cummings Research, Extension and Education Center being of a cow-calf focus, a difficulty was obtaining certain data related to alternate animal classes for inputs to the model. The limited data for this study simplified the inputs to the model by isolating the profit-generating animal class, brood cows, as it relates to the population that tends to produce the most direct revenue for a given Idaho ranch. The generalization of the alternate inputs required for the model provided stability across the two studies to isolate the price variation and impact to the ranch profitability.

### *Market Price Variability and Simulations*

This study uses a multivariable linear regression based on time series data representative of economic time series data considering periods of annual, quarterly, monthly, weekly, and daily observations (Diebold &. Kilian, 2001), where each of the price series can be described per the following equation:

$$y_t = k_1 + k_2 t + \rho y_{t-1} + \varepsilon_t$$

$$k_1 = a(1-\rho) + \rho b$$

$$k_2 = a(1-\rho)$$

Where $y_t$ is the price value at time $t$ reliant on the intercept from the OLS regression statistics $k_1$ plus the product of $k_2$ and a time trend $t$ plus the product of $\rho$ and the price of the previous period, plus the error term, $\varepsilon$.

The multivariate error terms from all prices were simulated by first calculating the error series of values via the use of the estimated equation's residuals which need to maintain their historical correlations. For this purpose, the following method provided by the simulation software Simetar (Richardson et al., 2011) is applied using a Microsoft Excel add-on function.

$e$ = Correlated Uniform Standard Deviation calculation(s) (CUSDs) from the LCM (Linear Correlation Matrix) of the Residual data from the OLS Regressions, considering the Mean and the Standard Deviation of these empirical residuals.

Once the computation of the CUSD's were complete, it is necessary to then calculated the error terms εt, which (in the appendix data) is called the shock. These shocks were calculated by taking the NORM, or the normal distribution for the mean and standard deviation of the residual data series, and their CUSD's,. These simulated error terms provide a variability factor for constructing the projected price data.

### *Data Sourcing, Cleaning and Application*

To begin, the analysis of cattle price analysis as related to grazing methods, it's important to have a significant data sample to accurately simulate future prices. This data, sourced from (CattleFax), describes the weekly cattle prices for steers, heifers, cull cows, and bulls. This data shows weekly data from multiple weight classes. Steers, ranging from 300-399 to 800-899 pounds and heifers ranging from 300-399 to 700-799 pounds. Cull cows and bulls are at fixed weight classes assumed from (Rimbey et al., 2001). The data, comprised of approximately 8 years of historical weekly prices, was then manually aggregated to show the price simulations needed to depict for input into the model, which is further explained below.

The initial process conducted was to set up the pricing data in a user-friendly manner for the model. The data provided by (CattleFax) provided historical data by week for 7 years, which was critical to the model. Initially, the approach was to take the individual weight classes and ran the time series regression analyses to accurately gather the residuals from a dignified data source. The attempt to aggregate the data before the simulation made the projected sample size far too small, and it had too much variance for what was needed to show with accuracy involved (See Appendix 1)..

So, to overcome this obstacle, the next step was to simulate prices from the weekly data first. After the regressions were run, and the necessary information was obtained to plug into the multivariable linear programming projection model, the next step was to forecast each weight range out forty years to show an appropriate price simulation. Obtaining low variance across the simulation was found by completing 100 individual iterations of 40-year simulated price data. This created an improved sample since the model used is static, i.e., has a set beginning and end of each simulation. If the data had been dynamic, one simple regression for 100 iterations all at once would have been sufficient (See Appendix 2).

The monthly average for each weight class for each year of the historical data was necessary to compile the price simulations. Based on information from the Nancy M. Cummings Research, Extension and Education Center, the annual livestock sale that would reflect price would occur in November. Next, each weight class was used to calculate the average weight for each year into a more simplistic view of what each iteration would reflect in November of each simulated year. By taking the weekly November prices and calculating the average over each year, one complete iteration based off the original data was compiled. This process was repeated 100 times, creating 100 different workpapers showing the projected time series of forty years while considering the assumption this is a time series-based study. One could not simply simulate4,000 data points because then it would be in discrete time, and this would not accurately show the projections with any degree of certainty across iterations. Simply put; each iteration must be re-run as if it was individually analyzed (See Appendix 3 & 4).

After addressing the above, the summary statistics were run to make sure the estimates were in the bounds of the historical data for accuracy of the simulated data in terms of minimum, maximum, and standard deviation. This modeling methodology smooths the data over any shock periods that may occur within the historical data. This is necessary for data simulation due to needing the overall sample to be consistent through each iteration without impacts of outlying price shocks to the model, thus lowering the variability of the simulated prices. The standard deviation of the summary statistics reflects the successfulness of the smoothing exercise. Thus, the smaller the standard deviation, the better the results.

Once it was established that the simulated data was appropriately portraying each individual weight class, the data was ready for import into the model.

### *Model Application*

The study required acquiring actual herd data from the University of Idaho Nancy M. Cummings Research, Extension, and Education Center in Lemhi County, ID. The Center is a beef cow-calf and (rangeland) forage research station which runs over 300 cows in a research herd. The ranch herd is split up between summer grazing on Rinker Rock Creek Ranch, a University of Idaho owned property of unirrigated rangeland, and irrigated pasture at Nancy Cummings facilities, for alternate forage studies and herd health, but also provided an ideal use case for this study.

# Chapter 4: Results

### *Overview*

The purpose of this study was to evaluate the long-term differences in ranch decisions and profitability resulting from each of the summer grazing systems. Next, is the the discussion of results regarding the ranch-level economic model. Optimal ranch-level decisions for land use and herd size were simulated over a 40-year time horizon for two summer grazing practices: grazing on non-irrigated rangelands and summer grazing on irrigated pasture. As a sensitivity analysis, the simulations were performed for two model parameterizations: a large (300 head) operation and small (150 head) operation. For simplicity, it is interpreted to use "rangeland" in discussion of the non-irrigated rangeland simulations and "irrigated pasure" for the irrigated pasture simulations going forward.

