2015

An Economic Analysis of High-Intensity, Short-Duration Grazing Systems in South Dakota and Nebraska

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AN ECONOMIC ANALYSIS OF HIGH-INTENSITY, SHORT-DURATION GRAZING SYSTEMS IN SOUTH DAKOTA AND NEBRASKA

By

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A thesis submitted in partial fulfillment of the requirements for the

Master of Science

Major in Economics

South Dakota State University

2015

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This thesis is approved as a creditable and independent investigation by a candidate for the Masters of Science degree and is acceptable for meeting the thesis requirements for the degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Major Advisor Date

Head, Economics Date

Dean, Graduate School Date

ACKNOWLEDGMENTS

First, I wish to thank Dr. Larry Janssen, my thesis advisor. Dr. Janssen's guidance was a key factor in the completion of not only this thesis, but my course work as well. I would like to thank Dr. Michael Miller and Dr. Matthew Diersen, the other members of my thesis committee, for advice and the opportunity to learn from them. I would also like to thank my fellow graduate students for support through my studies. I also thank Dr. Timothy Meyer, as he provided me with a vast amount of useful knowledge throughout my academic career. A huge thank-you also to Dr. Matt Stockton and other members of the UNL extension research for providing me with data and advice.

Finally, I would like to thank my parents and my family. Your support gave me not only the opportunity, but also the confidence to make it through this program. As the family motto says, "Uva Uvam Vivendo Varia Fit"

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ABSTRACT

AN ECONOMIC ANALYSIS OF HIGH-INTENSITY, SHORT-DURATION GRAZING SYSTEMS IN SOUTH DAKOTA AND NEBRASKA

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Four different grazing systems: two rotational, a continuous, and a high-intensity, short-duration (mob) system, replicated twice, were evaluated from an economic perspective. Mob grazing is defined as a system having very high stocking rates for a small amount of time. Livestock are forced to eat or trample the vegetation. Stocking rates and average daily gains (ADG) were collected from the UNL Barta Brothers ranch near Rose, Nebraska. The study started in 2011 and lasted until 2014. Using the performance data and other cost data relevant to South Dakota and Nebraska, budgets were set up for each system and extrapolated to a quarter section (160) of rangeland.

Profitability of each system, which was measured as returns to labor and management, was found for each replication. Next, Simetar© was used to determine the risk in each system and rank the systems according to risk preferences. These risk preferences were used to find a risk premium, the amount a producer would need to be indifferent between two systems. Finally, a sensitivity analysis ranked each system against a baseline when the system experiences decreases in cattle performance.

Some important results are as follows: 1) the rotational grazing system in which cattle pass through each paddock twice (4-PR-2) had the highest returns to labor and management, 2) the mob grazing system was the least preferred system per acre when risk was not considered, 3) when risk aversion increases, mob grazing becomes the third

preferred system per acre, 4) a risk neutral producer would need a risk premium of $22.92-$79.84 per animal or $32.43-$132.96 an acre to switch to mob grazing, 5) if ADG decreases by 5% from the baseline system (4-PR-2) the continuous system is the most preferred system per animal and per acre.

An implication of this study is that even though mob grazing was the least profitable system the potential for profitability was present. The system 4-PR-2, which had the next highest number of moves, had the greatest returns to labor and management. Therefore, a mob system could be profitable with adjustments to maintain animal performance.

Chapter I

Introduction

Economic and biological feasibility have long determined which type of grazing systems producers would use. Different grazing systems have been implemented in pasture settings in order to improve cattle or plant performance. Greater efforts to improve performance have been focused on cattle consumption efficiency, as feed costs represent nearly 65% of the cost associated with beef production (USDA, 2011). Of the total feed cost, pasture comprises the highest percentage of cost (Lawrence, 1999).

Rotational grazing is one way to gain efficiency in pasture systems. In order to establish a rotational grazing system, a producer must divide a pasture into smaller parcels referred to as paddocks. The division of the pastures allows for only certain parts of the pasture to be grazed at a time. The other paddocks are in a rest period. The rest period gives the forage in these paddocks time to recover. Rotational grazing is most successful when cattle movement between paddocks coincides with plant growth cycles. Rotational grazing systems vary by two main components: (1) the stocking rate of animals or intensity and (2) the duration that the animals are in a particular paddock (Undersander, 2002). High-intensity, short-duration grazing, referred to as mob grazing, is a very concentrated rotational grazing system.

Mr. Chad Peterson, who has been using mob grazing[1] since 2002, described mob grazing as a "buffet effect". The system works like the Pizza Hut buffet. You are full and do not think you need to eat anymore. However, you see the waitress bring out a fresh pizza. Someone at the table will decide he is not completely full yet and get up to go get

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[1] Throughout this paper the terms mob grazing and high intensity, short duration grazing will be used interchangeably. The terms are referring to the same type of grazing system.

another slice of pizza. Soon others at the table follow. Mob grazing systems works in a similar fashion, as the cattle will follow each other in order to get the best grazing first. Therefore, the cattle will still eat even if they sense they are too full (Peterson, 2013).

The purpose of this study is to examine the bio-economic impacts of high-intensity, short-duration grazing. The primary focus of the research will be to determine whether high-intensity, short-duration grazing is a profitable and viable system for producers to implement into their operations. Furthermore, the research will examine the amount of risk a producer would incur by switching to a high-intensity, short-duration grazing system. The amount of risk incurred will be used to determine how much of a risk premium a producer would have to receive to be indifferent between mob grazing and selected other grazing systems. Finally, the empirical data will be used to set up sensitivity analysis. This analysis will give insights into how much animal performance can be affected to make the system still competitive with the base line system.

Problem Identification

Allan Savory, a native of Zambia, Africa, first introduced high-intensity, short-duration grazing in the early 1980s. Savory had the opportunity to study ecology in Rhodesia, Africa (present day Zimbabwe). Few humans were living in this part of rural Africa at the time. However, the land was able to sustain enormous wildlife herds. He saw no problems with overgrazing in these areas. Through these observations, he realized how important hoof impact, feces, and urine were to the health of grasslands. When observing livestock operations, he concluded that they were being understocked and overgrazed. This translates into grasslands not having enough physical impact from livestock, while having grasses being overharvested (Savory & Parsons, 1980)

Producers plan the grazing scheme that the animals will follow. If the producer plans the system correctly, Savory claims, the system will reverse desertification (Nierenberg, 2014). The distinction between Savory's system and other grazing practices is that in traditional grazing systems some plants will be over grazed and other plants will be under grazed; this imbalance is where the negative changes occur (Nierenberg, 2014). According to Savory, if his system is implemented properly, the following desirable characteristics would occur: improved water infiltration in the soil, increased mineral cycling, a reduction in the number of ungrazed plants, more uniform use of the rangeland, an increase in the period when actively growing forage is available for livestock, and accelerated plant succession (Holechek, et al., 2000).

These benefits cannot be verified since scientific and economic research of mob grazing in the state of South Dakota and the surrounding areas has been very limited. Studies have tended to focus on less intensive, short-duration grazing schemes. These schemes have had lower stocking densities or longer grazing durations than the mob grazing systems. The glossary has more precise definitions of grazing terms.

Since mob grazing has received little economic research in the state, the claims by producers cannot be verified. The increased profitability that some producers are attributing solely to mob grazing may not satisfy the assumption of ceteris paribus. Mr. Pat Guptill explained that before he switched to mob grazing, his profitability per acre was approximately $12.50 per acre. Once he switched to mob grazing, his profitability increased to $50.00 an acre (Guptill, 2013). Producers are well aware of their accounting profitability, but they may be less aware of their actual economic profitability.

Economic profits will help to determine the feasibility of the mob grazing system. Wilson et al. (1987) found that in Arizona, the profitability of the mob grazing system only increased if there was a simultaneous increase in range, livestock, and business management practices. The long run profitability of mob grazing is highly dependent on livestock productivity because livestock performance has a higher impact on profits than either stocking rates or infrastructure costs. However, as infrastructure costs increase, the profitability of the system tends to decrease. On the other hand, as stocking rates increase, the profitability of the system tends to increase. Overall, Wilson found mob grazing systems to be profitable for producers.

Manley et al. (1997) found that profitability of the mob grazing system in Wyoming was very dependent on cattle prices. In years of good prices, producers could increase the profitability by implementing a mob grazing system. However, the high stocking densities did cause damage to the plant communities. Therefore, high stocking densities were not sustainable. Less desirable plants (shrubs mostly) started to take over the area after consistent high stocking densities. Since shrubs are less palatable than other grasses, the productivity of the area, as well as the profits, decreased. Occasional high stocking densities were discovered to leave the plant community unaffected and could be successfully implemented into the ranch's management practices (Manley et al., 1997).

Gillespie et al. (2008) found that the added labor cost per acre rendered all rotational grazing systems less profitable than a continuous grazing system along the Gulf Coast. The increased labor cost could be offset by potential benefits to the environment. The study also found the fixed costs per acre were higher for a high stocking density rotational grazing system. Producers had to invest more in the initial infrastructure in order to operate a high stocking density system (Gillespie, et al., 2008).

Research Objectives

The general objective of this study is to use empirical data to analyze the profitability of different grazing systems. Four grazing systems will be examined in this study: a continuous grazing system (CONT), a mob grazing system (MOB), a four pasture one-time grazing during the season (4-PR-1), and a four-pasture system two times grazing throughout the season (4-PR-2). Grazing system budgets will be used to estimate the returns to labor and management for each grazing system. The stochastic simulation program Simetar© will then be used to simulate risk with each system.

The risk involved with the mob system will give insights on how responsive producers will be to adopting a mob grazing system into their operations, if the system is profitable. If the biological and ecological benefits can be verified to be correct, a mob grazing system that is less profitable may be preferred due to these other benefits. Simetar© will be used to determine the risk premium, which is the amount a producer would have to receive to be indifferent among different grazing systems. Finally, a sensitivity analysis will be conducted to see how decreases in animal performance affect the systems relative to the baseline system.

Specific agenda:

1. Analyze the profitability of mob grazing and other traditional grazing systems in Nebraska and South Dakota from 2011-2014.
2. Determine the added risk, if any, when management adopts mob grazing.

3. Determine the amount of risk premium producers would need to be indifferent between mob grazing and other grazing systems.
4. Determine how sensitive the profitability of mob grazing is when animal performance changes.

Justification

This research will be used to provide local cattle producers with economic information on the different management systems that they could potentially implement into their own operations. In recent years, land conversion has been detrimental to livestock producers' supply of pasture and range. Increases in profitability would allow acres still in range or pasture to be more competitive to row crops and to the threat of conversion. This research will also expose producers to information that may be needed make the system more profitable. For example, the amount of initial infrastructure invested into the project will have an effect on the profitability. The ability to know an approximate amount of infrastructure to invest in will be an important decision-making tool for producers.

There are five chapters following this one. Chapter Two is a literature review, composed of two major sections, a formal and informal review section. The formal section focuses on what previous literature suggests about different grazing systems, stocking rates, and mob grazing. The second section has an informal literature review, which contains first-hand testimonies from South Dakota and Nebraska producers who are using mob grazing. Chapter Three consists of data formulation and analysis. This chapter gives insights to specific data and methods used in the analysis. Chapter Four is a discussion of the empirical results found through the analysis. Chapter Five contains the discussion related to the stochastic element of the study along with the sensitivity analysis. Finally, Chapter Six is a summary of the thesis, recommendations, and limitations of the study.

Chapter II: Literature Review & Producer Testimonies

This chapter will be split into two major sections. The first section is a formal literature review. It includes reviews of works from many different peer-reviewed journals in topics such as Agriculture Economics, Agronomy, Animal Science, and Ecology. The debate on the proper grazing system starts out the section, followed by a literature review of stocking densities and grazing pressure. This section ends with a more in-depth investigation of mob grazing. The final section of this chapter is an informal literature review, consisting of producers' testimonies and personal perspectives on how mob grazing has positively affected their operations. Since each operation is different, the informal review will also showcase the different ways producers use mob grazing. Although these producers' statements have not been externally verified, producers believe they are correct.

Grazing Systems Debates

Debates on the benefits of each grazing systems have been fierce. Briske et al. (2008) did a formal literature review of many different rotational grazing versus continuous grazing studies. Most of the studies were in U.S. locations, primarily in the Great Plains and Westerns states. Additional studies were from Alberta, Canada and South Africa. See Table 2-1 for further information on studies reviewed. In the review, Briske et al. (2008) found that in 35 of 38 major studies, animal production per head was equal or higher in continuous grazing when compared to rotational grazing. Similarly, animal production per area (acre/hectare) was equal or higher for continuous grazing in 27 of 32 different studies. The linkage Briske et al. (2008) emphasized was, competing ecological variables are constrained by management styles and not by grazing systems.

Table 2-1: Grazing Studies Featured in Briske et al. 2008

Study	Year	Location	Length (years)	Livestock Production per animal	Livestock Production per land area
1) Stocking rates are equal for continuous and rotational grazing					
McCollum et al.	1999	Oklahoma	5	CG > RG	CG > RG
Owensby et al.	1973	Kansas	17	CG > RG	CG > RG
Kothmann et al.	1971	Texas	8	CG < RG	CG < RG
Merrill	1954	Texas	4	CG = RG	CG = RG
Fisher and Marion	1951	Texas	8	CG = RG	CG = RG
Mcllvain and Savage	1951	Oklahoma	9	CG = RG	CG = RG
Manley et al.	1997	Wyoming	13	CG = RG	CG = RG
Hart et al.	1993	Wyoming	5	CG = RG	CG = RG
Hepworth et al.	1991	Wyoming	4	CG = RG	CG = RG
Hart et al.	1988	Wyoming	6	CG = RG	CG = RG
Rogler	1951	North Dakota	25	CG < RG	CG < RG
Derner and Hart	2007b	Colorado	9	CG = RG	CG = RG
Smoliak	1960	Alberta, CAN	9	CG > RG	CG > RG
Hubbard	1951	Alberta, CAN	6	CG = RG	CG = RG
Laycock and Conrad	1981	Utah	7	CG = RG	CG = RG
Hyder and Sawyer	1951	Oregon	11	CG > RG	CG > RG
Holechek et al.	1987	Oregon	5	CG = RG	CG = RG
Murray & Klemmedon	1968	Idaho	3	CG = RG	CG = RG
Winder and Beck	1990	New Mexico	17	CG = RG	CG = RG
Gutman et al.	1990	Israel	2	CG > RG	CG > RG
Gutman and Seligman	1979	Israel	10	CG = RG	CG = RG
Ratliff	1986	California	8	CG > RG	CG > RG
Heady	1961	California	5	CG > RG	CG > RG
Barnes and Denny	1991	Zimbabwe	6	CG = RG	CG = RG
Fourie and Engels	1986	South Africa	4	CG > RG	CG > RG
Kreuter et al.	1984	South Africa	3	CG > RG	CG > RG
Walker and Scott	1968	Tanzania	2	CG > RG	CG > RG
Bogdan and Kidner	1967	Kenya	5	CG = RG	CG = RG
2) Higher stocking rates for rotational grazing					
Heitschmidt et al.	1982a	Texas	2	CG = RG	CG < RG
Heitschmidt et al.	1982b	Texas	19	CG = RG	CG < RG
Volesky et al.	1990	South Dakota	2	CG > RG	CG < RG
Pitts and Bryant	1987	Texas	4	CG = RG	CG = RG
Anderson	1988	New Mexico	2	CG > RG	CG > RG

Source: Briske, et al., 2008 CG=Continuous grazing system

Review by: Bronc McMurtry RG=Rotational grazing system

In 2011, Briske et al. explained further why the benefits of a rotational grazing system may not come from the system, but rather from a change in the management style. When grazing system experiments are conducted: strict protocols must be followed to determine whether benefits are actually coming from a change in grazing systems. Briske et al. (2011) found that during grazing experiments, researchers have tendencies to change protocols due to events such as drought conditions. When these protocols are disrupted, changes to the ecology of an area can no longer be attributed to only a change in grazing system, but also in part to management (Briske et al., 2011).

Therefore, management changes associated with grazing systems can indirectly impact the ecology of an area either negatively or positively. When studying the effects of management skills and rotational grazing in north central Texas, Briske et al. (2011) found unconvincing results. Areas of high productivity had increases of plant production by 8.5% and increases in ground cover by 27%. However, in the less productive areas of the pastures, no changes were evident. Furthermore, the changes in plant productivity did not translate into any changes in livestock productivity (Briske et al., 2011).

Briske et al. (2011) had the final conclusion that a change in a grazing system may not be enough to achieve certain ecological effects desired by managers. Management changes must also occur. These changes in management follow a learning curve. Therefore, no ecological changes may be evident until management has learned to properly set up and monitor the system (2011).

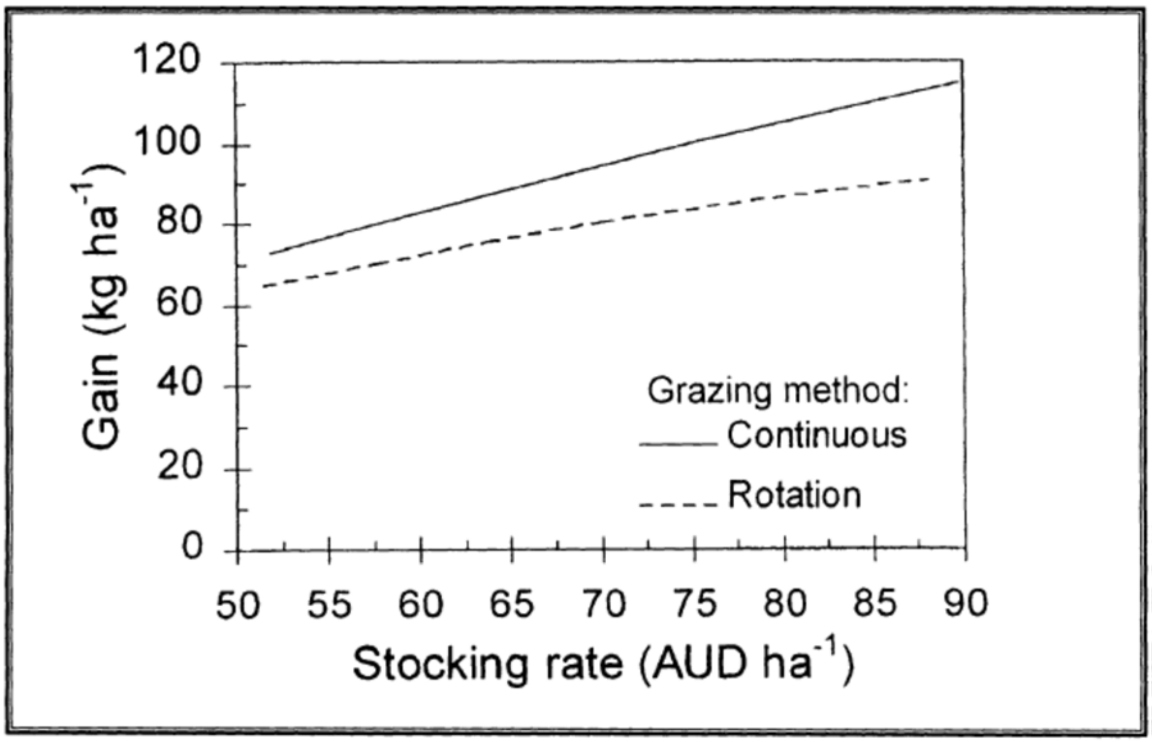
From 1982 to 1994, Manley et al. studied three different grazing systems (continuous, 4-pasture deferred, and 8-paddock time-controlled rotation) northwest of Cheyenne, Wyoming (1997). Each rotation had two replications with a moderate and heavy stocking density. The continuous grazing system also had a light stocking density. Different stocking rates were used to help determine the optimal system. Yearling steers were the livestock used in the study. Manley et al. (1997) found that consistent heavy stocking rates had a negative impact on favorable plant varieties. Less desirable plants would replace more favorable plants. Since the palatability of these plants is lower, animal rates of gain would be affected. When comparing specific systems in times of both favorable and unfavorable prices, continuous grazing systems were the most favorable. Total gain per hectare in good price scenarios for continuous grazing was 51 kilograms per hectare. This translated into returns to management and labor of $37.58 per hectare. Total gain per hectare was 45.2 and 43.6 kg/ha for deferred rotation and time-controlled grazing, respectively. Returns to labor and management per hectare were $33.90 for deferred rotational grazing and $29.82 for time-controlled grazing (Manley et al., 1997).

Manley et al. (1997) suggests that extensive cross fencing and water development are important if producers wish to have a more uniform utilization of forage, also it could lead to the minimization of energy costs for grazing animals. However, the cost of the development could cause the system to become more unfavorable. The optimal situation for cross fencing and water development would be in the subdivision of thousands of hectares, with both improvements done simultaneously. Furthermore, Manley et al. (1997) found that the benefits other studies contributed to rotational grazing were a function of increased management and not the type of system used.

McCollum III et al. (1999) found continuous grazing systems to be superior to rotational grazing systems in north central Oklahoma for yearling beef cattle. In this

Oklahoma study, as stocking rates increased, total beef production per hectare increased at a faster rate than the decrease in animal performance per hectare. Stocking rates were measured in animal unit days (AUD). This was true for both rotational and continuous systems. Because rotational grazing has greater costs and lower gains per hectare, the system would have lower returns if implemented (McCollum III et al., 1999)

Figure 2-1: North Central Oklahoma Continuous vs Rotational Grazing Study



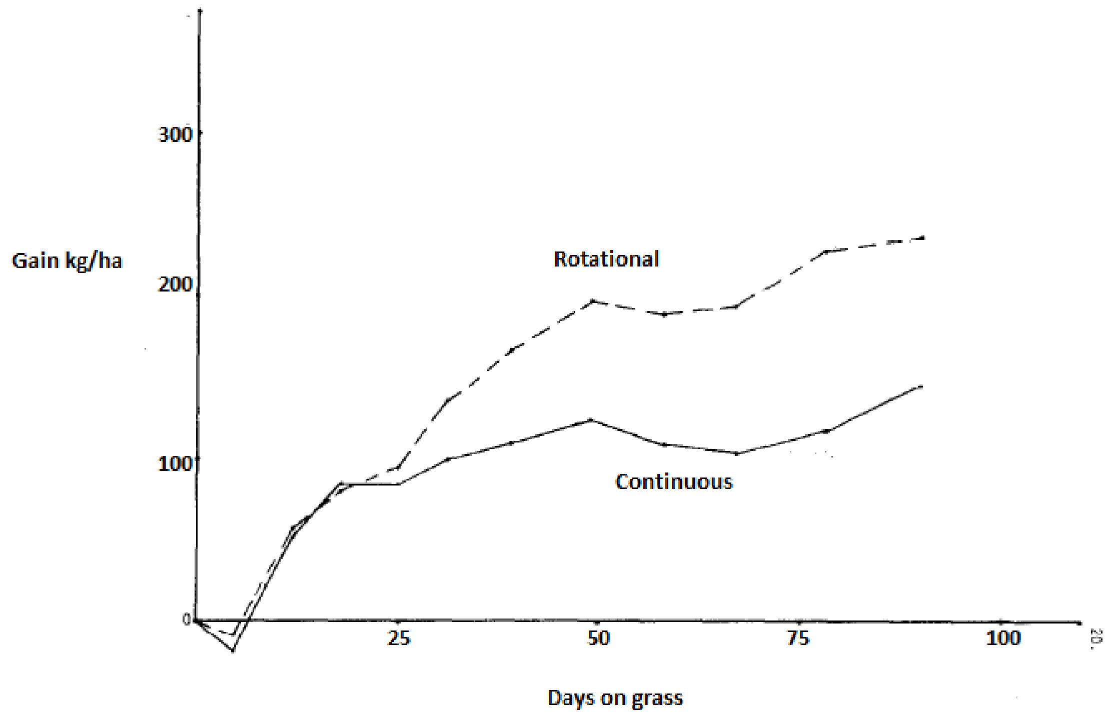
Source: (McCollum, et al., 1999)

The problem with scientific research of grazing systems is one of scale, according to Teague et al. (2008) and Norton (1998). In most grazing studies, the research is performed on a relatively small area of land, 25 hectares or less, and the numbers of animals used in the studies are small. Therefore, these studies cannot properly represent a commercial ranch. On a typical ranch that uses continuous grazing systems, livestock would experience many different types of terrain and plant communities. Also, the access to water may not be immediate. Small scale replications of grazing systems fail to capture these phenomena that influence animal performance. Animals in the small scale system would be able to cover an entire paddock in just one day. On a typical ranch, some areas would be over-grazed while other areas may not be grazed at all. Rotational grazing systems minimize these problems and help to control animal performance (Teague et al., 2008).

In a small scale continuous versus rotational grazing experiment in central Alberta, Walton et al. (1981) found rotational grazing was superior to continuous grazing. In the short 4-year study, there was a noticeable difference in the rate of gain per animal and per hectare between the two systems. Rotational grazing animals had an average daily gain of 1.23, 1.18, 1.13, and 0.82 kilograms per year, respectively. Continuous grazing animals had an average daily gain of 1.36, 0.73, 0.86, and 0.68 kilograms per year, respectively. In the rotational system, the animals were moved through the system two and a half times. Walton et al. (1981) found that the forage in the rotational system was more nutritious and had a higher palatability starting in year two. Therefore, as the growing season progressed, the forage quality was maintained longer in the rotational grazing system. The rate of gain per animal was greater for rotational grazing than for continuous grazing as the growing season progressed (Walton et al., 1981) (Figure 2-2).

The rotational grazing system had a higher cost associated with it compared to the continuous system. The added material and labor costs for the rotational system was between $67 and $135 per hectare (Walton et al., 1981). Since the rotational system had a higher rate of gain per hectare, these added costs were recouped after the second year of the system.

Figure 2-2: Rate of Gain per Hectare: Continuous vs Rotational Grazing Systems in Alberta, Canada



Source: Walton et al., 1981

In the flooding pampas of Argentina, Jacob et al. (2006) found that through rotation grazing systems producers were able to increase stocking rates by 30 percent. Increased stocking rates were accomplished because of increases in the quantity of higher quality forages from using rotational grazing. Conception rates and weaning rates were constant, even with the implementation of higher stocking rates. Finally, higher quality forages and higher stocking rates translated into increases in livestock production. By switching grazing systems, average kilograms gained per hectare increased from 66.4 to 105.2 (Jacob et al., 2006).

One of the earliest studies comparing grazing systems was in Mandan, North Dakota. The study was divided into two major parts. The first 17 years of the study, 1918-1934, used two year old steers as test subjects. There were three different grazing systems, according to Rogler (1951). The first system was a deferred rotational grazing system at a heavy stocking rate. Systems two and three were continuous grazing systems. One system had a heavy stocking rate, while the other had a moderate stocking rate. Steers on the rotational grazing system outperformed steers on the heavy continuous grazing system by an average of 34.8 pounds per head. However, steers on the moderate continuous grazing system outperformed the steers on the rotational grazing system by 44.5 pounds per head. Throughout this part of the study, land degradation was only present for the heavy continuous system (Rogler, 1951)

In the last 8 years of the study, yearling steers were used as test subjects. The yearling steers on both continuous systems gained more than the steers on the rotational grazing system. Moderate continuous grazing steers gained 28.8 pounds per head more than rotationally grazed steers, while heavily stocked continuous steers gained 20 pounds more per head than the steers on the rotational system. One important insight from the study is how the older animals performed better in rotational grazing systems than their younger counterparts when compared to the heavy stocked continuous system. Since the animals were older, they were more mature and their ability to utilize poor quality forage in late summer was better. Rotational grazing systems may show more benefits to older cattle than younger cattle (Rogler 1951).

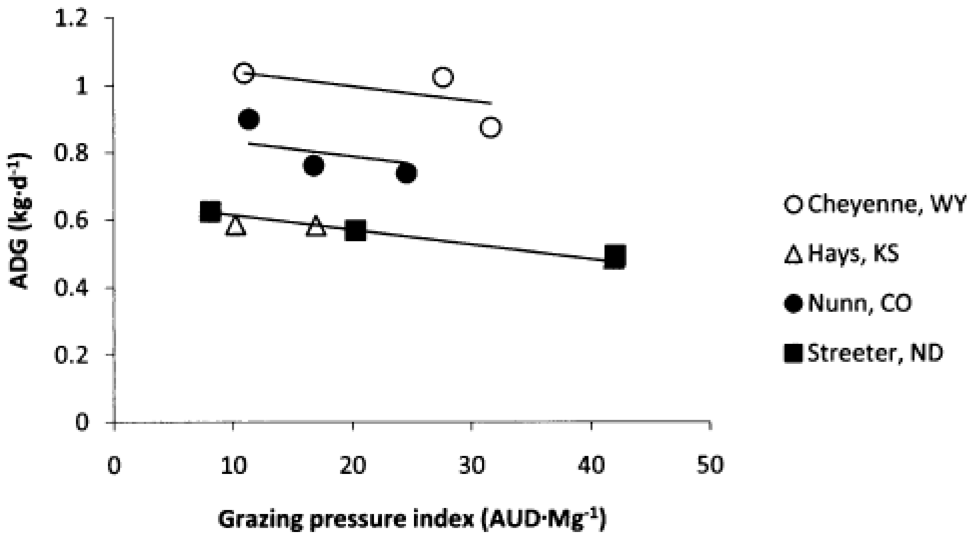
Stocking Rates and Grazing Pressures

Smart et al. (2010) reviewed previous grazing studies from Cheyenne, WY; Cottonwood, SD; Hays, KS; Nunn, CO; Streeter, ND; and Woodward, OK. The variables focused in the studies reviewed were grazing pressure index, harvest efficiency, utilization, grazing efficiency, average daily gain (ADG), and gain per hectare. Smart et al. (2010) found that harvest efficiency increases when the grazing pressure index also increases. Another important finding in this study was that utilization and the grazing pressure index share a quadratic relationship. This means that the utilization increases at a decreasing rate as grazing pressure increases. Grazing efficiency and grazing pressure followed a linear relationship (Smart et al., 2010).

The grazing pressure index was set up using stocking rates divided by peak standing crop (PSC). Stocking rate is defined as the relationship between the number of animals in a paddock over a particular time interval, and PSC is the total forage weight per paddock within the same time frame (Smart et al., 2010). By setting up the grazing pressure index, they were able to standardize systems and allow comparisons of systems with different climate, soil, and plant factors.

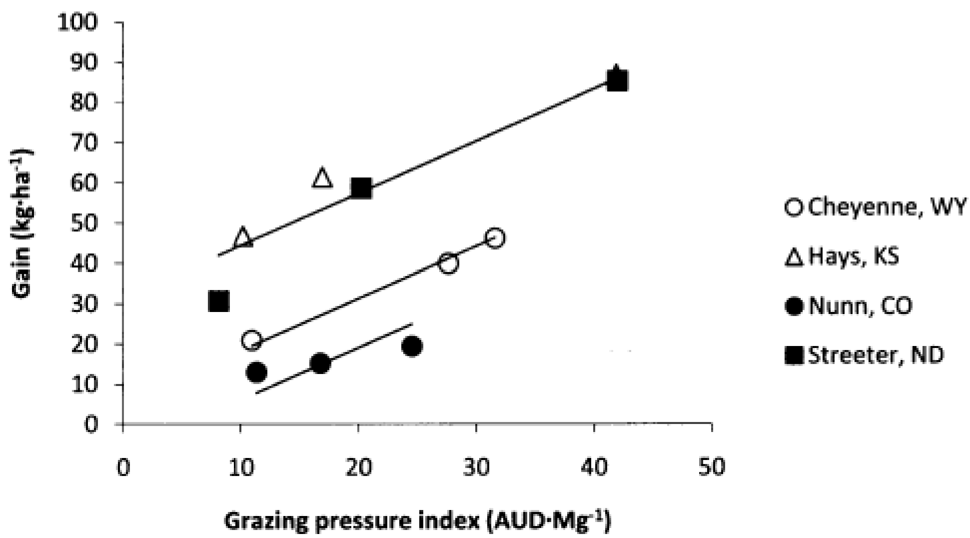
When examining the animal's performance, Smart et al. (2010), found wide variation across locations. However, they were able to point out some distinctive relationships. The average daily gain (ADG) was highest in the Cheyenne study, but in all cases the individual ADG decreases as grazing pressure increases (Figure 2-3). Streeter and Hays studies had the highest gain per hectare; however, in all cases, as grazing pressure index increased, so did gain per hectare (Figure 2-4) (Smart et al., 2010). Regression analysis showed the relationship between the grazing pressure index, ADG, and gain per hectare had an R^2 of .96 and was significant at .01 when location variables were aggregated together.

Figure 2-3: Average Daily Gain (ADG) and Grazing Pressure Index



Source: Smart et al., 2010

Figure 2-4: Gain per Hectare and Grazing Pressure Index



Source: Smart et al., 2010

Hart and Ashby (1998), in Colorado, found as the grazing pressure index increases, an individual animal's rate of gain decreases linearly. In the first ten years of a 55-year study, the average gains of heifers were 129.2, 122.6, and 99.5 kg per head for light, moderate, and heavy stocking densities. On a per hectare basis, the rates of gain were 13.0, 18.9, and 25.7 kg per hectare. Regression analysis was used to examine the effects of grazing pressure index and gain. Using all 55 years of data, Hart and Ashby (1998) found that grazing pressure index explained 45 percent of the variation in gain. Finally, the optimal stocking rate found in the study was slightly above the moderate stocking rate. This optimal stocking rate was dependent on price; however, the plant community was not sustainable if stockings rates were much higher than moderate (Hart & Ashby, 1998).

Batabyal et al. (2001) explored which variable, stocking rates or length of grazing cycle (the number of days in a calendar year used for grazing), was more important to range managers. The study was done on a theoretical basis with no actual cost or benefits included. Batabyal et al., with the help of Utah State University's experimental station, found the long run expected net unit cost (LRENC) of each variable. The long run is used because ranchers are concerned with cost and sustainability of the land in the long run. A rancher would want to minimize his LRENC. The final conclusion Batabyal et al. (2001) found was that in all cases, the LRENC was smaller for stocking rates than the LRENC for the length of grazing cycle, which means the long run per unit costs were smaller for stocking rate than length of the grazing cycle. Although, the length of the grazing cycle is still an important part of range management, stocking rates seem to have a greater impact on the systems (Batabyal et al., 2001).

In central Wyoming, Ritten et al. (2010) found that overall, leaving over half of the standing forage is economically optimal. In the study, the Noy-Meir's equation was used to determine the maximum carrying capacity. In the equation, cattle prices and forage growth rate had the greatest impact on financial returns. Another finding in the study was that if a producer wanted to improve the returns to the land, he had two possible options. The first option was more efficient animals. This means the animals have a higher ability to convert forage to gain. The second option was to improve quality of the range, which would translate into an improvement of animal performance (Ritten et al., 2010).

<u>Mob Grazing Systems</u>

In 1987, Quigley investigated mob grazing studies occurring in the United States. Many insights were found that determine the profitability of mob grazing systems. In Arizona, when mob grazing was implemented, no new employees were needed, but time devoted to management on the ranches increased noticeably due to the additional capital requirements and technical expertise required to operate a mob grazing system. The profitability of the ranches was extremely sensitive to the original investments in the system and the production efficiency. In Texas, on a 3000-acre ranch, research showed that if weaning weight change was between zero and 25 pounds less for mob grazing and cow conception decreased by no more than five percent, mob grazing systems were as profitable as conventional grazing systems (Quigley, 1987). Finally, Quigley found that the risk involved in mob grazing systems is higher compared to other grazing systems. Higher risk can be attributed to the higher level of management needed in a mob grazing system (Quigley, 1987).

Spring precipitation could have a big impact on how animals perform in a mob grazing system (Derner et al., 2007). In this 16-year study in Wyoming, two stocking rates were used for mob grazing: a moderate and a heavy stocking rate. When examining season-long average daily gain per animal, higher rainfall had a higher impact on moderate stocking rates. Regression analysis was used by Derner et al. (2007) to observe how average daily gain and beef production (kg/hectare) were dependent on stocking densities and rainfall. The R^2 for both systems' average daily gain was relatively low at 0.32 and 0.35 for moderate and heavy stocking densities, respectively. When examining the gain per hectare, higher moisture had a greater impact on the heavy stocking rate. Average gains per hectare were higher for heavy stocking rates compared to a moderate stocking rate. The R^2 for both systems were .68 and .74 for moderate and heavy mob grazing, respectively. Traditionally, the stocking rate has been the most noted important variable in grazing systems, but moisture may be just as important (Derner et al., 2007).

In Arizona, Wilson et al. (1987) found while many factors affect bioeconomic efficiency measures (BEM), cow performance within the mob grazing is of the highest importance. If cow performance declines due to mob grazing, the BEM will be negative, zero for performance that stays the same, and positive for an increase in performance. The BEM index ranged between -5 and 5. If there is some kind of negative affect of the BEM, the index automatically falls to -5 in this case. The index could be adjusted for severity of the effect, but was not done here. The effects of long run range deterioration would be captured by a decline in cow performance. Initial cost of the system and BEM were used to measure the profitability of mob grazing. If a producer implemented mob grazing with an infrastructure cost of $10,000 on 8,000 acres (located in Arizona), increased stocking rates by 25%, and the BEM of 5, the internal rate of return for mob grazing would be 39.3%. When the mob system's infrastructure costs are $40,000 and increased stocking rates do not exceed 75%, the system will have a negative internal rate of return. Negative BEM generally resulted in a negative internal rate of return. Therefore, Wilson et al. (1987) concluded that it is highly important to maintain or increase cow performance, as well as keep the cost of the system low.

In a literature review of mob grazing studies, Holechek et al. (2000) found that there was limited research on mob grazing, and usually mob grazing had no financial advantages. One study focused on the Chihuahua Desert of New Mexico. A model 250 cow-calf operation was set up with the ability to increase stocking rates 50% over recommended rates. Along with an increase in stocking rates was the assumption that there would be no change in livestock or forage production, no new fixed cost, and no interest rate cost. The total cost of the system came to $190,400; this was using average cattle price and livestock cost from 1986-1991. When analyzed as a best case scenario, the greatest return the project could have accomplished was 8.1%. This was relatively the same as a 30-years treasury bond in that time era (Holecheck, et al., 2000). The low return and the amount of risk involved with the system would make it unfavorable relative to other systems.

Redden (2014) investigated forage production, utilization, and animal performance on the Nebraska Sand Hills from 2010 to 2013. In the four year study, there were three grazing systems examined, a four pasture twice over rotational grazing system (4-PR-2), a four pasture once over rotational grazing system (4-PR-1) and a mob grazing system. The system also had a control which was a parcel of land that was not harvested by humans or livestock. In the fourth year of the study, above ground plant production had increased for mob grazing. All other treatments had seen no increases in above ground production throughout the study. In the three previous years, there had been no increases in plant production for mob grazing. Redden found no difference in litter mass between treatments. However, litter mass did differ among years (Redden, 2014).

Utilization is measured as a dual effect from grazing and trampling. The trampling target for the study was set at 60% for mob grazing. Mob grazing had the highest utilization when compared to 4-PR-1 and 4-PR-2. The system 4-PR-1 also had higher utilization than 4-PR-2 in all years. In 2011, utilization was the highest for all systems. However, Redden attributed this to the fact that there was less physical above ground mass. Mathematically, the smaller the total number, the easier it is to increase proportions (Redden, 2014).

Disappearance, another measure for harvest efficiency, was measured by the percent of standing live forage available for grazing that disappeared while the animals were grazing. The disappearance was 66% greater for 4-PR-1 than it was for mob grazing. Within each system, there was no significant difference between years. The low harvest efficiency for mob grazing was attributed to the high trampling target and the rapid movement of the animals. Since trampling was targeted at 60%, the maximum the harvest efficiency mob grazing could potentially reach was 40%, which was unlikely (Redden, 2014).

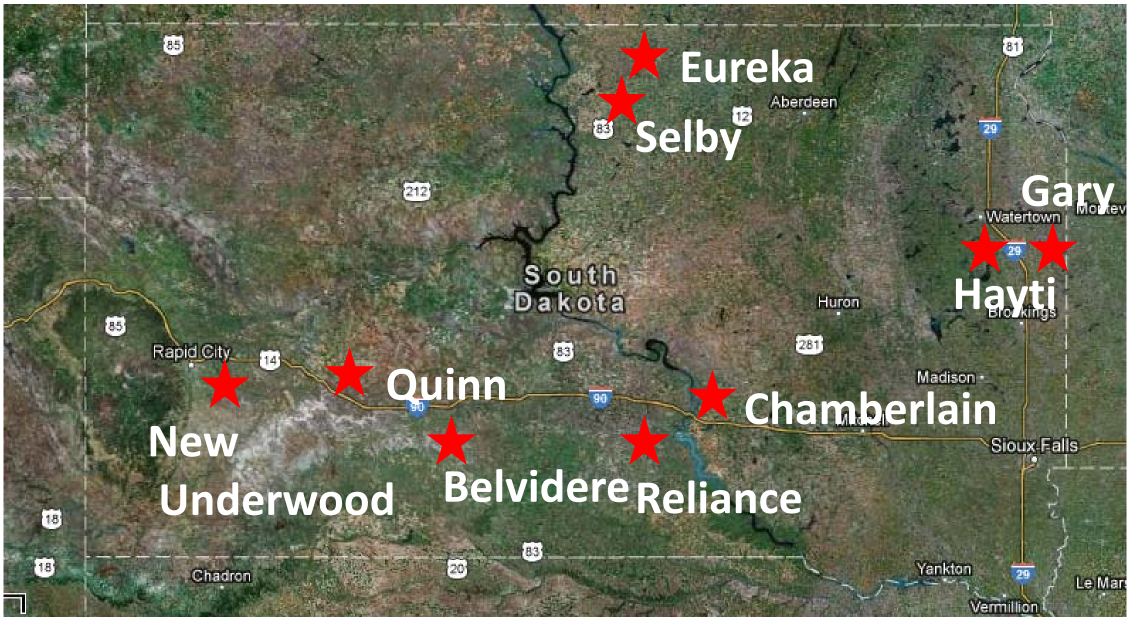
The forage composition was changed throughout the study. The amount of cool-season grasses decreased in all grazing systems from 2010 to 2013. The declines were measured at 15%, 19% and 13% in relative composition from the beginning to the end of the study for 4-PR-1, 4-PR-2 and mob systems, respectively. However, this was attributed to changes in weather patterns and not to the grazing systems. Drought was the main weather variable. Warm season grasses, which are more adapted to deal with drought, increased slightly throughout the study. The composition of sedges increased in all treatments by 17.5%. Finally, Redden cited that many producers claim mob grazing increases native warm season grasses and forbs. His study was unable to verify the validity of that statement (2014).

In all treatments, the relative composition of ground cover had a statistically significant change. From 2010 to 2012, the amount of litter cover increased by 6% in all treatments and litter cover did not decrease in 2013. The amount of soil surface covered by bare soil decreased by four percent in the first three years of the study. The amount of soil surface covered by plant base was .9% higher for 4-PR-2 than mob grazing. This was thought to be a function of random sampling and not the effects of grazing systems. Finally, Redden looked at forage quality, and found no difference in crude protein within systems or years (Redden, 2014).

<u>Producers Testimonies</u>

Producers from Nebraska and South Dakota have started to implement mob grazing into their grazing practices. Figure 2-5 shows the location of producers around South Dakota who use mob grazing. Two of the producers' testimonies ranches are highlighted on the map. These producers come from all areas of the state. Every one of these producers manages the system differently and they feel like they have been able to find ways for the system to be profitable to them. The differences among producers may shed light on where they suspect their profitability is coming from. This section will outline how producers use mob grazing in practice and some of the benefits they perceive they gain from the system.

Figure 2-5: Location of South Dakota's Mob Grazing Producers



Mr. Pat Guptill (2013) is a producer located near Quinn, South Dakota who has implemented mob grazing on his operation. He has around 2000 acres of pasture used for mob grazing. One part of his operation is summer grazing, breeding heifers for another producer. He received the heifers and breeding bulls around May 1^{st}. In the first few days, the heifers are given relatively larger pens. Once they figure out the system, he makes the pens smaller. When Mr. Guptill moves the animals more than once a day, he gives the cattle ten percent more area to graze. If the cattle run into the next pasture, he surmises something about the previous move was done incorrectly. What Mr. Guptill means is the previous move was done too quickly or not quickly enough, which cause cattle to have a shortage of feed intake. Around the first of July, he starts to increase the size of the paddocks. Lower forage quality is the main reason for the adjustment. Usually he tries to mob graze into September, depending on forage quality and moisture. Conception rates on these heifers are the highest in the owner's herd (Guptill, 2013).

Water has a very big impact on Mr. Guptill's system. Rural water was brought into the location as the main water source. Although the water is of high quality, the cost of the system is high. Mr. Guptill uses 400-feet of above-ground pipe to pump water to the paddocks. A small portable water tank is used for the cattle to drink from. In the past few summers, he has had a minor problem with cattle breaking three water tanks that had to be replaced. One of the biggest impacts Mr. Guptill has noticed through implementing mob grazing is water infiltration. Most water from big rains is absorbed directly into the soil, a success he attributes to the system (Guptill, 2013).

The other part of Mr. Guptill's operation is the family-owned, cow-calf operation. Angus and Red Angus are the primary breeds in the herd. He has a high turnover in his cow herd; most animals are under four years old. He has a closed herd, which means no new animals are brought into the system from someone else. Mr. Guptill usually fattens about 20% of his calves every year, and quality heifer calves are retained for breeding purposes. When their final weight is reached, at about 24 months, these fat cattle are sold as grass fed beef to a niche market in Rapid City and Pierre. Mr. Guptill claimed he once had a group of steers average 2.75 pounds of gain a day on this system (Guptill, 2013).