From an animal performance perspective, cattle that graze on irrigated pasture for the duration of summer will have greater average daily gains and body mass at time of sale. The question is whether the trade-offs of grazing irrigated pasture and not producing as much hay for winter feed are on net economically beneficial as compared to rangeland grazing and producing more hay for winter feeding.

### *Small Operations*

<u>Herd Size</u>

Figure 4.5 shows the average herd size of 157 head across the 40-year simulation through 100 price simulated iterations of the irrigated pasture grazing sample in the model. The rationale behind showing herd size as an average is to eliminate the impact of outliers as well as eliminate the model constraint of forcing the herd size back to the original size in Year 1 and Year 40.

Through this study, the model determines the herd size for an operation that grazes cattle on non-irrigated rangeland is slightly smaller on average than an operation that utilizes irrigated pasture over the entire simulation. This parameterization starts at 150 head in the beginning year, fluctuates through the simulation, then is forced back to 150 head due to model constraints, and ultimately shows efforts to sustain the herd for years after the simulation. This shows the impact cattle have more consistency and predictability across samples, but the irrigated pasture simulation provides more forage for the cattle, thus can have a higher capacity. The irrigated pasture parameterization had an eight percent herd size increase in the first portion of the study, while the increase for the non-irrigated rangeland parameterization was insignificant. Since the model uses the same prices for irrigated pasture grazing and public land grazing, this could imply the rancher had a couple good years at the beginning of the simulation, rebounded to a more realistic working level of profitability over the remainder of this operation's 40-year operating life. Having irrigated pasture, dependent on location, has a lot of intrinsic benefits such as less predatorial risk, lower risk of disease, higher level of accountability, and a higher level of consistency.

Table 4.1 Reflects results from the Irrigated Pasture & Range scenarios for average herd size

| Average Herd Size – Small Herd Size (Mo. 2 - 39) | |
|---|---|
| Irrigated Pasture | 157 |
| Rangeland | 152 |

Since non-irrigated rangeland summer grazing typically occurs on federal or state-owned allotments, there is inherent risk of predators, environmental stressors, and uncontrollable environmental hazards such as toxic plants and topography. The lifespan of cattle that are primarily on range versus irrigated pasture are vastly different and their useful life as a production cow are usually cut significantly shorter than cattle grazing on private irrigated pastureland with low predatorial risk, typically more favorable terrain, and in some cases eradicating poison and toxins.

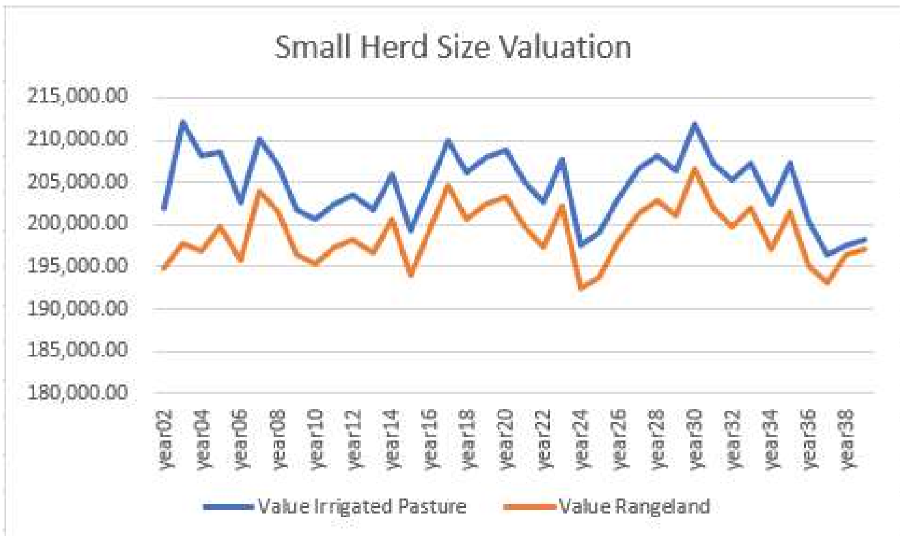
Land and forage availability and usage are also very important factors to include when evaluating the overall profit of a ranch operation. Though this is explicitly geographically based and must be considered when making recommendations, it is still very important for a producer to consider what forage types are available and when.  The model shows each sample type will use different forage sources to feed their cattle based on their seasonality. A comparison between the Range and Irrigated Pasture samples was performed, and the Irrigated Pasture still had more inputs regarding land use than the Range sample group did. Furthermore, the Irrigated Pasture sample considers forage costs that impact the overall cost of the operation. This is not as intuitive because in a normal scenario, the Range sample group would need more AUM's due to the lack of forage accessibility on public lands, thus higher forage costs, which is relative to location as well.

The overall goal of this study is to analyze the effect of price simulations in combination with different summer grazing practices. This was evaluated at a per cow basis and showed the optimal herd size between the two grazing practices via simulations. Regarding this portion of the study, the irrigated pasture summer grazing had a higher overall input cost than non-irrigated rangeland summer grazing sample, as well as a higher cost per AUY. This explains the rationale of ranchers not wanting to graze solely on irrigated pasture ground because it is very expensive to put forth the capital to graze in this methodology. Therefore, ranchers usually will try to use a public land source instead to save some money up front. The cost, as shown in the results below, for a larger (300 head) operation these amounts add up very quickly.

Herd Valuation

The small herd size value between irrigated pasture grazing and rangeland grazing follows a similar trend when comparative to price, while the rangeland grazing method has a lower herd value due to average herd size through the valuation.

Figure 4.1 Shows total herd value in respect to price and herd size for Small Irrigated Pasture & Range samples.