Finally, other important notes from the Guptill Ranch are that they rely on cattle as a means of weed control. No chemicals are used on the ranch. Flies are controlled through their mineral program. Mr. Guptill stated that his ranch qualifies to be organic, but he thinks it would be too much paperwork. However, he is satisfied where his ranch is because he feels mob grazing is more of a sustainable system compared to prior grazing systems used. Through mob grazing, the annual vet bill for sickness was reduced from $2500 to $0. With decreases in cost, returns have increased from $12.50 an acre to

$50 an acre. In addition, the stocking rate is 60% above Natural Resource Conservation Service (NRCS) recommendations for standard conditions/practices. All of this was possible with only adding one more labor hour per day (Guptill, 2013).

Another rancher, Mr. Randy Holmquist, has been using mob grazing on his operation near Reliance, South Dakota since 2004. Mob grazing usually starts around the end of April and lasts until the start of the breeding season. Ending mob grazing at this point was due in part to Mr. Holmquist being worried that mob grazing would affect conception rates. Mob grazing occurs in his low lands. In the summer of 2013, Mr. Holmquist used ultra-high stocking densities of 1 million pounds per acre. These cattle were rotated every 15 minutes. He did not see any additional benefits of this high stocking density, so he dropped the density back down to around 250,000 pounds per acre (Holmquist, 2013).

When mob grazing, animals have access to one permanent water tank for their drinking water. Mr. Holmquist has noticed more native grasses growing in the areas in which he mob grazes and seemingly better production in dry years. The reason for his switch to mob grazing: “I decided to try something new, I did not like sitting in a tractor all summer cutting hay.” Since then, he has sold all of his haying equipment, and Mr. Holmquist has noticed his production costs have decreased (Holmquist, 2013).

One of the first producers to start experimenting with mob grazing was Mr. Chad Peterson in 2002 in the Nebraska Sand Hills. He switched to mob grazing because he was having problems with forage utilization in his sub-irrigated meadows. “Matching the right animals to the right environment is important when mob grazing,” says Mr. Peterson. Therefore, Mr. Peterson sees Scottish Highlander cattle as a perfect fit. Mature highlander cows weigh around 900 pounds, much smaller than their Angus counterparts. Although Highlanders usually have lower ADG than Angus, they are more feed-efficient, which is why Mr. Peterson likes to utilize them. Highlanders naturally have horns, which make higher stocking rates difficult to achieve due to increases in the probability of injury, so cross breeding is used to create polled animals (Peterson, 2013).

Mob grazing usually starts around the middle of May, depending on moisture and grass volume, and stops when water lines start to freeze. Cows are grazed in the rolling hills during the winter months. The cattle are given three acres at the beginning of the day. They are moved three times a day with a back fence only being constructed right after the first morning move. A portable water tank is pulled by a tractor in the morning when the new three-acre paddock is opened up. The tractor is also used to pull over a creep feeder for calves. Calves average 1 pound per day of soybean hulls for the 60 days the creep feeders are in the pasture. Mr. Peterson's goal for mob grazing is to achieve maximum sustainable use per acre (Peterson, 2013).

The summers of 2010 and 2011 had above average moisture, and Mr. Peterson felt the cattle trampled too much grass into the ground. The summer of 2012 turned out to be very dry and Mr. Peterson was conservative about his stocking rates. He did not feel like the drought had a big impact on his operation. A big hailstorm came through in September of 2012 and damaged most standing cover; Mr. Peterson thinks that hurt his pasture production most. However, the layer of organic matter helped promote production in 2013. He is starting to notice more desirable plants emerging in his pastures. Mr. Peterson believes that the last mistake is most important. Cattle may be moved too early or too late and in order to be good at mob grazing, a producer has to be able to recognize this and adjust the system when one of these mistakes occur (Peterson, 2013).

One of the first things that many people notice about Mr. Peterson's herd is that the cattle have few flies on them. The cattle receive no fly control chemicals either. Mr. Peterson attributes this fact to his rotational scheme. In just four days, the cattle are a quarter of a mile away from where they were before. When the fly eggs hatch, the cattle are not around. Things that eat flies, such as spiders and other insects, are very plentiful in the pastures. Mr. Peterson thinks the mob grazing systems is beneficial to fly predators, which is another reason why he thinks he has few flies (Peterson, 2013). Lower fly rates should be reflected in higher animal productivity.

When it comes time to wean, the calves that look more Angus go straight to the sale barn. Calves that look more Highlander are shipped to a feedlot. When the highlander calves are fat, Mr. Peterson stated he gets the same price for Highlander calves as the people who are selling fat Angus. The best rate of gain that Mr. Peterson's cattle accomplished came from running yearlings one summer with average gain of 1.1 pounds per day. Through mob grazing and the right cows for the system, Mr. Peterson claims that he has been able to double his stocking rate. Mr. Peterson claims that most of the infrastructure he uses for the mob grazing are things he already had; he was just not using the resources. Finally, like Mr. Guptill, Mr. Peterson has the labor down to an art and says that he usually has less than one hour of labor into building new paddocks, and moving animals around per day (Peterson, 2013).

Figure 2-6: Producer Testimony Highlights

Mr. Pat Guptill
- *Increased per acre profitability four fold
- *Custom heifers have high conception rates
- *Vet bill reduced to virtually zero
- *Stocking rates are 60% higher than NRCS recommendations
- *Less than one additional hour of labor a day on the system

Mr. Randy Holmquist
- *Utilizes one water source
- *Likes working with cattle more than haying
- *Mob grazing has reduced the operations expenses

Mr. Chad Peterson
- *Switched to mob grazing to help with grass utilization
- *Goal is to maximize the sustainable use per acre
- *Very little problem with sickness in livestock
- *At least doubled the stocking rate
- *Few fly problems

Summary

In the debate of continuous grazing versus rotational grazing, researchers have very strong opposing views. Briske et al (2008), Manley et al. (1997), and McCollum (1999) found that continuous grazing systems were just as good as rotational systems and in some cases even better. In 2011, Briske et al. went further to say that the change in management had the biggest impact on increasing returns. In studies conducted by Jacobs et al. (2006) and Walton et al. (1981), rotational grazing systems seemed to be the superior system. Teague et al. (2008) and Norton (1998) argued that continuous grazing was only superior to rotational grazing in the data because of problems with scale. When proper scale was used, such as that is seen on a commercial ranch, rotational grazing systems have higher returns than continuous grazing systems.

The effects of stocking rates and grazing pressure seem to have an impact on livestock performance (Smart et al., 2010). As grazing pressures increase, the average daily gain per animal decreases and the gain per hectare increases. Although this is generally regarded as correct, the debate about the optimal stocking density is still unclear. Grazing pressure explains about 45 percent of the variation in gain (Hart & Ashby, 1998). Batabyal et al. (2001) found that stocking rates had a bigger impact on grazing systems than the interval of how long the animals grazed.

Along the same lines, the benefits of mob grazing are still heavily debated. Mob grazing may have higher risk involved than other grazing systems (Quigley, 1987). In Wyoming (Derner et al., 2007) found moisture is just as important as stocking rate in mob grazing systems. Mob grazing profitability is dependent on the initial investment in the system and how the livestock perform or the ability of the animals to maintain performance within the system (Wilson et al., 1987). When Redden examined mob grazing (2014), he was unable to find any evidence that mob grazing has additional agronomic benefits when compared to other grazing systems. Finally, producers across Nebraska and South Dakota feel that they are receiving higher returns from the systems. They feel that mob grazing has benefited their operation in many different ways, such as plant diversity, drought resistance, and decreasing costs.

Chapter III: Data Formulation and Analysis

The empirical data of this thesis is based on an analysis of three types of rotational grazing systems: four pastures with one pass throughout the grazing season (4-PR-1), four pastures with two pass throughout the grazing season (4-PR-2), a mob grazing system (MOB) and a continuous grazing system (CONT). This information is used to determine which grazing management strategy will help producers maximize profits. Producers are also concerned with the amount of risk within each grazing system. The higher the level of management needed in a system, the higher the potential risks involved. A formal insight on the risk analysis will help clearly determine the risk present in each system.

This thesis is an extension of M. D. Redden's thesis. Redden, a UNL agronomy graduate student, gathered most of the production data and many of the physical parameters of the study were set up according to his specifications. This thesis is an economic investigation of the same grazing system.

Results from this empirical analysis will also be used to set up a sensitivity analysis. The sensitivity analysis will help to determine how the effects of increased stocking rates affect the livestock performance. The livestock performance will then be used to determine the returns to labor and management to each system.

This chapter is divided into three major sections. The first section consists of the research methods. It covers where the data were collected and the specifications used to collect the data. Section two contains information on price and unit cost assumptions. Price and cost data were assumed for a 160-acre pasture. The final section on methods of analysis provides an in-depth insight of how the variables are going to be analyzed.

Research Methods

The University of Nebraska started the mob grazing study on its Barta Brothers Research Ranch in 2010. The ranch is located seven miles east of Rose, Nebraska, in north central Nebraska. According to Redden (2014), the soils on the ranch are fine sand, with combinations of clay, silt, and organic matter. The area has a shallow water table, typically 1 to 2 meters below the surface, causing the area to have poor drainage. The ranch's vegetation consists of native warm-season grasses, sedges, forbs and introduced cool season grasses. The grazing study was conducted on approximately 67 acres of sub-irrigated meadow on the ranch.

This grazing study was started to analyze the effects of different grazing strategies on soil and livestock properties. Redden examined net primary production, trampling, harvest efficiency, utilization, species composition, forage quality, animal performance and animal activity. This thesis will use the stocking rates and animal performance data for an in-depth economic analysis.

This grazing system study began in May of 2010. In years prior to the study, the meadow was used for forage production and was usually harvested in early July. The system was composed of six randomly placed treatments, each replicated twice. The first grazing system was a 120-pasture mob grazing (MOB) system in which animals only grazed each pasture once throughout the growing season. The second grazing scheme was a four-pasture set-up, with animals grazing each pasture once throughout the grazing season (4-PR-1). The third system was a four-pasture set-up, with animals rotated twice through the pastures during the grazing season (4-PR-2). The fourth was a continuously grazed pasture (CONT). The fifth system was not grazed but hayed instead. It was to be harvested in mid-July. Finally, a control system was used in which no standing forage was harvested by livestock or humans during the growth season. Each system was divided using electric fence. MOB, 4-PR-1, 4-PR-2, and CONT also had water tanks and mineral feeders within the system for animal usage. Redden did not use the continuous system in his analysis, even though the system was replicated along with the other grazing systems.

According to Redden, the 4-PR-2 had a grazing season length of 90 days in 2010, and then the grazing season was shortened to 80 days in 2011 through 2013. The MOB and 4-PR-1 each had a 60 day grazing season length throughout the duration of the study. The stocking rates were adjusted throughout the study due to climatic conditions, but the rates were the same for treatments within each year. The 4-PR-2 was set up to mimic traditional grazing methods of the area. Animals were able to take advantage of cool season grass growth early in the year and warm season grass growth later in the year.

The trampling target for MOB was set at 60%, which means 60% of the available grass is trampled into the earth. For this given target, MOB started later in the season. Cool season grasses, the main vegetation on the meadow, begins the reproductive life cycle stage when MOB starts. Redden explained that during this part of the life cycle, the grasses have a high stem-to-leaf ratio. Therefore, the probability the plant will be trampled is increased. The rotation 4-PR-1 started at the same time as MOB; this would make direct comparisons between the systems easier.

In the first year of the study, animals in 4-PR-1 and MOB had very poor performances. For this reason, the stocking rates and starting dates for the systems were adjusted. The stocking rates were decreased. This was implemented in order to improve nutrient uptake. The starting dates for the systems were moved to earlier in the grazing season. The purpose behind the starting date change was to have more overlap of the grazing season with the time in which higher quality forage was available. Towards the end of June 2013, stocking rates had to be decreased again due to the drought in 2012 and a cool dry spring 2013. Also, the starting date for all three systems was pushed back by one week to help with forage growth. Table 3-1 shows the detailed layout of each system. Included in the table is the year, the number of animals per rotation, the starting date, the number of pastures in each rotation scheme, and the stocking density, measured as live animal weight per hectare.

Table 3-1: General Description of Each Rotation

Year	Head	Start	Pastures	AU ha^{-1}	kg ha^{-1}
4-PR-1					
2010	10	July-1	4	16	7,472
2011	9	June-7	4	15	6,725
2012	9	June-5	4	15	6,725
2013	7	June-12	4	13	5,997
4-PR-2					
2010	10	May-19	4	11	4,982
2011	10	May-18	4	11	4,982
2012	10	May-22	4	11	4,982
2013	7	May-29	4	9	3,998
MOB					
2010	40	July-1	120	494	224,170
2011	36	June-7	120	445	201,753
2012	36	June-5	120	445	201,748
2013	26	June-12	180	515	233,880
CONT					
2010	4	**	1	**	**
2011	4	**	1	**	6,725
2012	3	**	1	**	6,725
2013	4	**	1	**	5,997

Source: (Redden, 2014) **Data unavailable

In order to account for lower stocking rates in 2013 for MOB, the moves per day were increased and pasture size was decreased to have similar stocking densities as previous years. Animals were moved at 7:00 a.m. and 2:00 p.m. during the first three years of the study. In 2013, animals were then moved at 7:00 a.m., 11:00a.m. and 4:00 p.m. The average paddock size was 0.15 acres from 2010 through 2012 and 0.1 acres in 2013. In all four years, animals would graze a total of 0.30 acres a day in MOB. Pasture size for 4-PR-1 was 1.04 acres and animals were given 13 to 16 days per pasture each year. Pasture size for 4-PR-2 was 1.56 acres and animals were given 8 to 12 days in each pasture per year. Animals in the CONT system were given 1.85 acres for the entire grazing season.

Data for 2014 was not included in Redden's analysis. The rates of gain for 2014 will be used for this thesis. The data for 2014 was not as well laid out as data from Redden, but through observing the stocking densities and individual animal performances, information about the data can be inferred. The 2014 data was included with the excel file, with the data from Redden's thesis, but did not have a description to go along with the data at previous years. However, with each individual animal observation included in the file, the inference was clear. Animal numbers per rotation were back to the 2012 levels. Other variables, such as stocking rates, durations of grazing cycle, and number of moves, were the same as the 2012 levels. Without a significant weather change disrupting the grazing cycle, returning to the original specifications creates more similar data points for the study.

Finally, the two other schemes in the study, haying and control, were not well-documented because of a lack of available labor and equipment. Thus, poor data collection occurred within these systems and no further analysis of these systems will be examined in this thesis.

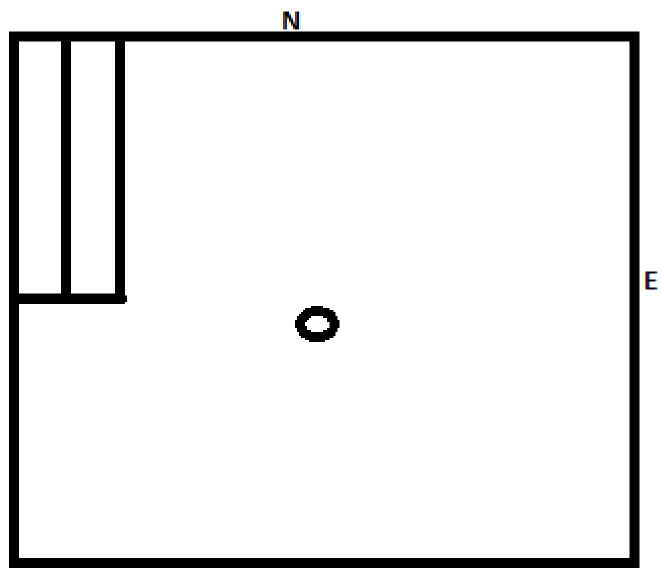
Model Pasture Size

In order to make the study a more realistic scenario, the budgets were set up for a quarter section pasture (160 acres). First, the original pasture size and number of animals were used to calculate the stocking rate. The original pasture size before cross fencing for MOB was 18 acres, 4.16 for 4-PR-1, 6.24 acres for 4-PR-2 and 1.85 acres for CONT. Once the stocking rate per acre was found, the stocking rate was multiplied by 160 acres.

The product was the number of animals needed to maintain the original stocking rate. A quarter section of rangeland (160 acres or 64.75 hectares) was used because it allowed the number of animals to range from 347 in 4-PR-1 to 180 in 4-PR-2. Also, larger acres of pasture would require more yearlings. According to the National Agricultural Statistics Service (NASS), the percent of operations with sales of fewer than 500 head of animals in 2012 accounted for almost 80% of the operations in South Dakota (NASS-USDA, 2014). Using a quarter section of land keeps all four rotations under 500 head and more closely related to the majority of farms in South Dakota. Therefore, increasing pasture size is unnecessary for any further analysis in representing South Dakota operations.

Within this quarter section, MOB pastures were assumed to be set up in a rectangular pattern. This would allow the cost of waterline to be minimized. The paddocks were 1320 feet x 44 feet in 2011, 2012, and 2014. Cattle first started in the northwest paddock of the system. They were rotated until they reached the east end of the quarter section. By doing so, they would have travelled through 60 paddocks. The next paddock would be built directly south of the final northeast paddock. Grazing would ensue back to the west until all 60 paddocks were grazed. Figure 3-1 depicts what the first two paddocks would look like for mob grazing. The circle in the center of the square represents the location of the water source.

Figure 3-1: Picture Description of MOB Pasture/paddock System Setup



<u>Animal Performance</u>

Average daily gain (ADG) was used to measure animal performance within each system. Animals were first weighed at the Agriculture Research and Development Center (ARDC). A week before leaving the ARDC for the research ranch, the steers were limit-fed. During the last two days at the ARDC, steers were weighed once per day. The average of these two weights was used as the starting weight (See Table 3-2). Animals were then hauled to the pastures to begin summer grazing. At the end of the grazing season, the animals were loaded and hauled back to the ARDC. Final weights were taken in the same manner as the initial weights. The difference between final weight and initial weight was then divided by the number of days on pasture.

This calculation represents the ADG per animal (Table 3-3). Redden also went further to explain that ending weights for 2010 were not recorded. In 2010, eleven steers had unexpected and unexplained deaths. Therefore, the study lacked enough sampling size to record animal performance information (Redden, 2014). Finally, ADG can be zero or even negative. Throughout the study a few incidents were recorded of animals gaining no weight or losing weight during the grazing season. These measurements were included in the calculations to compute the ADG for each replication and also to set up the empirical distributions for risk analysis.

Table 3-2: Beginning and Ending Average Animal Weight per System from 2011-2014 (pounds per animal)

	Beginning weight				Ending weight			
	2011	2012	2013	2014	2011	2012	2013	2014
MOB 1	728	726	793	775	747	748	823	841
MOB 2	725	727	793	778	740	754	830	827
4-PR-1 (1)	732	727	793	779	780	776	838	844
4-PR-1 (2)	734	727	793	775	772	762	832	860
4-PR-2 (1)	655	699	793	790	770	766	883	873
4-PR-2 (2)	658	700	793	794	790	770	877	896
CONT-1	725	725	795	778	782	798	857	870
CONT-2	746	727	794	776	810	776	863	865

Source: (Redden, 2014)

Table 3-3: Average Daily Gain in Pounds per System from 2011-2014

	2011	2012	2013	2014
4-PR-1 (1)	0.8	0.82	0.74	1.08
4-PR-1 (2)	0.63	0.58	0.64	1.41
4-PR-2 (1)	1.91	1.12	1.49	1.49
4-PR-2 (2)	2.18	1.16	1.40	1.70
MOB 1	0.33	0.38	0.49	1.09
MOB 2	0.24	0.45	0.62	0.83
CONT 1	0.94	1.22	1.03	1.54
CONT 2	1.06	0.81	1.15	1.49

Source: (Redden, 2014)

Prices

Purchasing and selling prices were obtained from the Livestock Marketing Information Center (LMIC). The prices used were the average cattle prices for all South Dakota auctions reported by USDA-AMS. LMIC has historic price data for steer cattle weighing from 200 to 1100 pounds. The price data is available for both weekly and monthly averages. Data is updated weekly and is archived back to January 6, 1996 (LMIC, 2014). The actual monthly average price was used for the purchasing and the selling price in each respective year. For budget purposes, cattle were priced as though they were purchased in May and sold in August.

Livestock producers usually have a limited time frame to buy or sell cattle. Since the choice to buy cattle was predetermined before grazing occurred each year, purchase price was given as a constant in the simulation part of the analysis. Animals were randomly selected for each grazing system, which caused the average beginning weights in each grazing system to be slightly different. However, the different weights do not affect the purchasing price. Livestock would have been bought as one group for the same price per hundredweight. Therefore, the purchasing price is constant between systems as well. Expected selling price will vary between the time the animals are purchased and when the animals are actually sold. The expected amount of gain will have a direct impact on the expected selling price. Therefore, the selling price should be stochastic in the model.

Table 3-4: Purchase and Selling Price of Steers in $/cwt

	Purchase Price	Selling Price
MOB		
2011	$ 136.37	$ 134.63
2012	$ 153.30	$ 142.32
2013	$ 130.95	$ 155.90
2014	$ 189.44	$ 220.12
4-PR-1		
2011	$ 136.37	$ 134.63
2012	$ 153.30	$ 142.32
2013	$ 130.95	$ 155.90
2014	$ 189.44	$ 220.12
4-PR-2		
2011	$ 136.37	$ 132.22
2012	$ 153.30	$ 142.32
2013	$ 130.95	$ 149.32
2014	$ 189.44	$ 212.20
CONT		
2011	$ 136.37	$ 132.22
2012	$ 153.30	$ 142.32
2013	$ 130.95	$ 149.32
2014	$ 189.44	$ 212.20

(Source: LMIC, 2014)

When it comes to cattle pricing, smaller cattle tend to sell for a higher price per hundredweight than similar cattle that weigh more. This is known as the livestock price slide. The reasoning behind the price slide is that lighter cattle have higher feed efficiency, they are able to gain more weight relative to the amount of feed they are given (Bailey & Holmgren, nd). Price slide is not just a theoretical part of agricultural economics. It can be seen at cattle auctions such as Superior Livestock Auction. Originally, the price slide was going to be set up using Superior Livestock Auction data from USDA's Agriculture Marketing Service (AMS-USDA). The assumption for the selling price was as follows: when the producer purchased the cattle in May, he was looking at current selling prices in August through a video auction service such as Superior Livestock for a baseline price. Once the producer had a baseline selling price he could do a break-even analysis for an idea on particular selling prices and the rate of gain the cattle need to reach certain selling weights. Data to set up the price slide for simulation purpose was almost non-existent for stocker cattle priced in May for August delivery. Delivery weights, geographic regions, and sex of the animal were also too sparse to make the simulations robust.

Therefore, agricultural economics theory was used to set up a price slide. According to Dhuyvetter and Schroeder (2000), there are many factors that play important roles in determining the price slide in cattle. Some of the main factors are time of year, recent feeding margins, and the sex of the animal (Dhuyvetter & Schroeder, 2000). Using multiple regression analysis with variables such as cattle prices, cattle weight, corn futures, futures price, feeding margin, number of head, sex of the animals and monthly variables, a price slide was discovered. Dhuyvetter and Schroeder (2000) used 46,081 data points in the model and found their model explained almost 91 % of the data. The base weight in the study was 650 pounds, prices dropped between $2.50 and $5.00 per hundredweight on average as cattle weights increased to 850 pounds. This average price slide varied slightly but was similar for many different factors as cattle weights increased (Dhuyvetter & Schroeder, 2000). Since, the price slide was consistent among different factors, this price slide will be used in the analysis.

<u>Land Rental Rates</u>

The cash rental rate per acre came from the Nebraska Farm Real Estate Market Highlights 2013-2014. This annual publication, printed by UNL, is a survey in which land experts across the state of Nebraska are interviewed. The respondents give their most accurate estimates of the farm real estate markets information in respective localities. The cash rental values were used from the North Agriculture District in Nebraska, which is where the grazing experiment took place. Therefore, the productivity of the rangeland is reflected in the cash rent values. The average cash rental price was $14, $16, $16 and $25 an acre for 2011 through 2014, respectively (Jansen & Wilson, 2014). Finally, rental rates increase drastically in 2014 due to the increased value of livestock.

Cost per Animal

Many of the variable costs associated with this grazing experiment are the same regardless of which scheme the animals are grazing. For example, the marketing cost per animal will be the same for every animal across each system. Other per animal costs that are the same regardless of system are vet costs, hauling, utilities, mineral, and interest. Vet costs may be higher for particular animals within a system, but the random placement of the animals in each system should offset the animal differences. Certain labor charges will also be the same across the spectrum. Some of the labor charges would be preconditioning the cattle, refilling of supplemental mineral, and trucking costs.

Historically, universities and private companies have kept very good track of these costs for cow-calf and feedlot operations in both South Dakota and Nebraska. Summer grazing budgets for yearling cattle have been more limited. Information exists for breeding heifers, but this type of system has entirely different costs and purposes when compared to summer grazing yearling steers. Current year summer yearling grazing budgets can be found, but the archived data has limited usefulness.

Since per animal cost data was limited, a variable must be chosen to accurately represent the costs. This variable must be relevant and reflect the actual costs. According to the USDA, higher priced grazing fees require land owners to cover certain costs associated with grazing cattle, while lower grazing fees require the livestock owner to cover the costs (USDA-WY Department of Ag, 2014). The grazing fee, which is measured in animal unit months (AUM), fluctuates yearly depending on the cost of these input prices. Therefore, using the grazing fee to reflect these costs in the budgets presents both a relevant and meaningful variable for budget analysis. An AUM is the cost of the amount of forage to sustain one animal unit for one month,

The grazing fee was found in the Nebraska Farm Real Estate Market Highlights 2013-2014 report. In the report, AUM was reported for cow-calf pairs. A 750-pound yearling, according to popular livestock text, would be equivalent to 0.806 AUM (Alberta Agriculture and Rural Development, 2007). In order to accurately depict the grazing fee for yearlings, the price reported in the Nebraska report was multiplied by 0.806. AUM for 2011 through 2014 in the North agriculture district was $21.90, $24.90, $25.15, and $31.30. Proposed average AUM ranges were also collected from the USDA-WY Department of Ag for 2011 through 2014 for simulation purposes.

One important clarification must be made about the AUM variable. One of the underlying pricing mechanisms for AUM is the value of the land. The rental value of land is found elsewhere in the budgets, so the land value seems to be double counted. However, because of the way the variable is used, the double counting is insignificant. When examining summer grazing budgets for steers from Kansas State (Dhuyvetter & Tonsor, 2014) and NDSU budgets (NDSU, 2014) the AUM variable used is less than the average values in the budgets, but within the range used for simulation purposes. The variable may slightly understated, but still represents the intended costs.

Fencing

Fencing costs have a major impact on the implementation of different grazing systems. One assumption made about the fencing costs is that the quarter section already has a good pre-existing perimeter fence. All fencing costs that occurred in 2011 were generated from subdividing the pastures for rotational purposes. The quarter section was split equally into four quarters for grazing systems 4-PR-1 and 4-PR-2. The mob grazing system fencing costs were determined by the amount of fence it would take to create two paddocks. When the cattle are moved from one paddock to the next, the old fence is taken down and moved ahead of the existing fence where the cattle are currently located. This creates a leap frog process for MOB fencing in which the same fence can be used many times.

The cost of the interior fence came from Iowa State Extension. There were two different fences used in the budgets. One fence, which was more permanent, was a high-tensile electrified wire fence. A fencing system such as this has an average cost of $0.89 per foot to install. (Table 3-5). Rotations 4-PR-1 and 4-PR-2 would utilize this fence as cross fences. The second fence was an electrified polywire fence. This fence was selected for MOB because it was easy to build and tear down. The average cost for the polywire fence is $0.17 per foot. (Table 3-6). Labor costs were excluded from the MOB fencing budget and will be accounted for in another section of the budget. Finally, the fence has annual maintenance to make sure the fence is still in proper working condition.

High tensile electrified wire's annual maintenance was $0.12 per foot. Polywire's annual cost of maintenance is $.07 per foot (Mayer & Olsen, 2012). (Table 3-7).

Table 3-5: Construction Costs for High Tensile Electrified Wire Fence

Item	Amount	Cost per Unit ($)	Total Cost ($)
Wood posts (8-in diameter)	6	28.00	168.00
Wood posts (4-in diameter)	4	9.00	36.00
Steel post (6.5 ft.)	52	5.00	260.00
Insulators	285	0.35	99.75
Springs	5	7.00	35.00
Strainers	5	3.50	17.50
High tensile wire 9 (ft)	6600	0.025	165.00
Energizer	0.25	110.00	27.50
Cut-out switch	1	7.50	7.50
Ground/lightning rods	4	16.00	64.00
Labor and equipment	18	16.25	292.50
Total			$ 1,172.75
Total per foot			$ 0.89

Source: (Mayer & Olsen, 2012)

Table 3-6: Construction Costs for Electrified Polywire Fence

Item	Amount	Cost per Unit ($)	Total Cost ($)
Wood posts (4-in diameter)	2	9.00	18.00
Fiberglass posts (3/8-in x 4 ft.)	33	1.75	57.75
Insulators	2	0.80	1.60
Post clips	42	0.30	12.60
Polywire (ft)	1320	0.03	39.60
Energizer	0.25	110.00	27.50
Cut-out switch	1	7.50	7.50
Ground/lightning rods	4	16.00	64.00
Total			$ 228.55
Total per foot			$ 0.17

Source: (Mayer & Olsen, 2012)

Table 3-7: Annual Average Ownership Cost by Type of Fence

Item	High Tensile	Polywire
Estimated useful life (yr.)	25	4
Average annual maintenance (percent of initial cost)	5	5
Depreciation ($)	47	65
Interest on investment (4%) ($)	47	10
Maintenance ($)	59	13
Total cost/year ($)	150	88
Total cost/foot/year ($)	0.12	0.07

Source: (Mayer & Olsen, 2012)

<u>Water</u>

Water is one of the most important parts of any grazing system. It was assumed there was an existing water source for each system before the grazing started. In the budgets, the cost of water was assumed to be captured in other parts of the budget. However, MOB needs to have a portable water tank and water line also added into the infrastructure costs. This was due to the fact that the MOB system had many paddocks and the water tank had to be moved constantly in order for the animals to be able to drink. The cost of the 350-gallon portable water tank in 2011 was $198.60 (Farm Ranch Store, 2014). In order to get the water pumped to the tank, 1300 feet of 3/8 inch polyethylene tubing was needed. This had a cost of $0.21 per foot or $258.18 in 2011 dollars (Agrimart, 2014). The existing water tank for 4-PR-1 and 4-PR-2 was located where all four paddocks came together in the middle, so it could be reached from any paddock the animals were in.

<u>Labor</u>

Labor costs have real effects on which type of grazing system producers plan to use. The cost of labor was obtained from NASS. Hired labor, wage rate for animal workers measured in dollars per hour, was the specific measure used. To make the labor costs relevant to both Nebraska and South Dakota, the geography level used was the northern plains. Summer labor costs were $10.96, $11.66, $11.58, and $12.82 per hour for 2011 through 2014, respectively (NASS-USDA, 2014). According to producer testimonies, labor associated with moving cattle and fence accounted for approximately one hour a day. Therefore, in this study the labor cost were defined as the amount of time used to move the cattle and the fence in the case of MOB. In 4-PR-1, total labor is 4 hours through the whole grazing system, since animals are only moved 4 times during the summer. In 4-PR-2 and MOB, total labor used was 8 and 60 hours, respectively. All other labor costs were captured within the cost of the AUM.

Methods of Analysis

The methods of analysis used for this thesis began with the construction of budgets for each system; this information was then used for analysis of stochastic dominance with respect to a function and stochastic efficiency with respect to a function analysis. In each budget, calculations are made to arrive at the returns to labor and management. Profitability of the system is reflected in the returns to labor and management (Table 3-8). Other areas of focus found from the budgets will be gross returns, infrastructure and labor costs, and total cost per system. The budgets in this analysis will be constructed in Microsoft Excel. By using Excel, reference cells can be linked to other areas in the budget. This linkage between cells will be crucial for risk analysis. One change in a parameter will be reflected throughout the budget and captured in the returns to labor and management. Simetar© will be used to simulate the data used for stochastic dominance and stochastic efficiency.

The same budgets will be used in the sensitivity analysis. In each budget, the animal performance will be adjusted according to certain parameters. Once the adjustments are made, Simetar©, will then be used in the same manner as before. The returns to labor and management for the new system will be evaluated according to profitability and risk.

Table 3-8: Sample of 2011 Mob-1 Grazing Budget

System	Year			
MOB-1	2011			
Purchase Weight:	727.42		INCOME	
Purchase Price:	1.3202		Sale Price:	1.3463
Purchase Cost:	960.3399		Gross Revenue/animal	1005.9823
			GROSS RETURNS:	325938.26
Avg. Daily Gain	0.33	lbs.		
Days in program:	60			
Sale Weight:	747.22	hd.	RETURNS OVER CASH COSTS	
Weight Gain:	19.8		total per head:	0.250884
			total	81.286412
Cash Costs/head:				
AUM	21.9		FIXED COSTS--(direct, annual)	
PER HEAD CASH COSTS	21.9		Own Labor:	657.6
			Water:	456.78
Number of Cattle:	324		TOTAL:	1114.38
Pasture-acres used:	160		Total per head	3.4394444
Stocking Rate:	2.025			
Pasture Costs/acre:				
fence:	4.4		RETURNS TO LAND & MANAGEMENT	
rent/taxes:	14			
Total/Acre	18.4	hd/ac	per head	-3.18856
Total/Head	9.08642		per acre	-6.456835
			TOTAL:	-1033.094
TOTAL CASH COSTS:	991.3263			
Death Loss	14.4051	1.5%		
TOTAL CASH COSTS:	1005.731			

Risk and Risky Alternatives

Risk can be defined in two major ways: (1) the chance of a bad outcome or (2) the variability of outcomes (Hardaker, 2000). When examining livestock budgets and choosing the proper system to use, both definitions of risk are relevant. Positive returns to labor and management are important in livestock budgeting, but the probability of the returns to be positive is just as important. According to Hardaker, a simple measure of risk is $P^*=P\ (X \leq X^*)$. P is the probability of the outcome, X is the uncertain outcome, and X* is known as the cut-off value. In this case, cut-off means a minimally accepted level of a good outcome, for example, positive returns. Risk can also be measured using variance, standard deviation, or coefficient of variation (Hardaker, 2000). In production agriculture, there are five major types of risk: production, price, financial, institutional, and human risk (ERS-USDA, 2013). This thesis will focus on price and production risk.

Knowing the level of risk involved in a certain situation does not tell the whole story; the ability to rank the differences in risk is just as important. According to the subjective expected utility (SEU) hypothesis, in order to assess the difference in risky outcomes, the decision maker's utility function must be known. The SEU hypothesis simply states that the ranking of different risky prospects is a weighted average of the decision maker's utility to each of those outcomes (Hardaker, 2000). Risk aversion, a person's attitude towards risk, allows grouping of different decision makers' weighted average of risk.

When measuring risk aversion, the first step is to assume that risk aversion is a function with respect to the individual's income. Defining risk aversion mathematically would be $r_a(W)= -U''(W)/U'(W)$. In this equation, U′ is equal to the first derivative of utility with respect to wealth, and U″ is equal to the second derivative of utility with respect to wealth (Hardaker, 2000). Generally, as wealth increases, the risk aversion ($r_a(W)$) will decrease. A decision maker's attitude towards risk is explained by the second derivative of wealth. If it is less than 0, the person is risk averse; if it is equal to 0, he is risk indifferent; and if it is positive, the person is risk loving (Simetar, 2008). Finally, a risk premium is the amount a person would have to receive in order to be indifferent between two treatments with a different level of risk (Pratt, 1964).

In Simetar©, risks are measured and ranked using stochastic dominance with respect to a function (SDRF) and stochastic efficiency with respect to a function (SERF). Stochastic dominance allows functions to be ranked by how each function's cumulative distribution lies with respect to the other functions' cumulative distributions. One convenience of stochastic dominance is that the utility functions do not have to be restricted in any form (Hadar & Russell, 1969). Stochastic dominance is helpful when one's preferences are not known or precise. The absolute risk aversion functions are located somewhere between an upper and lower bound for the entire decision maker's choice set. Solving for a decision maker's whole utility function is very complex; but, inferring the bounds of a decision maker's risk aversion coefficient is much easier (Hardaker & Lien, 2003).

Stochastic efficiency with respect to a function (SERF) is a method of selecting utility efficient alternatives, whereas, with SDRF a subset of dominated alternatives is found. SERF aligns the alternative choices in accordance with certainty equivalents. Results from running SERF are more efficient compared to SDRF because SERF will not ignore any small set that is efficient. SERF is able to do this because it only selects sets that are utility efficient alternatives and equates these sets with each other simultaneously (Hardaker & Lien, 2003). Therefore, using the SERF function after the SDRF function, systems will be ranked on superiority at different levels of risk.

Model Simulations

The software used for risk analysis is the Excel add-in program, Simetar©. The name Simetar© is derived from **Sim**ulation for **E**xcel **t**o **A**nalyze **R**isk. It was developed as an easy-to-understand system for evaluating data, simulating the effects of risk, and providing clear and meaningful results (Richardson et al. 2008). Budgets were set up in Excel because of Simetar's© ability to make variables become dynamic. A change in an early cell will have implications throughout the rest of the budget. The analysis for this research uses Simetar© to simulate variables, rank the risk of different systems, and present the results graphically.

As stated earlier, stochastic dominance with respect to a function (SDRF) and stochastic efficiency with respect to a function (SERF) can be easily performed in Simetar© to rank risk alternatives. Since a decision maker's specific utility function is very hard to define, Simetar© uses risk aversion coefficients for bounding purposes. Upper and lower risk bounds are set within the program. Next, Simetar© will use the information to rank each alternative according to the risk aversion coefficients. Finally, the stoplight function allows the probability of returns in each system to be sorted into three different levels.

Simetar© was used to simulate AUM costs, selling price, and average daily gain. Selling price data, which was viewed to have a uniform distribution, was simulated using (=Purchase Price-UNIFORM (minimum, maximum). The minimum and maximum were selected according to the average price slide found by Dhuyvetter and Schroeder (2000). Buying price was considered to be a predetermined decision made by the producers; therefore, there was nothing stochastic about the buying price, so it was left constant during simulation.

Animal Unit Months were simulated in a triangle distribution, which was selected because the maximum and minimum values are known, while the rest of the distribution is relatively unknown. The function to calculate a triangular distribution in Simetar© is: (=Triangle (Min, Mode, Max)). This allows the function to have a continuous distribution along a finite range. The mode for the distribution was found in the Nebraska Farm Real Estate Market Highlights 2013-2014. Specifically, the mode was the AUM price for the North agriculture district of Nebraska (Jansen & Wilson, 2014). The minimum and maximum were found at USDA-WY Department of Agriculture. The values used for the distribution were the reported high and low for southwestern South Dakota (Walthers & Orton, 2014), (Orton, 2012).

The average daily gain was evaluated on a multivariate empirical distribution. The multivariate empirical distribution was used because the distribution allows the simulated values to be focused around the most observed values. The function for multivariate empirical distribution in Simetar© is: (=MVEMPIRICAL(S_i,F(S_i)[CUSD])) (Richardson et al., 2008). As stated by Derner et al. (2007), rainfall could have a huge impact on how cattle perform in mob grazing. Empirical distribution will allow lower or higher rates of gain due to weather conditions or other factors to be captured in the distribution.

Finally, the new functions were entered into their respective cells (54 cells total). Once entered into Simetar©, the simulations were made to calculate the returns to labor and management of each system. The simulations were used to create 1,000 new data points for each year in each system. This resulted in 4,000 data points for each individual replication and 8,000 total data points for each type of system. Total costs and gross revenues were also simulated as other important variables of interest. This data was then used for stochastic dominance, stochastic efficiency, and stop light functions.

Summary

This chapter described the research design of the study. This included how the data was collected and why things were specified the way they were. Next, price and cost data were explained as well as where this information was found. This data was selected because of the way it aligned with the original data. Finally, the methods of analysis explained how Simetar© would be used to further analyze the risks involved in each system. The sensitivity analysis performed will use the same methods as the original stochastic analysis.

Chapter IV: Empirical Results and Discussion

Budget analysis was conducted for all four systems from 2011-2014. Specifically, total revenue, total costs, infrastructure and labor costs, and returns to labor and management were calculated. The mean, standard deviation, coefficient of variation, and mini-max were used to measure the static risk for each variable. However, in some cases these measurements give a result, but the result has no logical interpretation in the context of the data or provided nothing useful for analysis purposes. The individual replications were aggregated together in order to further evaluate each system. For example, the mean for MOB was the average of 2011 to 2014 for both MOB-1 and MOB-2. The same process was applied for estimating standard deviation, coefficient of variation, and mini-max. One downfall of using these as risk measurements was the evaluation is for a static system. Ranking systems from best to worst was the greatest insight on risk that was achievable. Stochastic simulation will be introduced later in the thesis and will provide greater insight into risk.

When examining these basic risk analysis strategies, some important insights are apparent and will help give producers information on which system would be the profit-maximizing grazing strategy. The mean of each rotation measures the average of that particular system. A high mean is preferred for returns to labor and management, but a high mean is not desirable for total costs. Standard deviation measures the amount of variability in each system. A high standard deviation indicates that large changes are present in the system throughout the period. A small standard deviation indicates that costs or profits are in a more narrowly defined window. An economic agent would want to choose a smaller standard deviation; this would allow them to more accurately predict the future costs and revenues of a system. However, standard deviation only takes absolute risk into account and not the relative risk.

The coefficient of variation helps to explain the relative risk of a system. The standard deviation is divided by the mean to produce the coefficient of variation. By using the coefficient of variation measurement, an economic agent can show that even though a system has a small standard deviation, it does not necessarily translate into less variance in the system. A small mean and relatively small standard deviation could still present a high coefficient of variation, making the system unfavorable. Mini-max is used to minimize the potential loss of a system if something would happen that would negatively affect the system. To calculate the mini-max, the minimum value is subtracted from the mean value of a system. The final value indicates the potential for loss for each system if something in the system were to turn unfavorable. A lower mini-max value is preferred over a higher mini-max value.

Returns to Labor and Management

The returns to labor and management explain the profitability of each system. Since each system is stocked at a different rate, evaluating the system on a per acre basis makes the analysis between systems more comparable. However, the returns to labor and management per animal is also important to examine. According to Smart et al, as the stocking rate increases, the individual animal's rate of gain will decrease (2010). The empirical data supported this statement. By examining the returns per animal, the loss of performance per animal can be evaluated in an economic perspective. Finally, some producers focus on returns per animal, while others focus on returns per acre; this is the rationale for evaluation from both perspectives.

Data in Table 4-1 and Table 4-2 display the rank and numerical value for each system on a per acre basis, while data in Table 4-3 and Table 4-4 display the rank and numerical value for each system per animal. The system 4-PR-2 has the highest per acre mean. The 4-PR-2 system also had the lowest relative risk, absolute risk, and lowest mini-max coefficient. 4–PR-2 is very desirable based on a per acre analysis. When examining returns per animal, 4-PR-2 is clearly the best rotation, as it ranks first in all four categories, as it did on a per acre basis. MOB has the lowest average returns and it also has the highest coefficient of variation. The 4-PR-1 system has a higher absolute risk, whereas MOB has a higher relative risk. The CONT system had the third highest mean, but was ranked second for both relative and absolute risk. The added cost of a rotational grazing system is offset more and overall profitability is greater when less intense grazing systems are used.

For CONT and 4-PR-1, the average returns to labor and management per animal and per acre are very close in terms of dollar value. This could have implications based on a producer's time. Since opportunity costs are important, a producer may be able to increase the overall profitability of his operation by changing other parts of the operation. The producer could continuously graze or increase the amount of management given to the grazing system to make it comparable to 4-PR-2.

Another important note is that the lower returns per animal in MOB were not recovered by higher returns per acre for MOB. Average returns per animal were \$50.77, \$27.17, and \$26.51 lower for MOB when compared to 4-PR-2, 4-PR-1 and CONT, respectively. On the per acre analysis, the difference between the average returns for MOB and the returns for 4-PR-2, 4-PR-1, and CONT was \$77.97, \$70.41, and \$67.81, respectively. Therefore, the ranking of MOB and the associated differences in returns per acre and returns per animal make the system undesirable.

Table 4-1: Rankings of Average per Acre Returns to Labor and Management Using Different Static Risk Analysis Strategies

	Mean	Standard Deviation	Coefficient of Variation	Mini-Max
MOB	4	3	4	2
4-PR-1	2	4	3	4
4-PR-2	1	1	1	1
CONT	3	2	2	3

Table 4-2: Average per Acre Returns to Labor and Management Used for Risk Ranking

	Mean ($)	Standard Deviation ($)	Coefficient of Variation (%)	Mini-Max ($)
MOB	108.02	305.85	283.13	404.31
4-PR-1	178.43	337.03	188.88	455.63
4-PR-2	185.99	206.88	111.23	313.92
CONT	175.83	278.93	158.63	405.56

Table 4-3: Rankings of Average per Animal Returns to Labor and Management Using Different Static Risk Analysis Strategies

	Mean	Standard Deviation	Coefficient of Variation	Mini-Max
MOB	4	3	4	3
4-PR-1	2	4	3	4
4-PR-2	1	1	1	1
CONT	3	2	2	2

Table 4-4: Average per Animal Returns to Labor and Management Used for Risk Ranking

	Mean ($)	Standard Deviation ($)	Coefficient of Variation (%)	Mini-Max ($)
MOB	66.44	160.89	242.15	212.75
4-PR-1	93.61	163.03	174.16	221.42
4-PR-2	117.21	132.55	113.08	196.86
CONT	92.95	136.70	147.07	199.19

In the first year of the study, all rotations except for MOB had positive returns to labor and management (Figure 4-1 and 4-2). The lower performance in 2011 for MOB, 4-PR-1, and CONT compared to 4-PR-2 was attributed to the late start date of these three grazing systems. However, MOB-1 had a loss of \$3.19 per animal and MOB-2 had a loss of \$10.47 per animal, so the loss per animal was slight. In 2012, drought conditions, which depressed forage quality, led to negative per animal and per acre returns in all systems. The negative returns were greatest for both MOB systems. In 2013 and 2014, 4-PR-1 performed the best per acre, followed by CONT, MOB, and 4-PR-2. When examining returns per animal, 4-PR-2 performed the best in the first two years; in the last two years of the study results were mixed. Cattle prices throughout the summer of 2014 were on an upward trend. The higher prices led to the higher returns per acre in each system when compared to previous years.