The figure above shows the herd valuation comparison between the irrigated pasture grazing method and the rangeland grazing method. It can be interpreted as the herd size is inherently going to be lower in the rangeland scenario due to variables such as maximum AUM's available to graze.

### *Large Operations*

Herd Size

The large results are vastly different, and important to consider when discussing herd management with profit maximization. Inherently, a larger herd brings a higher impact of the input costs and consequences relative to the variable price impact used in the model. Managing a larger herd calls for more land, higher death loss, and an increase in herd management practices comparative to the small herd size.

To accurately analyze the below results, one must consider the model constraints discussed previously in this paper are placed over both the large and small herd sample sizes while maintaining consistent price variability in the same respect over both samples. This is not a practical application, per the previously discussed to keep the experiment constant, it is assumed the ranch sizes are not directly correlated to producer preference.

The chart below shows the non-irrigated rangeland grazing scenario averages approximately 282 head for the life of the simulation. The irrigated pasture grazing scenario, on the other hand, averages 304 head for the life of the simulation. Theoretically, this could be explained by cattle grazing rangeland might have a higher death and disease rate as well as lower cow productivity, lower useful life, and lower average daily gain. These theoretical factors could drive a rancher to inherently have a lower herd size despite cattle prices.

Table 4.2 Reflects results from the Irrigated Pasture & Range scenarios for average herd size.

| Average Herd Size – Large Herd Size (Mo. 2 – 39) | |
|---|---|
| Irrigated Pasture | 304 |
| Rangeland | 282 |

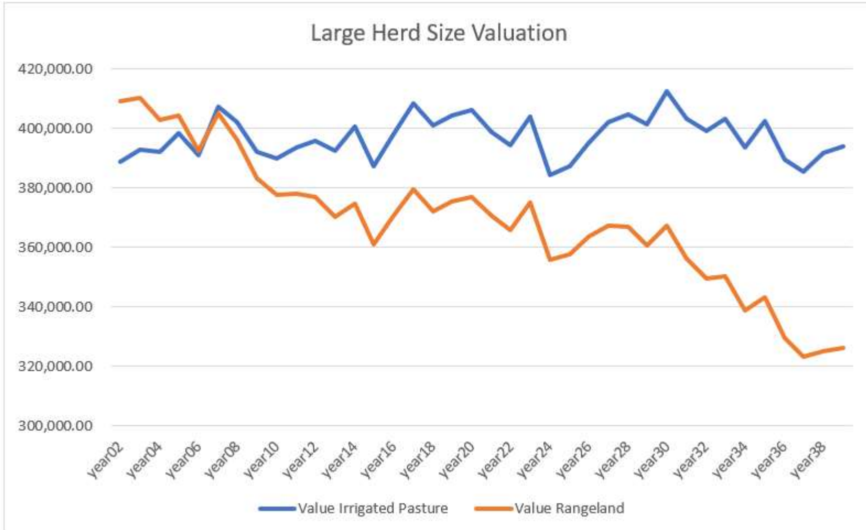
Over the course of a 40-year period on average over the 100 iterations it is not likely a rancher will be able to sustain this 300-head herd size for the time horizon grazing with the non-irrigated rangeland grazing option. Another observation of this study was the large size ranch remains constant with the small model as there is more AUM's used by the irrigated pasture simulation.

When observing the overall maximum profit for each ranching method, is not more than 1 percentage point either way for each scenario. The irrigated pasture scenario maximum profit calculates out to be $695,935.52, and the non-irrigated range scenario maximum profit comes in at $691,234.16. This is a very counter-intuitive observation to most ranchers and could be a very industry-changing outcome. Most ranchers believe the net outcome of using non irrigated rangelands would be much more cost effective, but as it shows it is just as cost effective at this level of operation to graze on privately leased ground.

<u>Herd Valuation</u>

The herd valuation of irrigated pasture grazing comparative to rangeland grazing methods for the large (300 head) sample is significantly higher in irrigated pasture. This is consistent with yield and herd longevity beliefs in the industry.

Figure 4.2 Showing total herd value in respect to price and herd size for Large Irrigated Pasture & Rangeland




The above chart represents a declining herd size in rangeland grazing from Year 2 to Year 39. The average herd size in the irrigated pasture grazing method for the large sample holds relatively constant throughout the whole model, which could be due to the constant availability of grazable land. The rangeland sample decline could be due to lack of AUM's available to graze and environmental conditions decreasing the lifespan of cattle, which would decrease the number of cattle a rancher could have in their herd.

### ***Results Interpretation***

Physical constraints in the experiment were held constant, dealing only with price variation and projection based off the historical data provided. Putting these prices in a consolidated scenario allowed for evaluation of the overall profit maximization directly to the other scenario relative to herd size. The larger herds, intuitively, bring more gross revenue to the rancher as there is more product to sell. But the interior results of the irrigated pasture versus rangeland grazing scenarios were important to evaluate.

Tables 4.3 and 4.4 summarize the net input costs for each simulated sample. The net input cost of the irrigated pasture grazing results in an average of $145.14 per head. The average net input cost of the same ranch operating on non-irrigated rangeland has an average input cost of $142.03 per head. In the smaller operations (150 head) analysis, the irrigated pasture results in an average $214.86 per head and the non-irrigated rangeland results had an average of $204.54 per head cost. With the average per head costs of each grazing type and size evaluated, it can be assumed the total operating cost of the irrigated pasture grazing method will be more costly to the rancher based on this study.