Figure 4-1: Average per Acre Returns to Labor and Management per System from 2011-2014

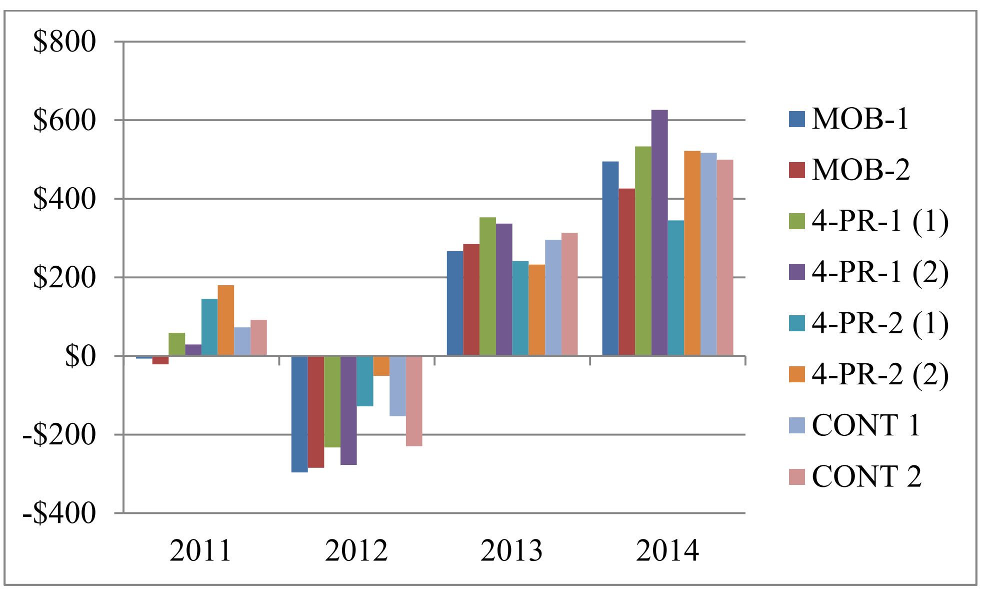
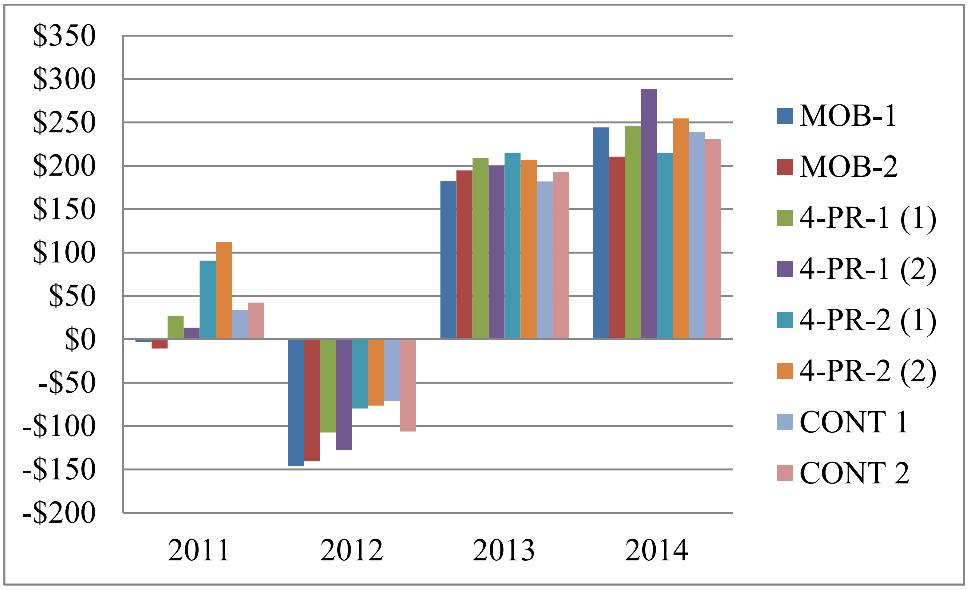


Figure 4-2: Average per Animal Returns to Labor and Management per System from 2011-2014



<u>Total Revenue</u>

Total revenue from a system shows the potential of a system to generate returns. The system 4-PR-1 had the highest average total revenue per animal (Table 4-5 and Table 4-6). The 4-PR-2 system had the second highest average total revenue per animal followed by CONT and MOB. Part of the reasoning behind 4-PR-1 outperforming 4-PR-2 was due to price slide effect. The selling price of the animal for each system was based on 100-pound weight increments; for example, 800-900 pounds. Cattle in 4-PR-2 had a high rate of gain in the first two years of the study; which caused them to be sold in a higher weight class than the other rotations, specifically 4-PR-1.

The price slide becomes apparent here. Cattle in 4-PR-2 would be on the lower end of the next 100-pound range (800-900 pounds), and cattle in 4-PR-1 would be in the higher end of the lower weight range (700-800). There would be a price slide between the two weight groups, but it may not have been as dramatic as the study shows. However, the difference in average total revenue per animal for 4-PR-1 and 4-PR-2 was $0.07. CONT on average was about $4.70 less than 4-PR-1 and 4-PR-2. MOB had the lowest mean total revenue per animal. Poor animal performance, especially in the first two years of the study, was the main factor behind this result.

Table 4-5: Rankings of Average Total Revenue per Animal Using Different Static Risk Analysis Strategies

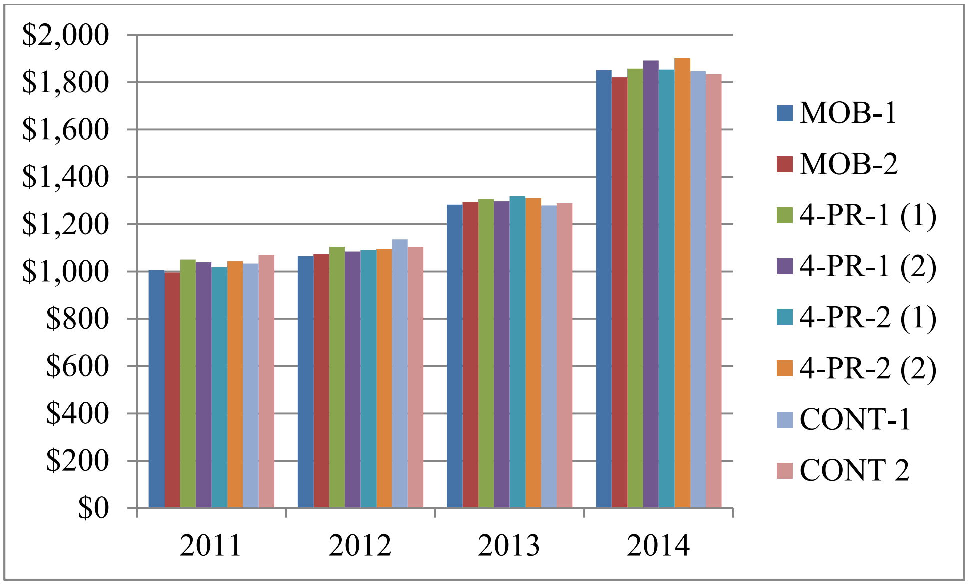
	Mean	Standard Deviation	Coefficient of Variation	Mini-Max
MOB	4	2	4	3
4-PR-1	1	3	2	1
4-PR-2	2	4	3	4
CONT	3	1	1	2

Table 4-6: Average Total Revenue per Animal Used for Risk Ranking

	Mean ($)	Standard Deviation ($)	Coefficient of Variation (%)	Mini-Max ($)
MOB	1,298.70	350.54	26.99	302.68
4-PR-1	1,328.80	352.51	26.53	290.02
4-PR-2	1,328.73	357.05	26.87	310.90
CONT	1,324.03	331.51	25.04	290.51

The CONT system had the smallest standard deviation and coefficient of variation per animal compared to the other three systems. This means that CONT has the smallest absolute and relative risk. The difference in standard deviations and coefficient of variation of 4-PR-1, 4-PR-2, and MOB were however, very small. Finally, 4-PR-1 had the smallest mini-max. This would mean that if something within the system would become unfavorable, 4-PR-1 would be the preferred system. CONT, MOB, and 4-PR-2 followed. Figure 4-3 shows how total revenue per animal varied little between systems per year. The biggest change in total revenue per animal was due to increased prices in 2014.

Figure 4-3: Total Revenue per System per Animal from 2011-2014



Other important trends appear between systems when total revenue is examined per acre (Table 4-7 and Table 4-8). 4-PR-1 had the highest average total revenue per acre, followed by CONT, MOB, and 4-PR-2. However, since each system has different stocking rates, the mean total revenue per acre is virtually useless for analysis purposes. The system with the highest number of animals should have the highest average revenues, as long as ADG differences are small. 4-PR-2 has the lowest per acre absolute risk of the four systems, but had the highest relative risks. The standard deviation of 4-PR-2 is $140 less than the next closest system. When the systems are compared using relative risk per acre, the coefficient of variation is smallest for CONT, followed by 4-PR-1, MOB and 4-PR-2. Finally, the mini-max variable is smallest for 4-PR-2. If something related to total revenue became unfavorable, 4-PR-2 total revenue would decrease by the least amount.

Table 4-7: Rankings of Average Total Revenue per Acre Using Different Static Risk Analysis Strategies

	Mean	Standard Deviation	Coefficient of Variation	Mini-Max
MOB	3	2	3	3
4-PR-1	1	4	2	2
4-PR-2	4	1	4	1
CONT	2	3	1	4

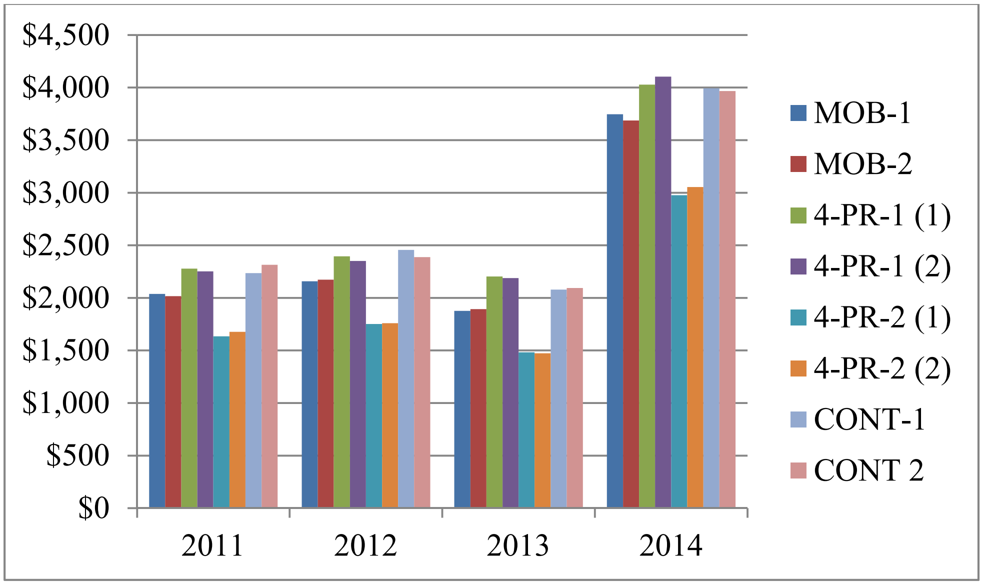
Table 4-8: Average Total Revenue per Acre Used for Risk Ranking

	Mean ($)	Standard Deviation ($)	Coefficient of Variation (%)	Mini-Max ($)
MOB	2,448.65	790.50	32.28	572.96
4-PR-1	2,725.28	830.58	30.48	537.31
4-PR-2	1,976.19	650.50	32.92	502.51
CONT	2,690.70	806.40	29.97	612.11

Figure 4-4 shows the total revenue per acre per system from 2011-2014. The ranking of the mean from Table 4-7 becomes evident in the figure. In each year, 4-PR-1 clearly has higher total revenue per acre than MOB, and MOB has higher total revenue per acre than 4-PR-2 in all four years. The CONT system total revenue is very close to 4-PR-1 in each year. Part of the differences and similarities between systems is due to the stocking rates. In the figure, 2013 has the lowest levels of total revenue for each replication; this was due to a decrease in stocking rates. As stated by Smart et al. (2010), higher stocking rates per acre lead to more pounds of beef produced per acre. The gain per acre would be translated into higher total revenues per acre. This was one of the reasons some producers switched to MOB systems.

Total revenue is also highly dependent on cattle prices. Higher per acre total revenue in 2014 was due to these higher prices and is very evident on the graph. Finally, the interaction between the stocking rates, animal performance, and sale price can be viewed in the graph. 4-PR-2 had the lowest stocking rate, but the highest ADG in 2011. This combination kept the system more competitive on total revenue per acre in 2011 compared to all the systems having a combination of good ADG and high cattle prices in 2014.

Figure 4-4: Total Revenue per Acre per System from 2011-2014



<u>Infrastructure and Labor Costs</u>

Infrastructure and labor cost consists of two major parts: infrastructure materials needed for each system and the labor costs of moving animals through each system. For MOB, the infrastructure costs consisted of the fencing materials, a portable water tank, and water line in the first year. After the first year, all infrastructure costs were maintenance costs of the fence. For 4-PR-1 and 4-PR-2, the infrastructure costs in the first year were the installation costs of the fence; thereafter, all infrastructure costs were maintenance costs. All labor costs within the system were the costs of moving cattle from one paddock to another. CONT will not be examined in this section, since there are neither labor costs in moving the animals nor infrastructure costs of maintaining cross fences.

Table 4-9 and Table 4-10 show the ranking of each system along with the respective values for each variable per acre. MOB ranked the most favorable in all four cases for infrastructure and labor costs per acre. The main reason behind this ranking is the low purchase cost and maintenance costs for the fencing materials needed for mob grazing. However, low infrastructure costs were greatly offset by the high labor cost associated with MOB grazing.

Table 4-9: Rankings of Infrastructure and Labor Costs per Acre Using Different Static Risk Analysis Strategies

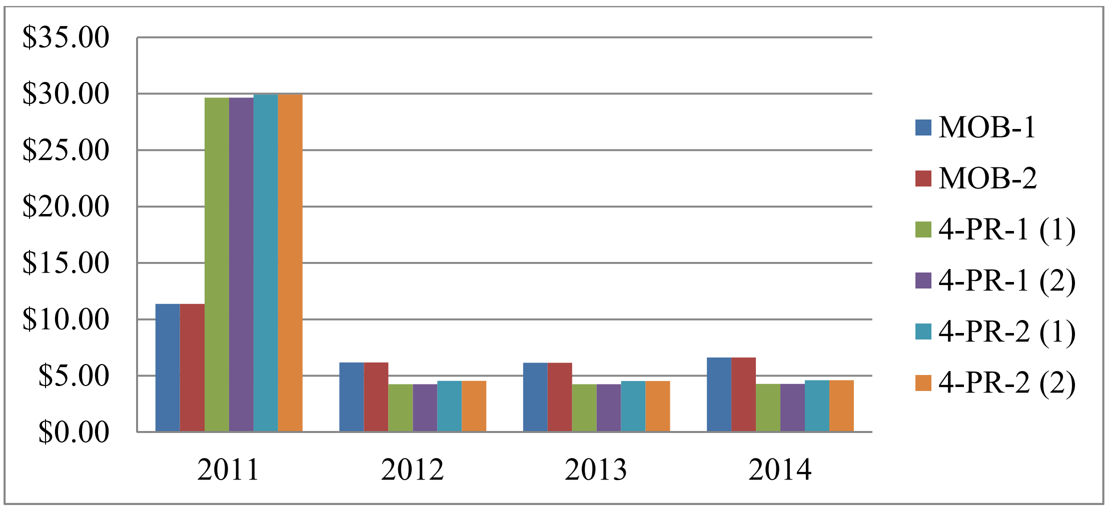
	Mean	Standard Deviation	Coefficient of Variation	Mini-Max
MOB	1	1	1	1
4-PR-1	2	3	3	2
4-PR-2	3	2	2	3

Table 4-10: Infrastructure and Labor Costs per Acre Used for Risk Ranking

	Mean ($)	Standard Deviation ($)	Coefficient of Variation (%)	Mini-Max ($)
MOB	7.58	2.34	30.94	1.43
4-PR-1	10.61	11.75	110.79	6.36
4-PR-2	10.90	11.74	107.69	6.36

Figure 4-3 shows the infrastructure and labor costs per acre of the four years of the study. MOB was the lowest installation costs when compared 4-PR-1 and 4-PR-2. This caused MOB to have the lowest costs in 2011. However, starting in 2012 through 2014, MOB had the highest infrastructure and labor costs. The annual maintenance cost was cheaper for the fence in the MOB system when compared to 4-PR-1 and 4-PR-2. However, the high labor costs of the system caused MOB to have the higher per acre costs from 2012 through 2014. One more year of data would have had important implications for the infrastructure and labor cost. The fence used in the MOB system only had a lifespan of 4 years. In the 4-PR-1 and 4-PR-2 systems; the fence had a lifespan of 20 years. Having to replace the fence for the MOB system would cause it to have higher infrastructure costs every fifth year compared to 4-PR-1 and 4-PR-2. This may cause the system to become unfavorable as new materials are purchased or as labor costs increase.

Figure 4-5: Infrastructure and Labor Costs per Acre per System from 2011-2014



On a per animal basis, MOB has the lowest labor and infrastructure costs, but has the highest absolute and relative risk. Through the duration of the study the hourly labor rate charged increased; this fact caused MOB to have a higher absolute and relative risk. The system 4-PR-1 ranks second for labor and infrastructure cost per animal due to lower labor demands. Even though MOB ranks above 4-PR-1 on average costs, 4-PR-1 ranks better in the final three categories, which makes the system more favorable. Also, on average the difference between the two systems is $0.20 per animal. Systems 4-PR-1 and

4-PR-2 were more closely related on absolute and relative risk than either system with MOB.

Table 4-11: Rankings of Infrastructure and Labor Costs per Animal Using Different Static Risk Analysis Strategies

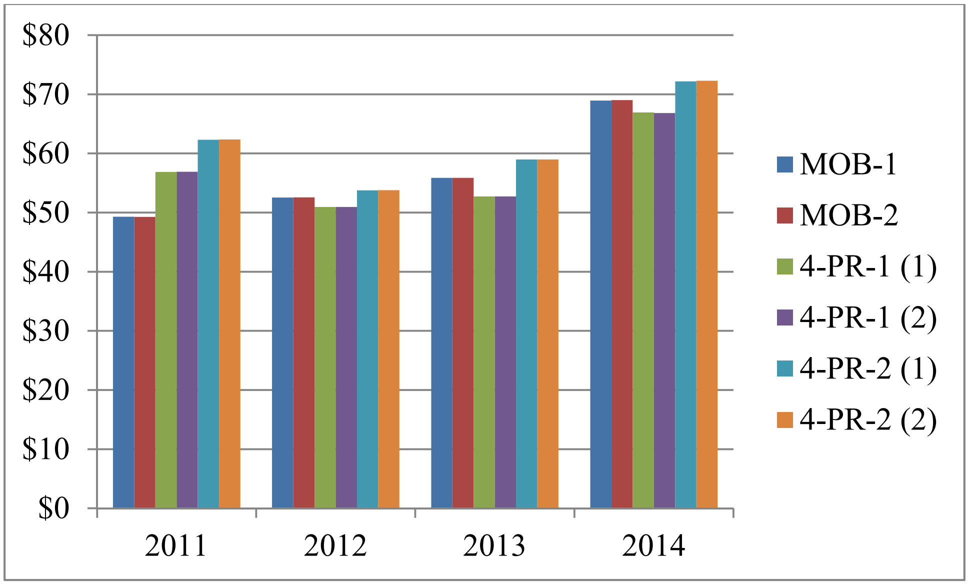
	Mean	Standard Deviation	Coefficient of Variation	Mini-Max
MOB	1	3	3	2
4-PR-1	2	1	1	1
4-PR-2	3	2	2	3

Table 4-12: Infrastructure and Labor Costs per Animal Used for Risk Ranking

	Mean ($)	Standard Deviation ($)	Coefficient of Variation (%)	Mini-Max ($)
MOB	56.67	7.99	14.10	7.41
4-PR-1	56.87	6.60	11.60	5.91
4-PR-2	61.83	7.20	11.64	8.07

In 2011, the low purchase cost of the infrastructure needed for MOB was less compared to the infrastructure cost of the other two systems (Figure 4-6). Thereafter, infrastructure costs played less of a role in the difference between systems. This fact is because the maintenance cost was less than the original purchase and installation costs in all three systems. The system 4-PR-2 consistently had the highest cost per animals compared to 4-PR-1 per animal, throughout the study. The system had the same fencing maintenance cost as 4-PR-1, but 4-PR-2 had the higher labor cost due to animals being rotated twice as much through the system. A sharp increase in the labor cost caused per animal costs in 2014 to be higher than any previous year.

Figure 4-6: Infrastructure and Labor Costs per Animal per System from 2011-2014



<u>Total Cost</u>

Total cost is important when implementing any grazing system. Since the purchase price of cattle is incorporated into each system, looking at the total cost alone will give a bias, favoring the system with the least amount of animals. In this study, 4-PR-2 had the least amount of animals, making the overall cost of this system less than the other systems. Therefore, total costs will be evaluated on per animal and per acre basis. Total costs per animal will show the difference between grazing systems and the total costs per acre will show the differences between stocking densities.

Average total cost per animal was greatest for 4-PR-1 (Tables 4-13 and Table 4-14). 4-PR-1, however, had the lowest absolute and lowest relative risk among the four systems. Having a small standard deviation is important because it allows producers to better predict what the expected costs of the system will be. The system 4-PR-2 is the least preferred system for both absolute and relative risk per animal. CONT had lower infrastructure and labor costs than 4-PR-2 but ranked second in total costs per animal mostly due to beginning weights of the animals when they entered the system. Overall, CONT ranks favorably because of the lack of infrastructure and labor costs, which other systems in the study would incur.

Table 4-13: Rankings of Total Costs per Animal Using Different Static Risk Analysis Strategies

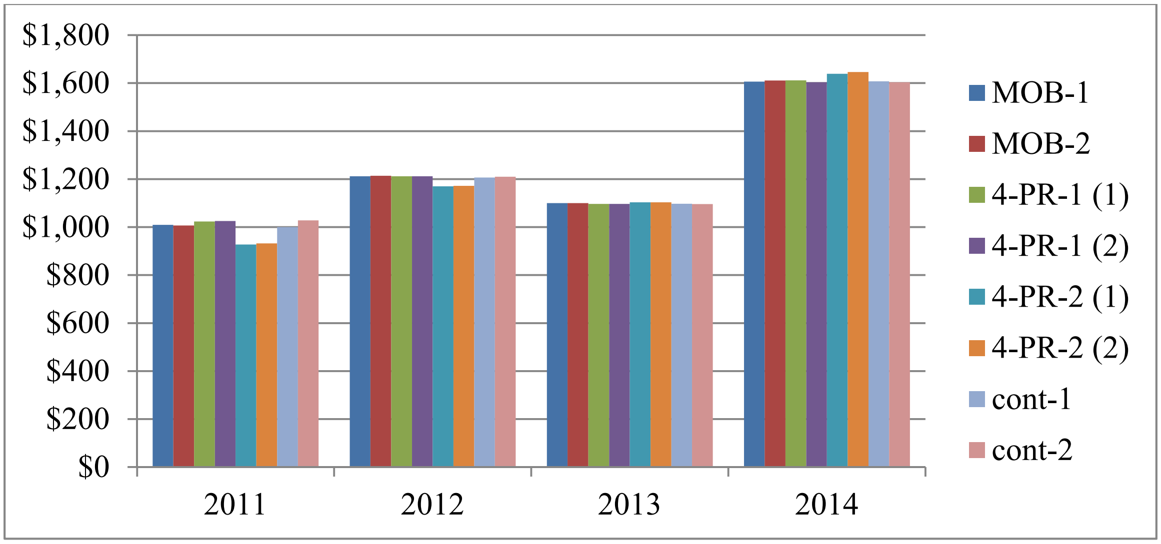
	Mean	Standard Deviation	Coefficient of Variation	Mini-Max
MOB	3	3	3	2
4-PR-1	4	1	1	1
4-PR-2	1	4	4	4
CONT	2	2	2	3

Table 4-14: Total Costs per Animal Used for Risk Ranking

	Mean ($)	Standard Deviation ($)	Coefficient of Variation (%)	Mini-Max ($)
MOB	1,232.26	244.76	19.86	225.77
4-PR-1	1,235.16	240.67	19.49	211.79
4-PR-2	1,211.52	282.14	23.29	284.31
CONT	1,231.07	242.72	19.72	231.20

Total costs per animal were greatest in the final year of the study. This was mostly due to the high purchase price of the cattle. Figure 4-7 shows the total costs per replication in each system from 2011-2014. In 2011, 4-PR-2 had the lowest total costs per animal. However, the animals placed in 4-PR-2 were smaller on average, so the smaller weights gave these cattle a lower purchasing cost. In all other years, total costs per animal were very similar. Increased labor costs per animal in MOB were offset by higher infrastructure costs in both 4-PR-1 and 4-PR-2. Even with labor and infrastructure costs per animal lacking in the CONT systems, it was ranked very similar to the rotational grazing systems.

Figure 4-7: Total Costs per Animal per System from 2011-2014



When total costs per acre are examined, the difference in stocking rates becomes more apparent. Tables 4-15 and 4-16 show the ranks of each system and their respective numerical values. The rotational system 4-PR-2 ranks best for average total costs per acre. The average total costs for 4-PR-2 was $527.35 less than MOB, $701.59 less than CONT, and $733.50 on average less than 4-PR-1 per acre. However, since the difference in the mean total cost is attributed to the stocking rate, little value can be drawn from this data. When observing absolute risk, 4-PR-2 was the most favorable. MOB, CONT, and 4-PR-1 were closely ranked in absolute risk. When relative risk is observed, 4-PR-1 is the most favorable system followed by CONT, MOB and 4-PR-2. Finally, 4-PR-2 was most favorable for mini-max, but has little interpretation in this context.

Table 4-15: Rankings of Total Costs per Acre Using Different Static Risk Analysis Strategies

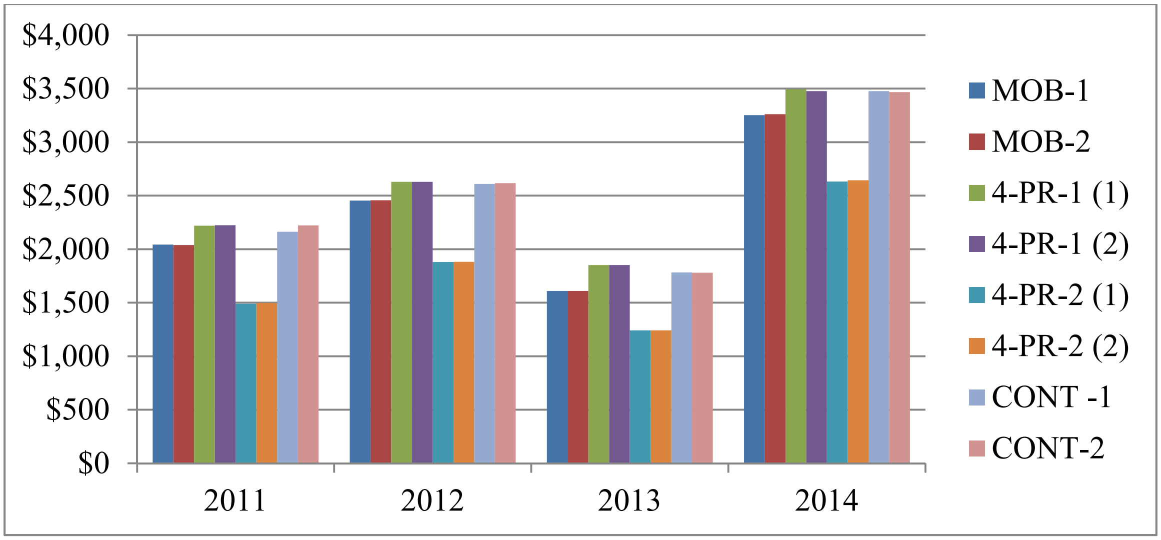
	Mean	Standard Deviation	Coefficient of Variation	Mini-Max
MOB	2	2	3	3
4-PR-1	4	3	1	2
4-PR-2	1	1	4	1
CONT	3	4	2	4

Table 4-16: Total costs per Acre Used for Risk Ranking

	Mean ($)	Standard Deviation ($)	Coefficient of Variation (%)	Mini-Max ($)
MOB	2,340.63	649.89	27.77	731.81
4-PR-1	2,546.78	650.08	25.53	695.73
4-PR-2	1,813.28	564.42	31.13	572.21
CONT	2,514.87	669.32	26.61	734.30

The average total costs per acre were lower for 4-PR-2 compared to all other rotations in each of the respective years. Figure 4-8 displays the total costs per acre from 2011-2014. The differences due to different management systems are not as apparent. In 2013, stocking rates were decreased in all systems; this caused the total costs per acre to be the smallest in all four years. Stocking rates returned to previous levels in 2014. Changes in cattle prices have the biggest effect on total costs per acre when stocking rates remain constant. The systems 4-PR-1 and CONT had similar stocking rates, but the cattle placed in 4-PR-1 were slightly smaller. The added labor and infrastructure costs caused 4-PR-1 to be higher than CONT, but only slightly.

Figure4-8: Total Costs per Acre per Systems from 2011-2014



<u>Summary</u>

Using the empirical data, budget analysis indicated that the system 4-PR-2 was the best system for returns to labor and management. It ranked first in mean, standard deviation, coefficient of variation, and min-max for returns to labor and management for both per acre and per animal. The MOB system ranked last for average returns to labor and management both per acre and per animal. The system also ranked poorly for absolute and relative risk measures. The Mob system appeared to have advantages on labor and infrastructure costs; however a longer timeline or a higher labor cost may change this advantage. Since total cost cannot differentiate the fact some systems have heavier stocking rates, the ranking of MOB compared to other systems gives little overall insight.

Chapter V: Stochastic Results and Discussion

This chapter of the thesis will feature two major sections. The first section will use the empirical data and the simulation capabilities of Simetar© for further analysis in order to rank systems according to risk preferences. In the second section, a sensitivity analysis of returns to labor and management will further examine how average daily gains (ADG) affect each system. Within each section, the budgets will be recalculated to test how sensitive the returns to each system will be at different animal performance levels.

Stochastic Analysis

Simetar© was used to execute Stochastic Dominance with Respect to a Function (SDRF) and Stochastic Efficiency with Respect to a Function (SERF). By doing SDRF and SERF, each grazing system can be evaluated based on risk preferences. First, each system's return to labor and management were simulated 1000 times for each replication in each year. Next, the two separate replications were combined to create 8000 separate data points for each rotation. The aggregated data was used to perform SDRF and SERF, consisting of 32,000 total data points. Output from SDRF and SERF are as follows: probability of return to labor and management (stoplight function), cumulative distribution functions (CDF), efficient set based on SDRF, stochastic efficiency ranks schedule, and negative exponential utility weight risk premiums.

Finally, the returns to labor and management will be observed on both a per animal and a per acre basis. As found by Smart et al. (2010), as stocking rate increases, individual animal performance decreases, while overall animal performance per acre increases. By examining both scenarios, insights can be gained on whether the tradeoff of animal performance is actually profitable for a producer. Individual animal performance is important, because poor performance can cause the overall system to be unprofitable. Redden (2014) found that MOB had no additional agronomic benefits to the plant community or soil. With no agronomic benefits found, the tradeoff between animal performance and soil/plant health does not exist and will not help the systems with increased profitability.

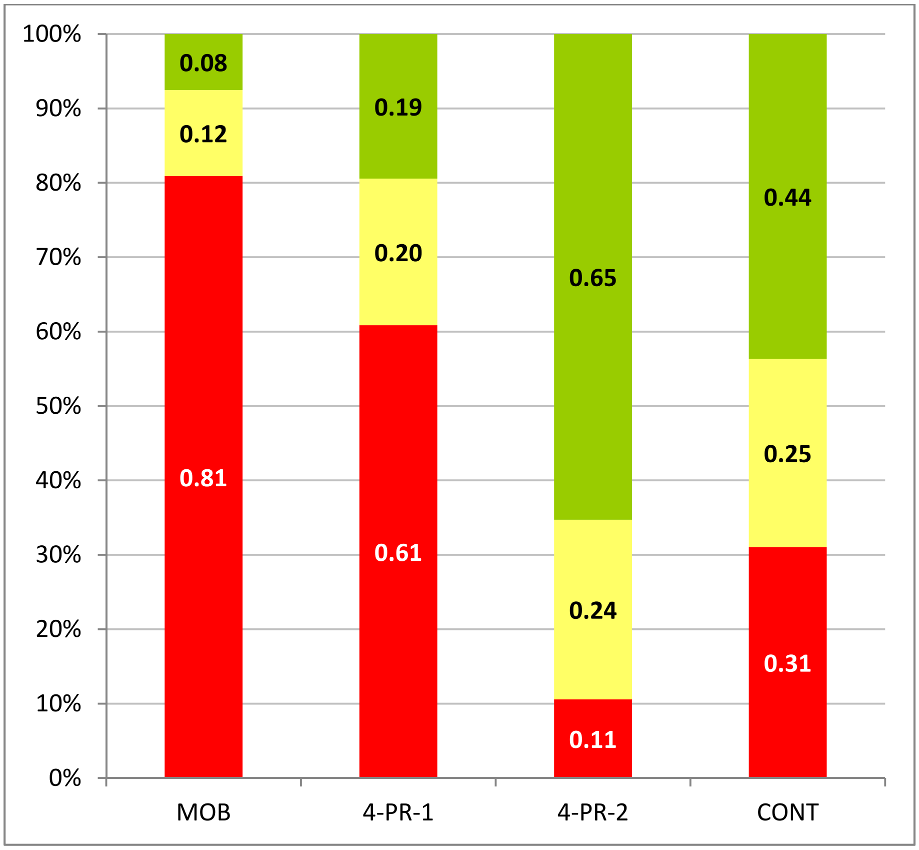
Stoplight analysis

The stoplight analysis allows for three different scenarios to be set up for analysis purposes. In a stoplight analysis, an upper cut-off value and a lower cut-off value are chosen as noteworthy points in the analysis. Simetar© will examine the data and assign probabilities of the data being below the lower cut-off value, between the lower and upper cut-off value, and finally above the upper cut-off value. The probabilities are then compiled into a chart (Figure 5-1 and Figure 5-2). The vertical axis of the figure is probabilities ranging from 0-1; the bottom of each bar represent the respective grazing systems. The name stoplight is drawn from the color of the chart. The probability below the lower cut-off value is red, between the lower and upper is yellow, and above the upper value is green.

The lower cut-off value is $0.00 per animal. This will allow the probability of negative returns per animal per system to be found. The next range is from $0.00 to $31.30 per animal, which will state the probability of individual animal returns falling within this range. Finally, returns greater than $31.30 will show the probability of returns per animal to be greater than $31.30 per animal in each rotation. The stoplight analysis per acre works the same as per animal stoplight. However, the upper cut-off value for per acre analysis was $25.00. The reason these values were chosen as the upper cut-off values is done with respect to cost. In the budgets, the highest AUM amount was $31.30 and the highest rent cost per acre was $25.00. Using these values provides insight on the probability of having returns above leasing the pasture per acre or per AUM. In the original budgets, the AUM was used as a cost variable. However, knowing the amount of the actual AUM rate is helpful. Using the highest AUM rate and highest cash rental rate, the probabilities of having returns higher than what a land owner would receive from cash renting the land is found.

MOB had a high probability of negative returns per animal at 81 percent. Next, the probability of 4-PR-1 being unprofitable per animal was 61 percent, followed by CONT at 31 percent and 4-PR-2 at 11 percent. Profitability above $31.30 an animal for 4-PR-2 was 65 percent of the time followed by CONT with a 44 percent chance. Both 4-PR-1 and MOB had a very low probability of having returns per animal over $31.30, nineteen percent and eight percent, respectively. A risk averse producer would likely view the risk associated with these two systems as too high for implementation. With such a low probability of returns above the leasing rate, a producer would not likely use 4-PR-1 or MOB.

Figure 5-1: Probabilities of Returns to Labor and Management Less Than $0.00 and Greater Than $31.30 per Animal.

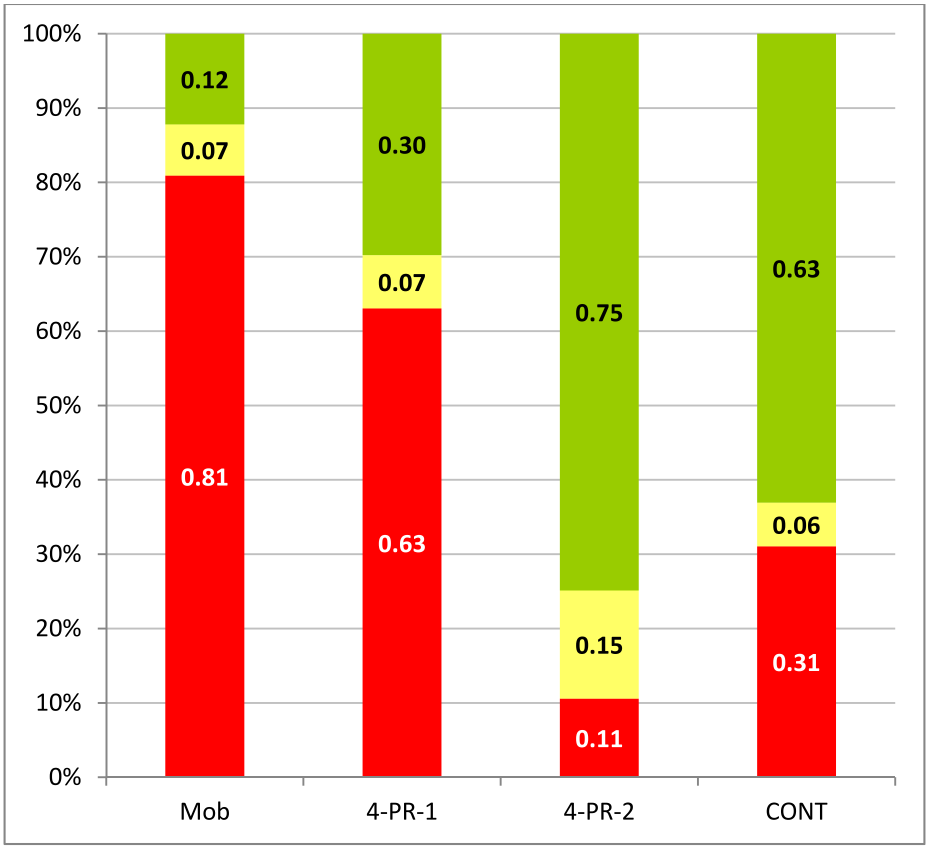


In Figure 5-2, the probabilities of returns are examined on a per acre basis. There are little changes on the probability of negative returns in each system compared to the per animal stoplight function. However, the probability of negative returns increased to 63 percent for 4-PR-1. The probability of having returns above the maximum cut-off value increased for all systems when examined on a per acre basis. 4-PR-2 has the highest probability at 75 percent, followed by CONT at 63 percent. The probabilities of returns for both 4-PR-1 and MOB greater than $25 are less than half of that of CONT.

One important implication is found from the stoplight analysis. The decreased individual animal performance is not compensated for by increased returns of overall animal performance per acre. The probability of positive returns did not increase for

MOB when returns were examined on a per animal and a per acre basis. Under both models, 4-PR-2 performed the best, followed by CONT, 4-PR-1, and MOB.

Figure 5-2: Probabilities of Returns to Labor and Management Less Than $0.00 and Greater Than $25.00 per Acre



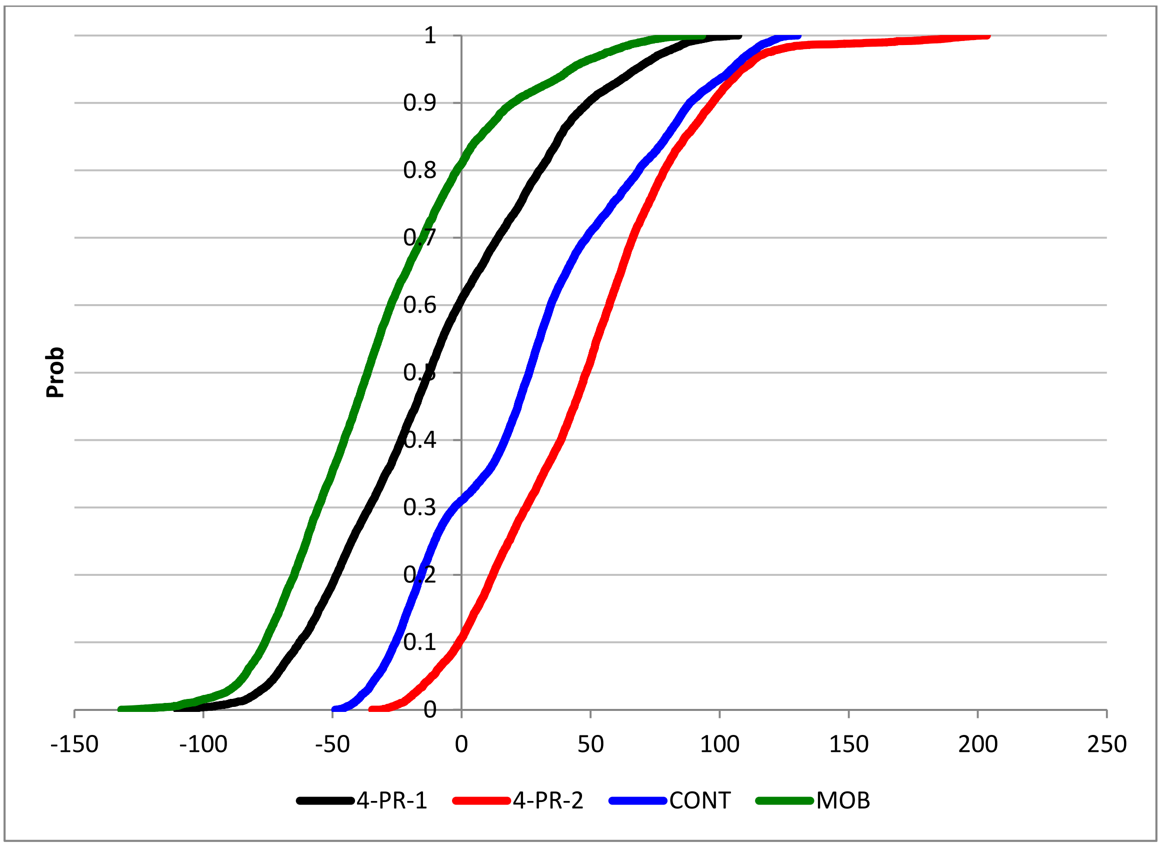
Cumulative Distribution of Returns to Labor and Management

By examining the cumulative distribution functions (CDF) for all systems based on returns per acre and returns per animal, the probability of a specific level of returns occurring can be verified. In a CDF, the y-axis is the probability of variable X occurring and the x-axis is the value of X. Therefore, at any certain point on the distribution, the probability of X or any value less than X occurring can be found by matching the point where X occurs on the CDF with the y-axis.

Figure 5-3 displays the CDF per animal and figure 5-4 displays the CDF per acre. When examining CDF, the system whose distribution is furthest towards the right is the more preferred system. The system 4-PR-2 is a dominant system for returns per animal. However, when returns per acre are examined, no system is dominant.