Table 4.3 High/low evaluation for NPV based on herd size, and grazing methodology based on Standard Deviation.

| | SMALL (150 Head) | LARGE (300 Head) |
|---|---|---|
| Irrigated pasture | $524,471 / $518,496 | $703,444 / $688,426 |
| Non-irrigated rangeland | $482,919 / $477,088 | $698,919 / $684,287 |
| Standard Deviation Irrigated Pasture | $2,987 | $7,508 |
| Standard Deviation Rangeland | $2,915 | $6,946 |

Table 4.4 Cost per head analysis based on the four scenario types.

| | SMALL (150 Head) | LARGE (300 Head) |
|---|---|---|
| Irrigated pasture | $214.86/head | $145.14/head |
| Non-irrigated rangeland | $204.54/head | $142.03/head |

The objective function of this portion of the study shows a significant gap in the overall profit comparatively. The irrigated pasture summer grazing impact shows a NPV of $521,483.46, with a $214.86 cost per head, while the non-irrigated rangeland scenario shows a NPV of $480,003.58, with a $145.14 cost per head. This large difference could be from the inherent risks, or the increase in herd size, discussed earlier.

In the large-sized rangeland grazing scenario, even though the longevity of the herd is declining, the value of the ranch operation in the large rangeland grazing scenario is proportionate to the large-irrigated pasture grazing method. This implies each simulation results in a similar level of productivity per head on irrigated pasture as they were on leased rangeland. Though the two scenarios yielded a similar profitability, the rangeland herd was deteriorating in size over the 40 years, which may be due to externalities that could not be captured in the model such as disease, death, predatorial impacts, climate, and yield. The irrigated pasture herd stayed very consistently flat over the course of the study, which also intuitively may be due to the safety factors, better forage availability, and higher yield at the sale barn.

Within the large herd size rangeland and irrigated pasture grazing, observations of the analysis show an operational cost per head analysis. Through an in-depth cost analysis, it was apparent that the net cost per head relative to forage cost and animal costs were within $3.00/head of each other, with a total herd cost of the base impact scenario being $51,349.97 and the impact scenario being $46,582.39. The results also display a net profitability from the four sample sections, resulting in the Large Irrigated scenario being the most profitable and the Small Rangeland sample being the lowest profit potential.

Table 4.5 Reflects the quick analysis of the pertinent costs for each of the analyses in a simplified form.

| | **Forage Cost** | **Animal Cost** | **Total Cost** | **Net Profit** | **Cost per Head** |
|---|---|---|---|---|---|
| **Large Irrigated** | $162,525.96 | $98,552.11 | $261,078.07 | $51,349.97 | $145.14 |
| **Large Rangeland** | $129,120.76 | $79,828.23 | $208,948.99 | $46,582.39 | $142.03 |
| **Small Irrigated Pasture** | $81,089.74 | $28,900.14 | $109,989.88 | $38,207.16 | $214.86 |
| **Small Rangeland** | $72,315.33 | $23,821.95 | $96,137.28 | $35,408.28 | $204.54 |

## ***Cost Per Head Analysis***

Large Herd

When looking at the net cost per head, it might not be clear as to why the costs are so similar. This can be found diving deeper into the individual cost classifications (Forage Cost, Animal Cost, Total Cost) set out for this analysis as well.

Observing the forage cost per head difference, the Irrigated Pasture scenario has a higher cost per head of $459.38 than the rangeland scenario at $393.68, with a difference of $65.70 per head difference. The animal costs, however, are not so intuitive as the animal cost for the base scenario are higher, $278.56 per head, than the impact scenario, $243.39 per head. The potential rationale behind this could be due to transportation costs to the irrigated pasture ground dependent on where the rancher must find adequate pastureland, as well as feed price variability during the seasons where grazing is not available. Having to purchase feed for non-grazing months can be expensive and takes a significant hit to the profitability of the ranching operation.

Small Herd

Conversely, the smaller herd size has a larger variance in the overall net cost per head due to the nature of lower herd size directly correlated with cost. The cost per head variance is significantly larger than the previous sample, making the value of each cow higher. The less inventory you have (i.e., sellable stock), the more risk you take on per unit as herd size fluctuates. The overall impact to the herd from a total production cost basis incurs more risk for the producer, as each cow is more valuable both in revenue and cost. The producer may choose to be more risk-averse in the scenario of hedging against disease, death loss, and overall health of the herd. This could imply the producer, though not presented in this study, may choose to invest more in the herd health by having more cattlemen on the ranch, more frequent veterinary visits, higher quality of feed (if permittable), and increased vaccination monitoring.

The producer in the small herd size scenario appears to be faced with more operationally critical decisions day to day than the large herd producer would be in either grazing scenario. This is important to understand and recognize when recommendations are being provided to ranchers across the herd size board, so the overlying risk factors are considered.

### *Ranching Impacts*

Results from the applied model show over a 40-year time horizon a rancher with a 300-head herd of cattle can be competitive in the market whether they choose to have irrigated pastureland or rangeland to graze. This may affect many smaller ranchers as well because the results despite a preference to the irrigated pasture grazing methods. This could be because the marginal profit per head is higher with a smaller herd size, which does make sense intuitively as there are fewer costs associated.

# Chapter 5: Conclusion

The results of the study conclude there is a difference between grazing on private land versus public land. Both grazing types were profitable on average, and both herd sizes remained viable through the life of the study. This shows when factoring in price variability over 40 years, the ranch, in concept, can be profitable if the rancher operates in a model-based manner. In other words, if the rancher makes operational decisions according to the model assumptions, these figures could be an optimal outcome. Further studies may choose to evaluate the impacts of price shocks to the study, such as the COVID- 19 impact. COVID-19 also played a large part in the decrease in production facilities that remained in operation due to closures, which was a price driving impact as well. Further studies may also choose to evaluate the economic impact of large beef production plants and their closures due to the virus.