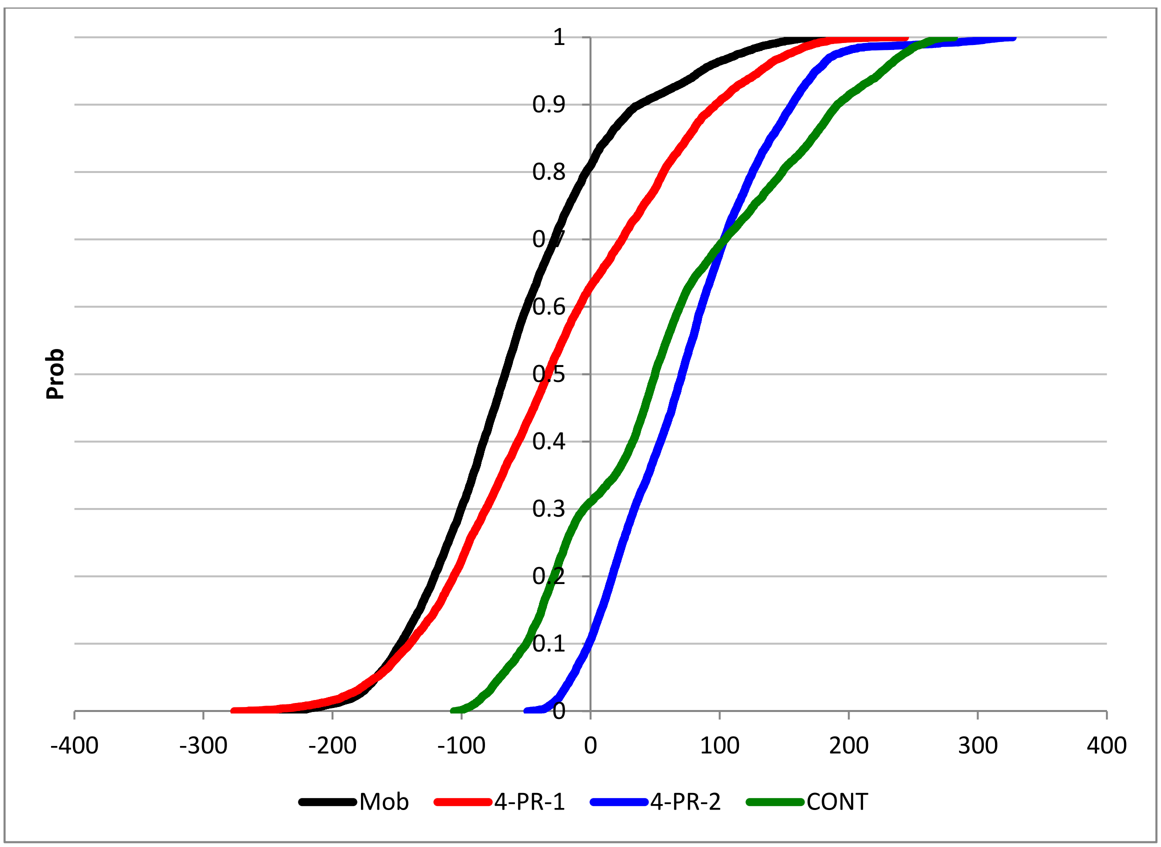
CDFs do not take into account risk preferences when mapped. MOB has the highest probability of negative returns, and it also has the highest probability to lose the most money compared to other systems per animal; whereas 4-PR-2 has the lowest probability of negative returns and the possibility to have higher returns per animal. According to the CDF, 4-PR-2 has a ten percent probability of having returns over $100 per animal.

Figure 5-3: Cumulative Distribution Function of Returns to Labor and Management per Animal



Different characteristics emerge when the returns to labor and management are examined on a per acre level. CONT is a more favorable system than 4-PR-2 from the probabilities 70 percent to 95 percent. MOB is slightly preferred to 4-PR-1 up to seven percent. The system 4-PR-1 has a capability of greater negative returns compared to MOB. Another important insight is that for the majority of the distribution, MOB has the lowest amount of returns per acre. In fact, the probability of the returns to labor and management being less $100 per acre accounted for 90% of the distribution for MOB and 4-PR-1.

Figure 5-4: Cumulative Distribution Function of Returns to Labor and Management per Acre



Risk aversion

The stochastic dominance with respect to a function will rank the efficient set based on a certain level of risk aversion. Tables 5-1 and 5-2 display SDRF per animal and per acre, respectively. According to SDRF, there are no preference changes per animal in the ranking of the systems as risk aversion increases. However, SDRF per acre finds a shift in risk preferences as risk aversion increase. A risk neutral person would rank MOB last, but as risk aversion starts to increase, 4-PR-1 becomes the least preferred system per acre.

Table 5-1: Stochastic Dominance with Respect to a Function per Animal

Efficient Set Based on SDRF at					
	Lower RAC	**0**		Upper RAC	**1**
	Name	Level of Preference		Name	Level of Preference
1	4-PR-2	Most Preferred	1	4-PR-2	Most Preferred
2	CONT	2nd Most Preferred	2	CONT	2nd Most Preferred
3	4-PR-1	3rd Most Preferred	3	4-PR-1	3rd Most Preferred
4	MOB	Least Preferred	4	MOB	Least Preferred

Table 5-2: Stochastic Dominance with Respect to a Function per Acre

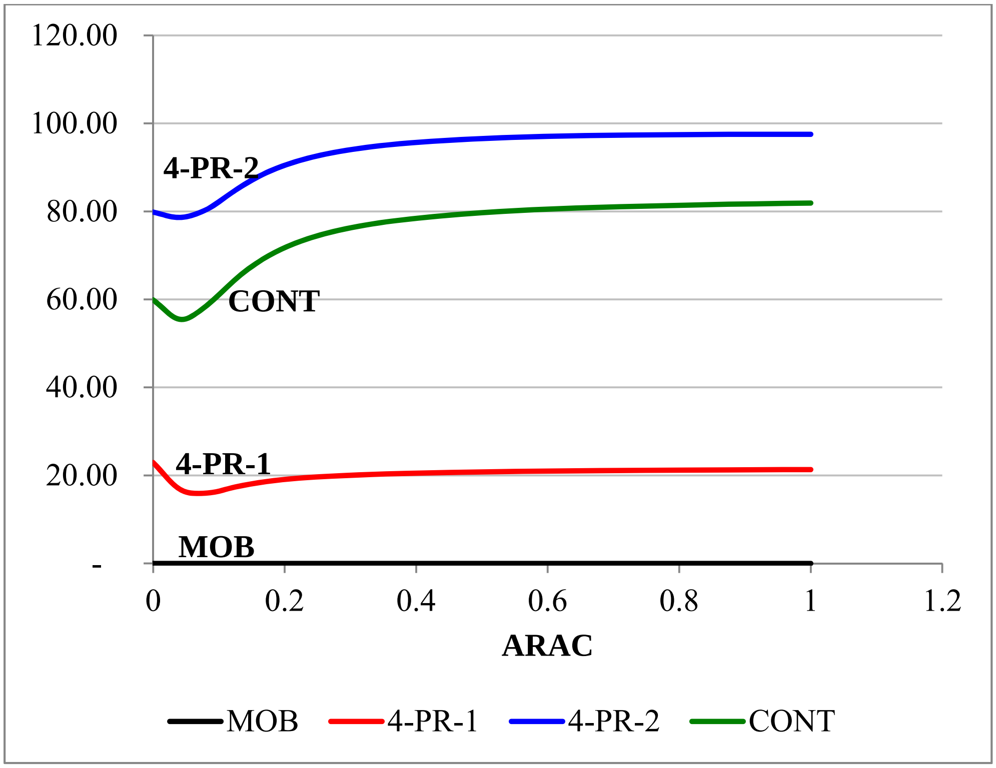
Efficient Set Based on SDRF at					
	Lower RAC	**0**		Upper RAC	**1**
	Name	Level of Preference		Name	Level of Preference
1	4-PR-2	Most Preferred	1	4-PR-2	Most Preferred
2	CONT	2nd Most Preferred	2	CONT	2nd Most Preferred
3	4-PR-1	3rd Most Preferred	3	MOB	3rd Most Preferred
4	MOB	Least Preferred	4	4-PR-1	Least Preferred

In order to better define when risk preferences change, Stochastic Efficiency with Respect to a Function must be performed. The SERF function does not give any extra insight per animal than SDRF. No additional insights are available because risk preferences do not change as risk aversion changes. However, SERF tells an important story per acre. The top two performing systems, 4-PR-2 and CONT, do not change as risk aversion coefficients (RAC) change per acre, but the systems 4-PR-1 and MOB do change rankings. When the RAC is 0, 4-PR-1 ranks above MOB and remains ranked above MOB until the RAC becomes .0417. At this point, MOB becomes the third most preferred system.

Risk Premiums

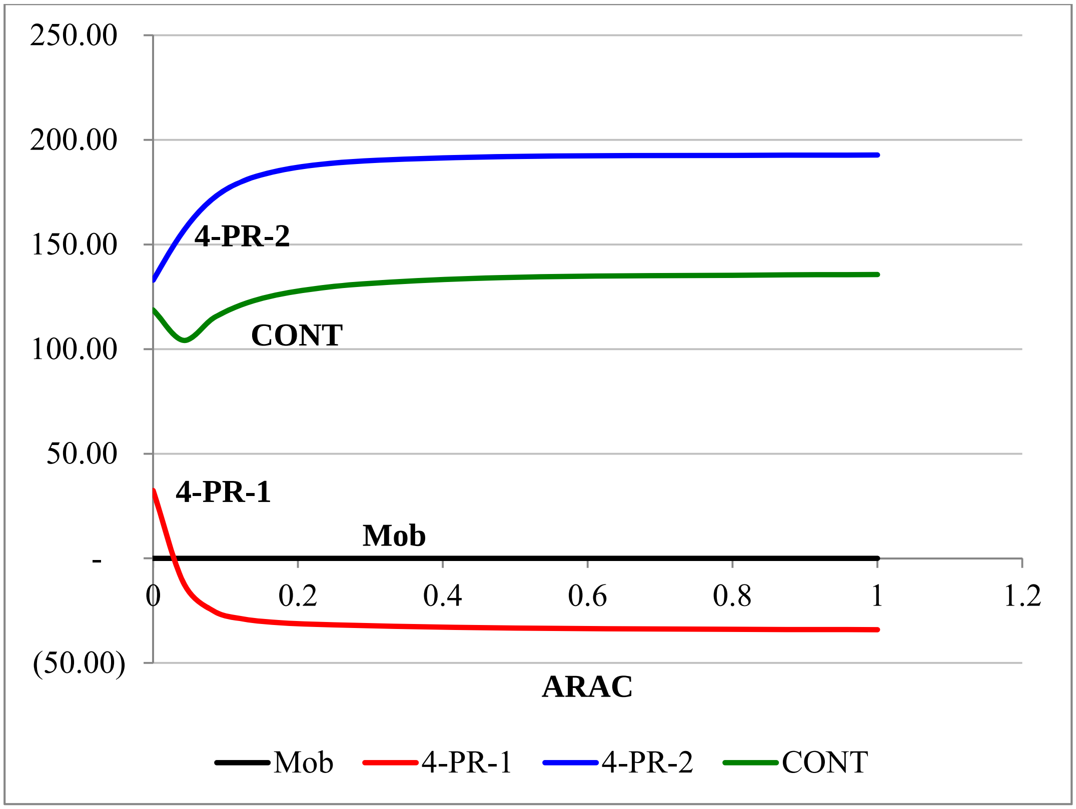
A risk premium is the amount a producer would have to receive to be indifferent between two systems. In Figure 5-5, MOB is the baseline for the analysis. At an absolute risk aversion coefficient (ARAC) of 0, a producer would need a $79.84 payment per animal to switch from 4-PR-2 to MOB, $59.89 per animal to switch from continuous to MOB and $22.92 per animal to switch from 4-PR-1 to MOB. A slight increase in ARAC causes the risk premium to decrease slightly for all rotations. However, when the ARAC is increased to 1, the risk premiums per animal for 4-PR-2, CONT, and 4-PR-1 are $91.53, $81.90, and $21.33. The system 4-PR-1 is the only system whose risk premium at ARAC of 1 is less than the risk premium at ARAC of 0. However, all systems would need a positive risk premium to switch to MOB.

Figure 5-5: Negative Exponential Utility Weighted Risk Premiums Relative to MOB per Animal



In Figure 5-6, risk premiums are examined on a per acre basis. Again, MOB is the baseline for this analysis. At an ARAC of zero, the risk premium needed to switch from 4-PR-2, CONT, and 4-PR-1 to MOB is \$132.96, \$118.70 and \$32.43 per acre, respectively. When the ARAC switches to .0417, the risk premium for 4-PR-1 becomes negative (\$-11.47). This means a producer would need to receive a risk premium to switch from MOB to 4-PR-1. When the ARAC is increased to one, a producer would require a risk premium of \$192.73 and \$135.62 an acre to switch from 4-PR-2 and CONT to MOB. A producer would need a risk premium of \$34.10 an acre to switch from MOB to 4-PR-1. Therefore, MOB is more preferred per acre to 4-PR-1 as risk aversion increases.

Figure 5-6: Negative Exponential Utility Weighted Risk Premiums Relative to MOB per Acre



<u>Summary</u>

Using Simetar© to simulate variables allows for further analysis among the grazing systems. The MOB system had a high probability of having negative returns. The system ranked last on a per animal basis no matter the level of risk aversion. A risk neutral producer would not choose MOB. However, as risk aversion increases, MOB becomes a more preferred system per acre relative to 4-PR-1. A risk neutral producer would have to receive some kind of risk premium in order to switch to a mob grazing system. However, if the agronomic conditions users of the system claim to be true are found to be valid, the risk premium required would decrease.

Sensitivity analysis

The 4-PR-2 rotation is comparable to grazing systems currently used by most local ranchers. This system also had the lowest stocking rate. One of the objectives in this paper was to test the sensitivity of profits according to changes in the systems. Researchers such as: Smart et al. (2010), Rogler (1951), and McCollum III et al. (1999) found that average daily gain per animal decreases when stocking rates are increased. However, the decrease in daily gain varied among locations in these studies. Therefore, in this section management changes are examined according to a producer switching from 4-PR-2 and increasing his stocking rates, and how much of a decrease in animal performance are still acceptable.

Across all four years of the study, the ADG was less for 4-PR-1, CONT, and MOB compared to the ADG of 4-PR-2 (Table 5-3). The actual average daily rate of gain can be seen in Table 3-3. Average daily gain for MOB was at least 37% lower than 4-PR-2 in all four years. In studies such as this, protocols are set to be strictly followed. Any changes to the system must be done only as a last resort. Because of this, average daily gains may be hindered due to constraints on management. The sensitivity analysis will give insights into management changes in the system that could make the system more effective. In this effect, the average daily gains will be increased from their levels in Table 5-3.

Table 5-3: Original Percentage difference of ADG in all system Relative to 4-PR-2

	2011	2012	2013	2014	Overall
4-PR-1	-65.1%	-42.0%	-52.6%	-19.3%	-45.9%
CONT	-51.0%	-10.3%	-24.9%	-1.9%	-25.2%
MOB	-86.4%	-63.1%	-61.6%	-37.9%	-64.4%

In their testimonies, producers gave details on how they make mob systems more effective. Mr. Pat Guptill (2013) says that if he moves animals more than once a day he gives the cattle ten percent more ground to graze. As the grazing season progresses, roughly around the first of July, Mr. Guptill starts to enlarge the paddock size due to lower forage quality. In his cow herd, Mr. Guptill has a high turnover in his cows. Mr. Guptill is always pushing his cows to be hardier and more efficient, which causes high turnover. Finally, he sells grass-fed beef in a niche market in order to receive a premium for his livestock (Guptill, 2013).

Another producer, Mr. Randy Holmquist (2013), only uses the mob system early in the grazing season when forage quality is at its highest. Mr. Chad Peterson (2013) uses Scottish Highlander cattle on his mob grazing operation because he feels these animals are more suited for a mob grazing setting. To help with profitability, Mr. Peterson uses idle resources he has around his ranch and does not have to buy many new inputs (Peterson, 2013). All three producers talked about monitoring the cattle and to assess how the cattle are reacting to the moves. The animal's performance will let you know if something with the systems is incorrect. Usually this means cattle were moved too soon, too late, or paddock size was not large enough.

Therefore, using this management information, the sensitivity analysis will be performed. The hypothesis of this section is that the producers realize management changes can help lessen the decrease in animal performance. The ADG from the original 4-PR-2 system will be the daily gain used in all four systems. This is due to the fact that 4-PR-2 is the baseline system. Next, the MOB, 4-PR-1, and CONT systems will have the new ADG reduced by 5%, 12.5%, and 25% to test the differences in profitability. In

Table 5-3, we can see that the new overall ADG has increased compared to the original data. Adjusting ADG relative to the original ADG would be more confusing to interpret. Therefore, a uniform decrease in ADG relative to 4-PR-2 is used instead.

The budget analysis will be performed in the same manner as previously done. However, 4-PR-2's ADG was aggregated to one budget. In all three scenarios, 4-PR-2 will use the same ADG throughout; whereas the other three systems will use only a percentage of 4-PR-2's ADG. Finally, since only one budget was used for each replication, there were only 1000 data points replicated for each year. This created a total of 16,000 data points to analyze with SDRF and SERF. Each scenario will have both returns per animal and returns per acre examined.

This section is important because it will help give insights on the amount ADG can decrease relative to the baseline system (4-PR-2) and still be a profitable system for the producer to adopt. By using some of the management suggestions from the local producers, the ability for these levels of ADG to be attained may be possible. Finally, this section will also help to investigate the economic tradeoff between decreases in animal performance due to increase in stocking rate for an overall increase in gain per acre.

5% Decrease in Animal Performance Analysis

In this scenario, the assumption is that increased stocking rates have very little effect on individual cattle rates of gain (-5%), but still affect them nonetheless. Figure 5-7 displays the stoplight analysis per animal. With only a five percent decrease in animal performance from the 4-PR-2 levels, all systems are very similar. MOB has the highest probability of negative returns per animal, while CONT has the highest probability of earning returns above the AUM rate. In Figure 5-8, returns to labor and management per acre are displayed. Although the probability of having negative returns per acre remained the same as the probability for negative returns per animal for all four systems, the probability of returns above the rental rate increased for all systems. CONT has the greatest probability of returns above the per acre rental rate, and 4-PR-1 appears to be better than 4-PR-2. However, the stoplight does not include risk or the amount of potential gain or loss in a system. Further analysis is needed.

Figure 5-7: Probabilities of Returns to Labor and Management Less Than $0.00 and Greater Than $31.30 per Animal with a 5% Decrease in Animal Performance

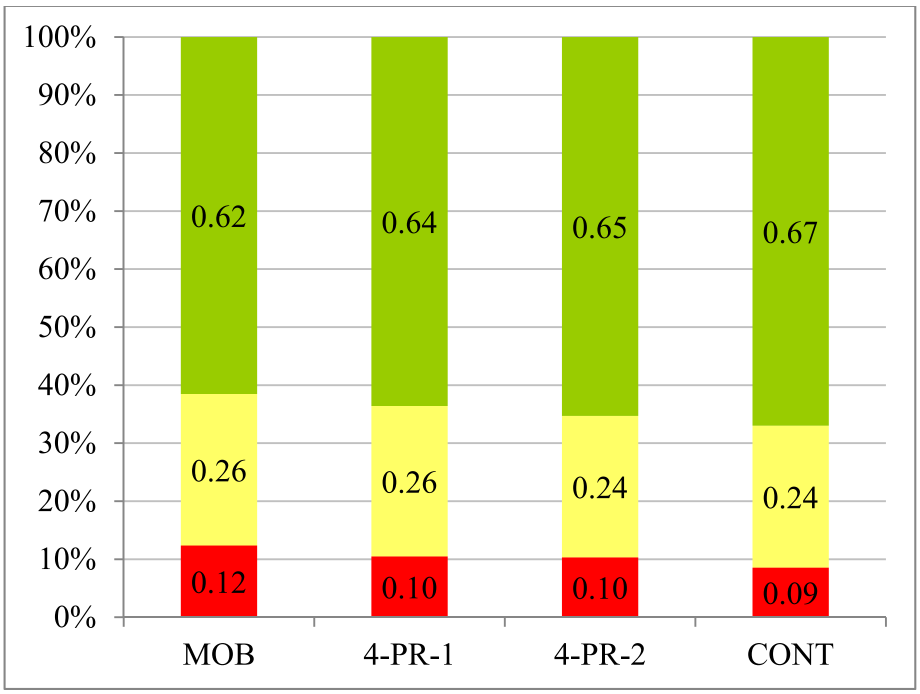
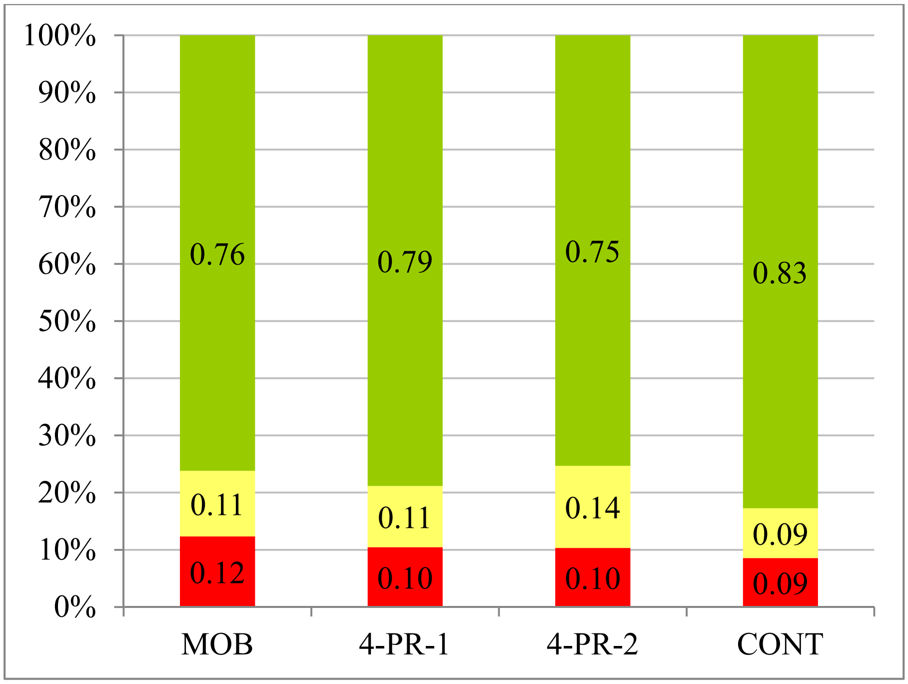


Figure 5-8: Probabilities of Returns to Labor and Management Less Than \$0.00 and Greater Than \$25.00 per Acre with a 5% Decrease in Animal Performance



Cumulative distribution functions display the probability of returns. In Figure 5-9, the CDF per animal has no clear dominant strategy. It appears that CONT is slightly towards the right of the other rotations, but not far enough to be considered a dominant strategy. 4-PR-1 is to the left of all other rotations once a probability of 50 percent is reached, but not much more insight can be drawn. In Figure 5-10, returns per acre appear to discount 4-PR-2 the most, as it appears to the left of the other rotations for the majority of the distribution. On the right side of the distribution, the returns to labor and management for CONT help make it the preferred strategy.