## *Future Study Recommendations*

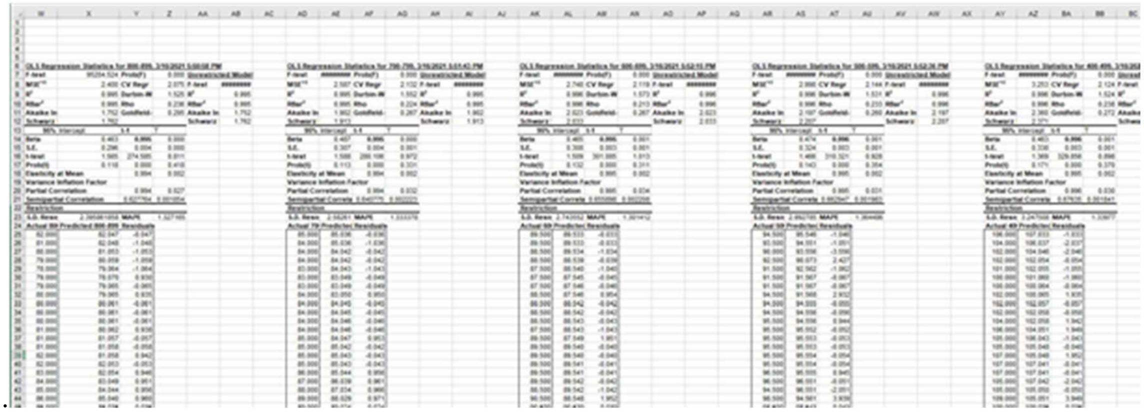
The COVID-19 pandemic played a huge part in a global shock of commodity goods, services, and business ventures. Future studies might consider studying the impact of the COVID-19 economic impacts on cattle ranchers and decide what the shift in producer preference results in relative to price impacts. This would be a beneficial literature contribution due to the consideration that global shocks of this magnitude are an anomaly, and it is imperative to seize the opportunity as economists to evaluate these conditions and how  to advise the ranching community to stay ahead of the curve, and further educate themselves on best practices in these types of scenarios

# Appendix A

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Page | 1 | | | | | | | | | | | | | | |
| 2 | Cattle-Fax | Feeder | Cattle | Cash | Prices | | | | | | | | | | | |
| 3 | IDAHO | Min | 66.00 | 72.00 | 77.50 | 80.00 | 89.00 | 98.00 | 67.00 | 71.50 | 73.50 | 81.00 | 88.00 | 33.50 | 24.00 | 37.50 |
| 4 | | Max | 225.50 | 240.00 | 260.50 | 285.50 | 328.00 | 365.50 | 228.00 | 247.50 | 264.50 | 298.00 | 329.50 | 121.00 | 113.00 | 137.50 |
| 5 | | | | | | | | | | | | | | | | |
| 6 | | Range | 159.50 | 168.00 | 183.00 | 205.50 | 239.00 | 267.50 | 161.00 | 176.00 | 191.00 | 217.00 | 241.50 | 87.50 | 89.00 | 100.00 |
| 7 | | | | | | | | | | | | | | | | |
| 8 | | | Steers | | | | | | Heifers | | | | | Culls | | |
| 9 | | | | | | | | | | | | | | | | |
| 10 | Week | Week Ending | 800-899 | 700-799 | 600-699 | 500-599 | 400-499 | 300-399 | 700-799 | 600-699 | 500-599 | 400-499 | 300-399 | Cow/Util | CanCut | Bulls |
| 11 | | | | | | | | | | | | | | | | |
| 12 | 31 | 4-Aug-00 | 82.00 | 85.00 | 89.50 | 95.50 | 107.00 | 117.00 | 80.00 | 82.50 | 86.50 | 97.00 | 104.00 | 41.00 | 37.00 | 49.50 |
| 13 | 32 | 11-Aug-00 | 82.00 | 85.00 | 89.50 | 94.50 | 106.00 | 116.00 | 81.00 | 83.50 | 86.50 | 96.50 | 104.00 | 42.00 | 38.00 | 50.50 |
| 14 | 33 | 18-Aug-00 | 81.00 | 84.00 | 89.50 | 93.50 | 104.00 | 114.00 | 80.00 | 83.50 | 84.50 | 94.00 | 103.00 | 40.00 | 36.00 | 48.50 |
| 15 | 34 | 25-Aug-00 | 80.00 | 84.00 | 88.50 | 90.00 | 102.00 | 111.00 | 79.00 | 82.50 | 83.50 | 92.00 | 101.00 | 41.00 | 36.00 | 48.50 |
| 16 | 35 | 1-Sep-00 | 79.00 | 84.00 | 88.50 | 92.50 | 102.00 | 111.00 | 78.00 | 81.50 | 83.50 | 91.00 | 98.00 | 41.00 | 35.00 | 47.50 |
| 17 | 36 | 8-Sep-00 | 78.00 | 83.00 | 87.50 | 91.50 | 101.00 | 109.00 | 77.00 | 81.50 | 83.00 | 91.00 | 96.00 | 41.00 | 35.50 | 48.00 |
| 18 | 37 | 15-Sep-00 | 79.00 | 83.00 | 87.50 | 91.50 | 100.00 | 109.00 | 78.00 | 81.50 | 82.50 | 90.00 | 97.00 | 39.00 | 34.00 | 46.50 |
| 19 | 38 | 22-Sep-00 | 79.00 | 83.00 | 87.50 | 91.50 | 100.00 | 109.00 | 78.00 | 81.50 | 82.50 | 90.00 | 97.00 | 38.00 | 34.00 | 46.50 |
| 20 | 39 | 29-Sep-00 | 80.00 | 84.00 | 88.50 | 94.50 | 102.00 | 111.00 | 79.00 | 81.50 | 84.50 | 93.00 | 99.00 | 38.00 | 34.00 | 46.50 |
| 21 | 40 | 6-Oct-00 | 80.00 | 84.00 | 88.50 | 94.50 | 102.00 | 111.00 | 79.00 | 81.50 | 84.50 | 92.00 | 99.00 | 37.00 | 32.00 | 44.50 |
| 22 | 41 | 13-Oct-00 | 80.00 | 84.00 | 88.50 | 94.50 | 102.00 | 112.00 | 79.00 | 81.50 | 84.50 | 92.00 | 99.00 | 37.00 | 31.50 | 46.00 |
| 23 | 42 | 20-Oct-00 | 80.00 | 84.00 | 88.50 | 95.50 | 104.00 | 114.00 | 79.00 | 81.50 | 85.50 | 92.00 | 99.00 | 35.00 | 30.00 | 45.00 |
| 24 | 43 | 27-Oct-00 | 81.00 | 84.00 | 87.50 | 95.50 | 106.00 | 117.00 | 80.00 | 82.50 | 86.50 | 92.00 | 104.00 | 36.50 | 32.00 | 45.00 |
| 25 | 44 | 3-Nov-00 | 81.00 | 85.00 | 89.50 | 95.50 | 105.00 | 117.00 | 81.00 | 83.50 | 86.50 | 93.00 | 103.00 | 36.50 | 32.00 | 45.00 |
| 26 | 45 | 10-Nov-00 | 81.00 | 85.00 | 89.50 | 95.50 | 105.00 | 117.00 | 81.00 | 83.50 | 86.50 | 93.00 | 103.00 | 37.00 | 32.00 | 45.00 |
| 27 | 46 | 17-Nov-00 | 82.00 | 85.00 | 89.50 | 95.50 | 107.00 | 117.00 | 81.00 | 82.50 | 86.50 | 95.00 | 103.00 | 37.00 | 32.00 | 45.00 |
| 28 | 47 | 24-Nov-00 | 82.00 | 85.00 | 89.50 | 95.50 | 107.00 | 117.00 | 81.00 | 82.50 | 86.50 | 95.00 | 103.00 | 37.00 | 32.00 | 45.00 |
| 29 | 48 | 1-Dec-00 | 83.00 | 86.00 | 89.50 | 96.50 | 107.00 | 118.00 | 82.00 | 82.50 | 87.50 | 97.00 | 105.00 | 37.00 | 32.00 | 45.00 |
| 30 | 49 | 8-Dec-00 | 84.00 | 87.00 | 89.50 | 96.50 | 105.00 | 115.00 | 83.00 | 83.50 | 87.50 | 97.00 | 105.00 | 36.00 | 32.00 | 44.00 |
| 31 | 50 | 15-Dec-00 | 85.00 | 88.00 | 88.50 | 94.50 | 105.00 | 115.00 | 84.00 | 83.50 | 87.50 | 97.00 | 105.00 | 38.00 | 32.00 | 45.50 |

Shows the initial data provided by CattleFax.com showing the historical data based pricing simulations from eight class evaluations for price simulation.

# Appendix B



Shows the OLS regression statistics data from the original price simulation work.

# Appendix C

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Simetar Simulation Results for 2,080 Iterations. 8:41:19 AM 4/10/2021 (37 sec.). © 2019. | | | | | | | | | | | | | | |
| 2 | Variable | SYEAR | SCALF | 600 | 500 | 400 | 300 | HYEAR | HCALF | 500 | 400 | 300 | Cow/Util | CanCut | Bulls |
| 3 | Mean | 131.1519 | 145.6607 | 163.6587 | 175.1675 | 192.68 | 207.6927 | 129.1347 | 145.648 | 158.148 | 172.1676 | 189.1763 | 66.68005 | 59.73748 | 81.19453 |
| 4 | StDev | 2.375072 | 2.59966 | 2.7647 | 3.02601 | 3.211228 | 3.501352 | 2.426061 | 2.69597 | 2.752267 | 3.176257 | 3.404972 | 1.9419 | 2.094155 | 2.160201 |
| 5 | CV | 1.810932 | 1.784737 | 1.689308 | 1.727495 | 1.666612 | 1.685833 | 1.878706 | 1.851017 | 1.740311 | 1.844863 | 1.799894 | 2.912264 | 3.505597 | 2.660526 |
| 6 | Min | 122.7911 | 135.0608 | 154.5748 | 164.1191 | 180.2193 | 192.1744 | 120.5691 | 136.7052 | 149.1839 | 161.245 | 177.8445 | 60.93289 | 53.22116 | 73.32734 |
| 7 | Max | 139.7151 | 153.4181 | 172.1492 | 184.8637 | 203.3535 | 220.267 | 137.9978 | 154.7277 | 167.9654 | 182.5745 | 200.6782 | 73.2198 | 67.22069 | 88.58449 |
| 8 | Iteration | SYEAR | SCALF | 600 | 500 | 400 | 300 | HYEAR | HCALF | 500 | 400 | 300 | Cow/Util | CanCut | Bulls |
| 9 | 1 | 130.1923 | 144.1063 | 161.9636 | 171.011 | 188.9003 | 203.5909 | 128.473 | 145.7685 | 158.3577 | 172.8296 | 188.9995 | 66.12743 | 57.87199 | 79.4024 |
| 10 | 2 | 131.9397 | 144.3467 | 163.0896 | 177.6323 | 193.0552 | 207.2696 | 129.7459 | 144.6512 | 162.485 | 173.086 | 189.1668 | 67.85387 | 58.47218 | 83.87524 |
| 11 | 3 | 134.2285 | 149.5662 | 166.9278 | 180.4824 | 197.3867 | 212.0288 | 129.4196 | 143.2732 | 155.6038 | 168.5451 | 188.2539 | 65.97207 | 59.98135 | 82.08671 |
| 12 | 4 | 127.3099 | 143.2896 | 160.2036 | 167.2517 | 185.2359 | 202.9722 | 130.6143 | 145.6278 | 160.4997 | 170.7836 | 186.3635 | 65.87442 | 59.11552 | 79.27062 |
| 13 | 5 | 131.506 | 143.5527 | 163.7507 | 178.3246 | 193.0659 | 206.717 | 129.1707 | 146.107 | 157.3708 | 168.8108 | 187.9603 | 64.63017 | 58.26816 | 83.03313 |
| 14 | 6 | 132.7844 | 146.8193 | 168.5682 | 179.399 | 198.3725 | 214.0083 | 130.1171 | 145.0548 | 157.5133 | 173.2631 | 185.8376 | 70.32464 | 64.556 | 86.35886 |
| 15 | 7 | 134.5726 | 149.1582 | 163.8743 | 175.5152 | 191.2298 | 202.6303 | 128.2214 | 144.1576 | 156.9047 | 170.1881 | 185.1622 | 68.25656 | 57.48536 | 87.00488 |
| 16 | 8 | 131.1633 | 144.883 | 162.5273 | 174.6997 | 189.6783 | 207.8698 | 131.4803 | 149.0663 | 160.9238 | 176.8821 | 197.6829 | 66.68342 | 56.89163 | 78.89963 |
| 17 | 9 | 132.1411 | 146.2658 | 162.9488 | 174.6815 | 190.0132 | 205.2053 | 126.5506 | 141.2963 | 156.8016 | 170.8618 | 186.8722 | 63.91398 | 57.36558 | 78.35329 |
| 18 | 10 | 130.9296 | 146.0613 | 163.6836 | 177.122 | 192.5083 | 208.5076 | 132.6571 | 151.8434 | 161.5361 | 175.4419 | 190.9659 | 68.50035 | 60.79345 | 80.19922 |
| 19 | 11 | 133.3336 | 147.894 | 159.8724 | 173.491 | 194.0212 | 208.3396 | 133.3243 | 148.6896 | 160.0885 | 178.6433 | 193.8212 | 68.4379 | 59.99859 | 86.4934 |
| 20 | 12 | 130.4924 | 146.4413 | 165.6054 | 180.241 | 198.0821 | 209.6546 | 128.1484 | 145.4306 | 157.6476 | 173.8519 | 191.9115 | 68.27114 | 61.08472 | 80.88828 |
| 21 | 13 | 129.728 | 143.9011 | 162.6205 | 170.9016 | 194.5483 | 207.4023 | 128.6724 | 147.6656 | 160.2534 | 175.0216 | 194.5114 | 66.72577 | 59.18139 | 81.75395 |
| 22 | 14 | 132.4468 | 145.8925 | 166.3985 | 176.2981 | 198.3973 | 211.2085 | 129.7087 | 148.3057 | 157.7715 | 170.1972 | 184.9616 | 69.13897 | 60.45211 | 80.30313 |
| 23 | 15 | 130.5704 | 143.3729 | 161.1177 | 171.9859 | 187.4989 | 203.3015 | 129.8975 | 145.9459 | 157.6762 | 174.1633 | 190.9164 | 65.35004 | 61.17867 | 80.17475 |
| 24 | 16 | 131.23 | 147.1542 | 165.5597 | 177.3723 | 194.8713 | 208.9531 | 131.7723 | 147.6394 | 158.2284 | 175.778 | 187.948 | 66.21558 | 56.90141 | 78.10884 |
| 25 | 17 | 128.6601 | 142.7294 | 158.8801 | 170.3952 | 188.4072 | 204.0634 | 127.7619 | 143.2982 | 156.1529 | 171.1651 | 188.7549 | 62.73714 | 55.46543 | 78.9177 |
| 26 | 18 | 128.5362 | 142.801 | 165.6236 | 176.0298 | 193.2592 | 213.1017 | 126.7695 | 142.8691 | 155.7844 | 168.3492 | 187.7392 | 64.75005 | 59.34077 | 82.45203 |
| 27 | 19 | 131.1746 | 146.0733 | 164.5991 | 175.9323 | 195.3903 | 210.1188 | 132.0655 | 148.3155 | 161.798 | 175.8573 | 192.0437 | 62.52466 | 57.01643 | 77.44466 |
| 28 | 20 | 128.0524 | 142.4091 | 159.5497 | 171.75 | 187.9468 | 206.1235 | 122.7937 | 139.5619 | 152.742 | 165.997 | 182.4652 | 66.27663 | 58.86645 | 81.8155 |
| 29 | 21 | 127.6688 | 142.996 | 160.3514 | 173.2654 | 190.698 | 205.314 | 125.2408 | 142.3269 | 157.3425 | 174.0878 | 194.5881 | 64.96138 | 57.10742 | 80.23125 |
| 30 | 22 | 129.1684 | 144.6009 | 162.492 | 174.5031 | 193.8411 | 207.9354 | 127.3513 | 144.9326 | 156.9204 | 170.0676 | 186.1938 | 69.27463 | 62.91172 | 81.33881 |
| 31 | 23 | 130.856 | 145.2597 | 161.9374 | 173.1712 | 191.6946 | 205.74 | 125.5065 | 142.013 | 155.4459 | 165.5948 | 184.1841 | 66.56471 | 58.92553 | 81.31904 |
| 32 | 24 | 132.9465 | 148.8883 | 161.8049 | 175.7484 | 193.9141 | 205.949 | 124.4486 | 141.9465 | 155.6259 | 169.7642 | 184.5632 | 67.25685 | 59.00594 | 82.82121 |
| 33 | 25 | 133.2479 | 146.2297 | 164.2511 | 175.0832 | 191.9163 | 204.9994 | 132.8444 | 151.6532 | 166.8777 | 181.1468 | 195.3068 | 66.46173 | 57.87103 | 80.30936 |
| 34 | 26 | 133.4897 | 148.3755 | 166.2687 | 177.6637 | 197.0874 | 213.4526 | 130.5674 | 149.0783 | 160.1299 | 173.101 | 191.8816 | 66.43537 | 60.15014 | 85.41139 |
| 35 | 27 | 122.8863 | 135.0608 | 154.5748 | 165.6843 | 183.944 | 198.7942 | 127.4677 | 147.4128 | 157.9456 | 171.7751 | 185.7684 | 66.28456 | 58.66381 | 79.84656 |

... MASTER.EXPORT ITER001 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Shows a partial view of the OLS regression statistics data compiled by iteration with summary statistics to provide a check for consistency and accuracy of the OLS regression runs.

# Appendix D

| | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | |
| 2 | | MAX | 153.4181 | 154.7277 | 70.02322 | 88.58449 | 153.8426 | 135.6156 | 139.7151 | 137.9978 | 1913.894 | |
| 3 | | MIN | 135.0608 | 136.7052 | 57.07703 | 73.32734 | 138.2198 | 122.5569 | 122.7911 | 120.5691 | 124.494 | |
| 4 | | SD | 2.59966 | 2.69597 | 1.918326 | 2.160201 | 2.084158 | 1.911181 | 2.375072 | 2.426061 | 260.9515 | |
| 5 | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | |
| 7 | ITER | Week | SCALF | HCALF | CULLCOW | BULL | PURSCALI | PURHCALI | SYEAR | HYEAR | BUYBCOW | |
| 8 | ITER001 | 1 | 144.1063 | 145.7685 | 61.99971 | 79.4024 | 146.3451 | 129.8401 | 130.1923 | 128.473 | 1158.183 | 1 |
| 9 | ITER001 | 2 | 144.3467 | 144.6512 | 63.16302 | 83.87524 | 146.1758 | 131.1411 | 131.9397 | 129.7459 | 1302.18 | 2 |
| 10 | ITER001 | 3 | 149.5662 | 143.2732 | 62.97671 | 82.08671 | 145.5869 | 131.1221 | 134.2285 | 129.4196 | 1075.619 | 3 |
| 11 | ITER001 | 4 | 143.2896 | 145.6278 | 62.49497 | 79.27062 | 145.6144 | 129.6821 | 127.3099 | 130.6143 | 677.7436 | 4 |
| 12 | ITER001 | 5 | 143.5527 | 146.107 | 61.44917 | 83.03313 | 144.5911 | 128.7855 | 131.506 | 129.1707 | 972.2618 | 5 |
| 13 | ITER001 | 6 | 146.8193 | 145.0548 | 67.44032 | 86.35886 | 146.0683 | 129.8706 | 132.7844 | 130.1171 | 1427.747 | 6 |
| 14 | ITER001 | 7 | 149.1582 | 144.1576 | 62.87096 | 87.00488 | 149.0747 | 129.6278 | 134.5726 | 128.2214 | 1645.866 | 7 |
| 15 | ITER001 | 8 | 144.883 | 149.0663 | 61.78753 | 78.89963 | 146.0628 | 128.1548 | 131.1633 | 131.4803 | 1870.02 | 8 |
| 16 | ITER001 | 9 | 146.2658 | 141.2963 | 60.63978 | 78.35329 | 143.7778 | 127.9728 | 132.1411 | 126.5506 | 1527.314 | 9 |
| 17 | ITER001 | 10 | 146.0613 | 151.8434 | 64.6469 | 80.19922 | 147.0885 | 128.2483 | 130.9296 | 132.6571 | 1338.484 | 10 |
| 18 | ITER001 | 11 | 147.894 | 148.6896 | 64.21824 | 86.4934 | 149.5556 | 135.6156 | 133.3336 | 133.3243 | 1309.206 | 11 |
| 19 | ITER001 | 12 | 146.4413 | 145.4306 | 64.67793 | 80.88828 | 145.4993 | 128.3426 | 130.4924 | 128.1484 | 1351.631 | 12 |
| 20 | ITER001 | 13 | 143.9011 | 147.6656 | 62.95358 | 81.75395 | 144.3981 | 129.2939 | 129.728 | 128.6724 | 1287.17 | 13 |
| 21 | ITER001 | 14 | 145.8925 | 148.3057 | 64.79554 | 80.30313 | 144.8176 | 128.7569 | 132.4468 | 129.7087 | 1299.468 | 14 |
| 22 | ITER001 | 15 | 143.3729 | 145.9459 | 63.26436 | 80.17475 | 145.5507 | 129.2944 | 130.5704 | 129.8975 | 634.0544 | 15 |
| 23 | ITER001 | 16 | 147.1542 | 147.6394 | 61.55849 | 78.10884 | 146.1635 | 128.455 | 131.23 | 131.7723 | 1247.217 | 16 |
| 24 | ITER001 | 17 | 142.7294 | 143.2982 | 59.10129 | 78.9177 | 151.3984 | 133.3206 | 128.6601 | 127.7619 | 1381.291 | 17 |
| 25 | ITER001 | 18 | 142.801 | 142.8691 | 62.04541 | 82.45203 | 146.7254 | 130.2346 | 128.5362 | 126.7695 | 1260.996 | 18 |
| 26 | ITER001 | 19 | 146.0733 | 148.3155 | 59.77055 | 77.44466 | 145.9705 | 130.0812 | 131.1746 | 132.0655 | 1326.622 | 19 |
| 27 | ITER001 | 20 | 142.4091 | 139.5619 | 62.57154 | 81.8155 | 147.7731 | 131.2716 | 128.0524 | 122.7937 | 1598.289 | 20 |
| 28 | ITER001 | 21 | 142.996 | 142.3269 | 61.0344 | 80.23125 | 144.55 | 130.1337 | 127.6688 | 125.2408 | 1888.548 | 21 |
| 29 | ITER001 | 22 | 144.6009 | 144.9326 | 66.09317 | 81.33881 | 147.276 | 129.1953 | 129.1684 | 127.3513 | 1496.903 | 22 |
| 30 | ITER001 | 23 | 145.2597 | 142.013 | 62.74512 | 81.31904 | 146.0317 | 129.8303 | 130.856 | 125.5065 | 1371.074 | 23 |

... MASTER.EXPORT | ITER002 | ITER001 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16

Shows the first compiled iteration of pre-aggregated data into correct weight buckets, this is a key component of the data export preparation process.

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