Figure 5-9: Cumulative Distribution Function of Returns to Labor and Management per Animal with a 5% Decrease in Animal Performance

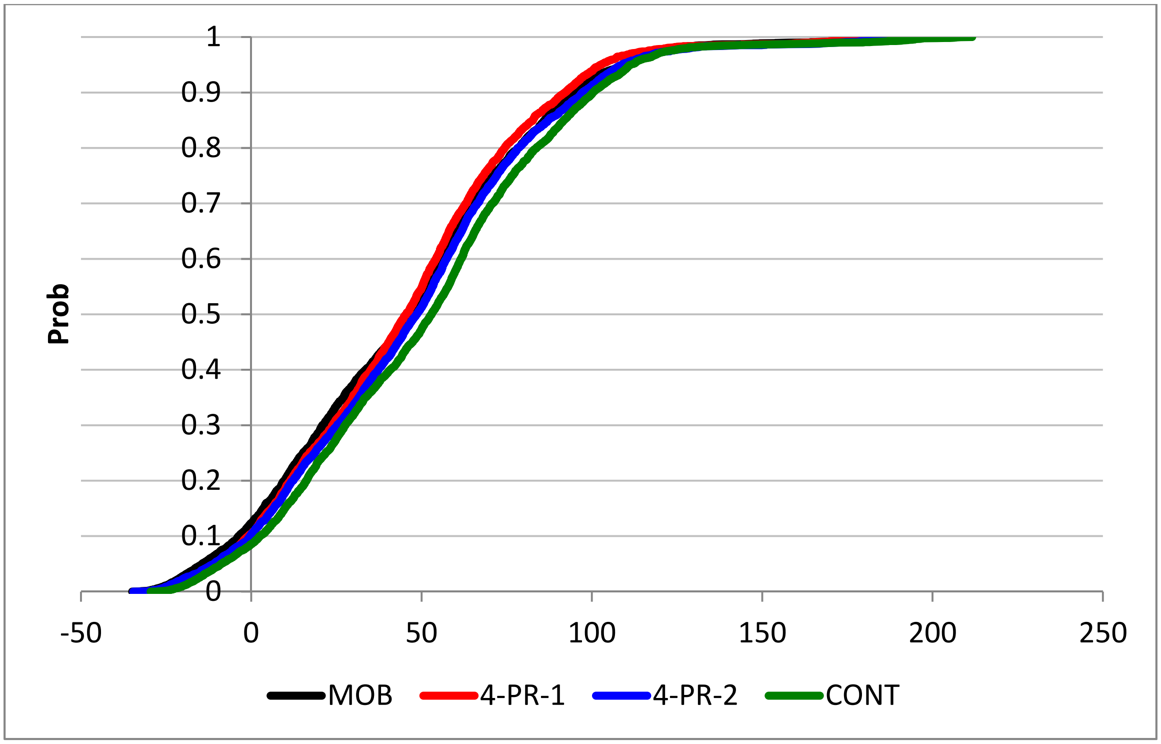
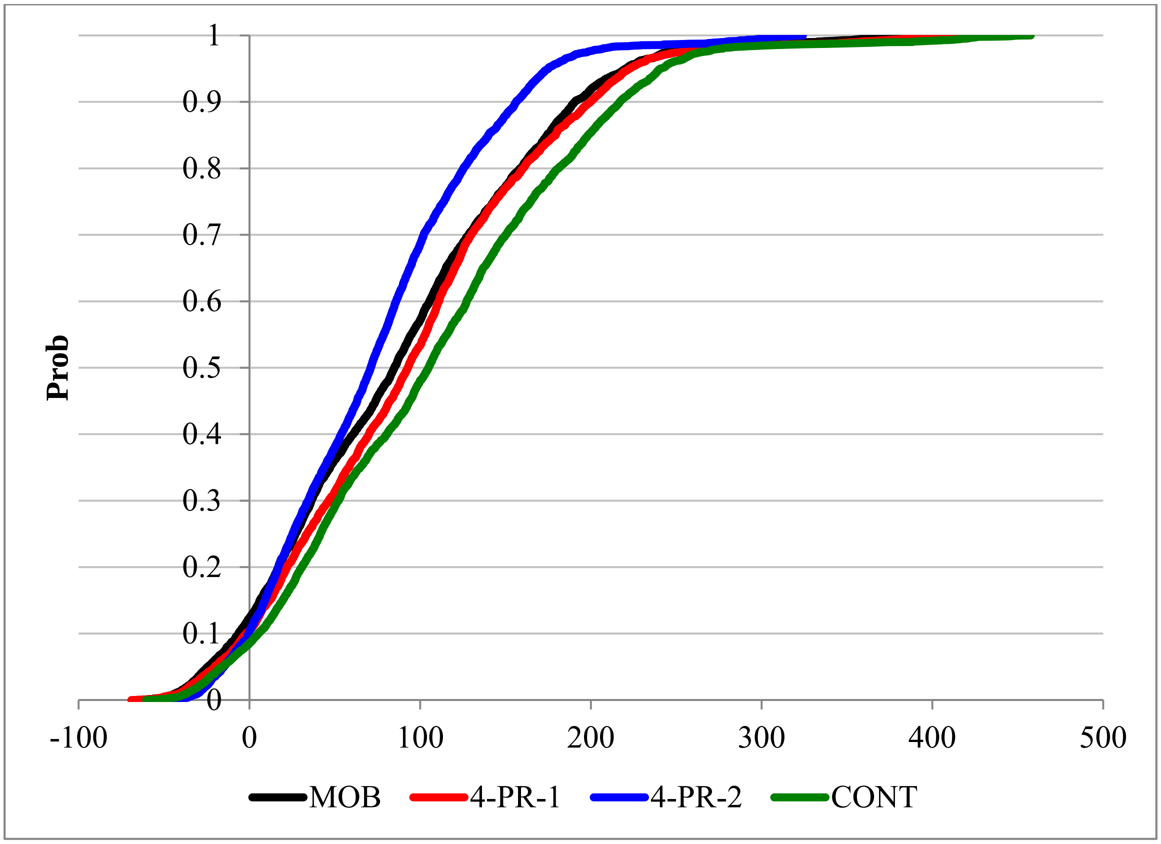


Figure 5-10: Cumulative Distribution Function of Returns to Labor and Management per Acre with a 5% Decrease in Animal Performance



Tables 5-4 and 5-5 display the SDRF and SERF per animal. In SDRF, systems are ranked according to specific risk aversion coefficients (RAC), specifically 0 and 1. At a RAC of 0, CONT is the most preferred system per animal, followed by 4-PR-2, MOB, and 4-PR-1. When the RAC is increased to 1, risk preferences change; therefore, the preferred systems also change. The new preference choice is CONT, 4-PR-1, 4-PR-2, and MOB. Next, by examining the SERF ranking of each rotation, the specific point at which risk preferences change can be observed. Preference change first happens when the ARAC reaches .0417. At this point, 4-PR-1 is no longer the least preferred system; MOB is. At a RAC of .0833, 4-PR-1 overtakes 4-PR-2 as the second most preferred system per animal. Thereafter, risk preferences do not change as risk aversion increases. The 4-PR-2 system is hindered in this scenario due to its lower stocking rate.

Table 5-4: Stochastic Dominance with Respect to a Function per Animal with a 5% Decrease in Animal Performance

Efficient Set Based on SDRF at					
	Lower RAC	**0**		Upper RAC	**1**
	Name	Level of Preference		Name	Level of Preference
1	CONT	Most Preferred	1	CONT	Most Preferred
2	4-PR-2	2nd Most Preferred	2	4-PR-1	2nd Most Preferred
3	MOB	3rd Most Preferred	3	4-PR-2	3rd Most Preferred
4	4-PR-1	Least Preferred	4	MOB	Least Preferred

Table 5-5: Stochastic Efficiency with Respect to a Function per Animal with a 5% Decrease in Animal Performance

	ARAC		
Rank	0	0.0417	0.0833
1	CONT	CONT	CONT
2	4-PR-2	4-PR-2	4-PR-1
3	MOB	4-PR-1	4-PR-2
4	4-PR-1	MOB	MOB

When the per acre returns to labor and management are examined with a 5% decrease in rate of gain, preferred systems change greatly as risk preferences change (Table 5-6 and Table 5-7). Without examining risk, RAC =0, CONT is the most preferred system, followed by 4-PR-1, MOB, and 4-PR-2. When risk aversion increases slightly to an ARAC of .0417, 4-PR-2 becomes the second most preferred system. At an ARAC of .0833, 4-PR-2 overtakes CONT as the most preferred system. When absolute risk aversion increases to .1667, 4-PR-1 becomes the least preferred system. One important implication of changes in risk preferences is that at a 5% decrease in animal performance, the increase in management due to MOB is preferred to less management of 4-PR-1on a per acre basis. However, CONT, with very little management, is still preferred to both systems. Finally, using the empirical data, 4-PR-2 was the most preferred system per acre. In this case, even with a 5% decrease in animal performance, 4-PR-2 quickly becomes the most preferred system per acre as risk aversion increases. This means that the overall gain per acre does not compensate for the lower ADG per animal.

Table 5-6: Stochastic Dominance with Respect to a Function per Acre with a 5% Decrease in Animal Performance

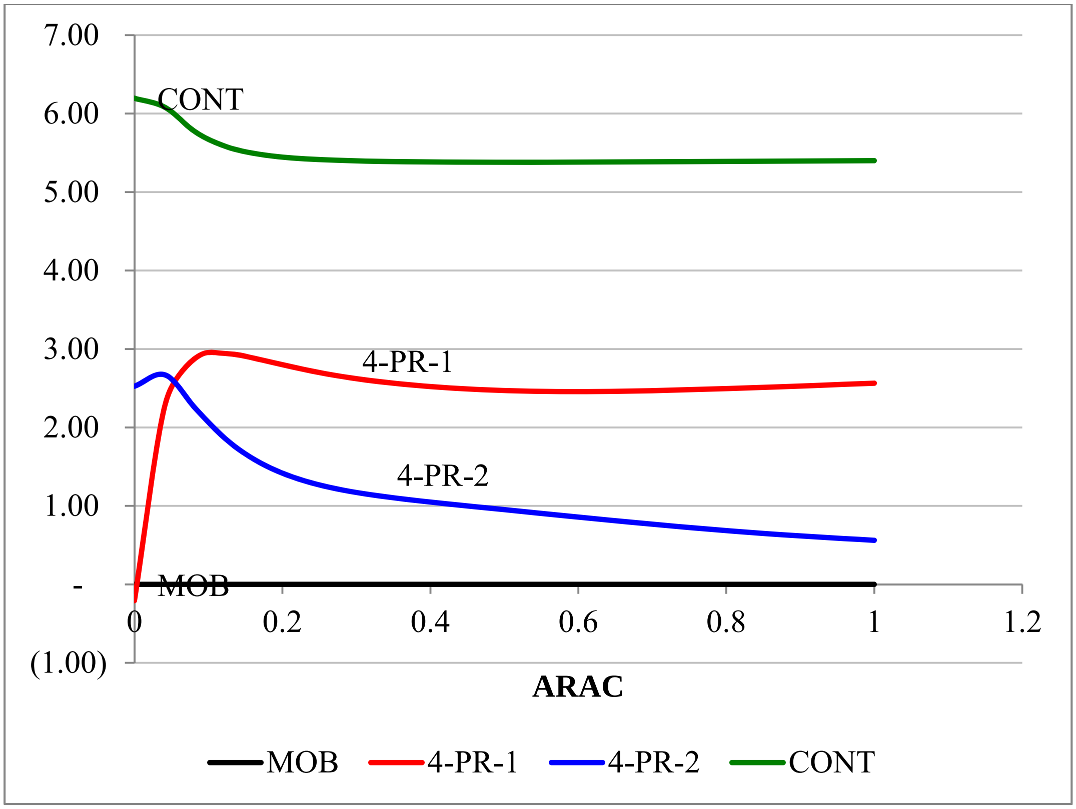
Efficient Set Based on SDRF at					
	Lower RAC	**0**		Upper RAC	**1**
	Name	Level of Preference		Name	Level of Preference
1	CONT	Most Preferred	1	4-PR-2	Most Preferred
2	4-PR-1	2nd Most Preferred	2	CONT	2nd Most Preferred
3	MOB	3rd Most Preferred	3	MOB	3rd Most Preferred
4	4-PR-2	Least Preferred	4	4-PR-1	Least Preferred

Table 5-7: Stochastic Efficiency with Respect to a Function per Acre with a 5% Decrease in Animal Performance

	ARAC			
Rank	0	0.0417	0.0833	0.1667
1	CONT	CONT	4-PR-2	4-PR-2
2	4-PR-1	4-PR-2	CONT	CONT
3	MOB	4-PR-1	4-PR-1	MOB
4	4-PR-2	MOB	MOB	4-PR-1

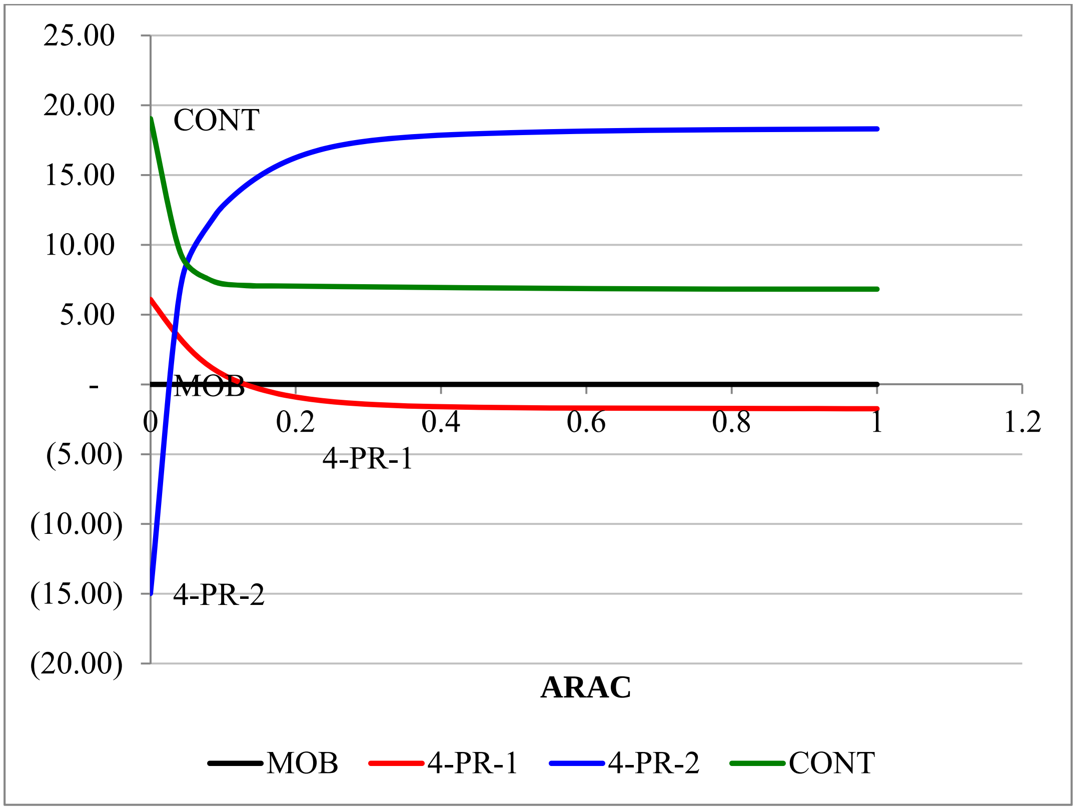
The risk premium a producer would require provides key information on which system producers would choose (Figure 5-11). When a person is risk neutral he would require a risk premium of $6.20 and $2.52 per animal to switch from CONT and 4-PR-2 to a MOB system. The producer would require a $0.21 risk premium per animal to switch from MOB to 4-PR-1. However, as ARAC increases, a producer would need a risk premium to switch from all three systems to MOB. When ARAC reaches 1, the CONT demands the highest risk premium at $5.20 per animal. Although the risk premium is a calculated figure, when measured on a per animal basis, the risk premium is very small compared to the overall value of the animal.

Figure 5-11: Negative Exponential Utility Weighted Risk Premiums Relative to MOB per Animal with a 5% decrease in animal performance.



The risk premium per acre needed to be indifferent between systems gives greater insight (Figure 5-12). A risk neutral producer would need a risk premium of $19.04 and $6.09 per acre to switch from CONT and 4-PR-1 to MOB. The system 4-PR-2 would need a $14.98 risk premium per acre for a producer to switch from MOB grazing to 4-PR-2. As risk aversion increases, an important trend emerges. The risk premium per acre for 4-PR-2 quickly become positive and reaches a maximum of $18.30 an acre. CONT risk premium declines to $6.83 an acre. Finally, a producer would need a risk premium of $1.74 an acre to switch from MOB to 4-PR-1.

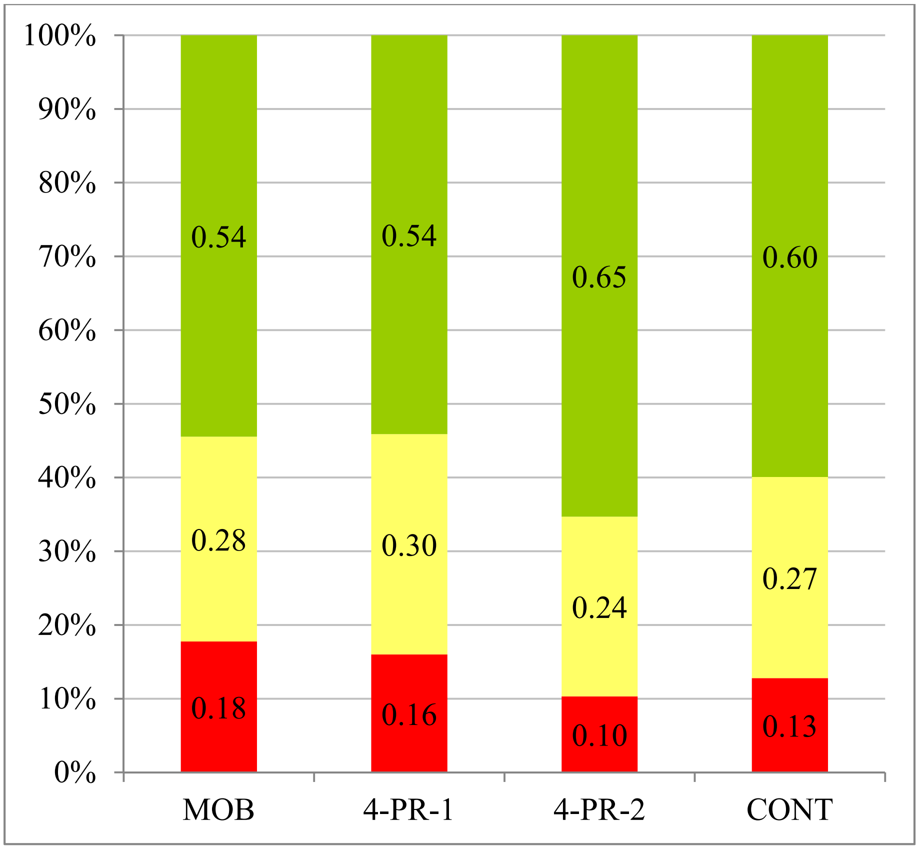
Figure 5-12: Negative Exponential Utility Weighted Risk Premiums Relative to MOB per Acre with a 5% Decrease in Animal Performance



12.5% Decrease in Livestock Performance Analysis

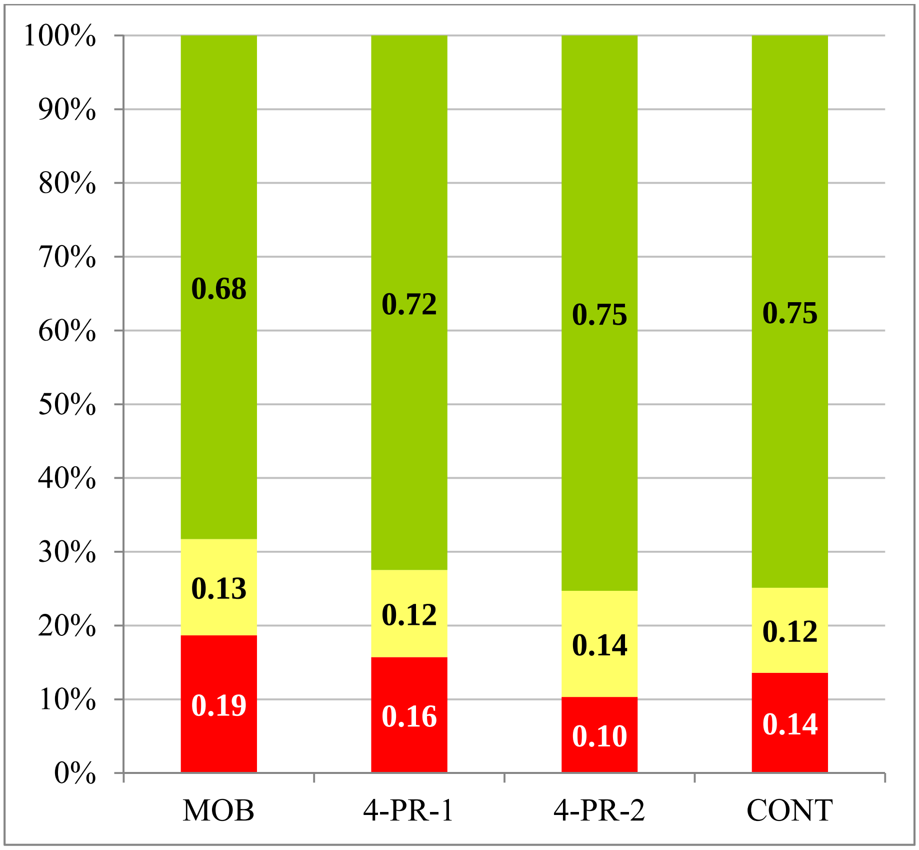
In this section, the average daily gain will be reduced from the original 4-PR-2 by 12.5%. The system 4-PR-2 begins to appear like the better system per animal when rates of gain are reduced by 12.5% (Figure 5-13). Although, CONT follows close behind 4-PR-2, the system has a larger probability of negative returns and a smaller probability of returns above $31.30. MOB and 4-PR-1 are about equal but are less desirable than 4-PR-2 or CONT. In each system, the probability of returns to labor and management being greater than $31.30 remains over 50%.

Figure 5-13: Probabilities of Returns to Labor and Management Less Than $0.00 and Greater Than $31.30 per Animal with a 12.5 % Decrease in Animal Performance



On a per acre analysis, the probabilities of having returns above $25 an acre is approximately equal for 4-PR-1, 4-PR-2, and CONT (Figure 5-14). MOB has a slightly lower probability of gains above $25 with a 12.5% reduction in ADG. The system also has the highest probability of negative returns, followed by 4-PR-1, CONT, and 4-PR-2. An important detail in the figure is the competitiveness of CONT to 4-PR-2. Even with a 12.5% decrease in ADG, the probability of returns for CONT is still relatively close in probability to that of 4-PR-2. One of the major reasons behind the closeness is the differences in input costs into the two systems.

Figure 5-14: Probabilities of Returns to Labor and Management Less Than $0.00 and Greater Than $25.00 per Acre with a 12.5 % Decrease in Animal Performance



The cumulative distribution functions give more insights to the probabilities of returns (Figure 5-15 and Figure 5-16). The CDF per animal shows that 4-PR-2 is almost a completely dominant system. The curve for 4-PR-2 is to the right of the other curves for most of the distribution. CONT is in the middle, while MOB and 4-PR-1 have very similar distributions. At a probability of 1, 4-PR-2 has the chance of having the highest amount of returns. When the systems are examined on a per acre basis, CONT is to the right of the other three systems over half of the distribution. However, no system is clearly dominant or inferior.

Figure 5-15: Cumulative Distribution Function of Returns to Labor and Management per Animal with a 12.5 % Decrease in Animal Performance

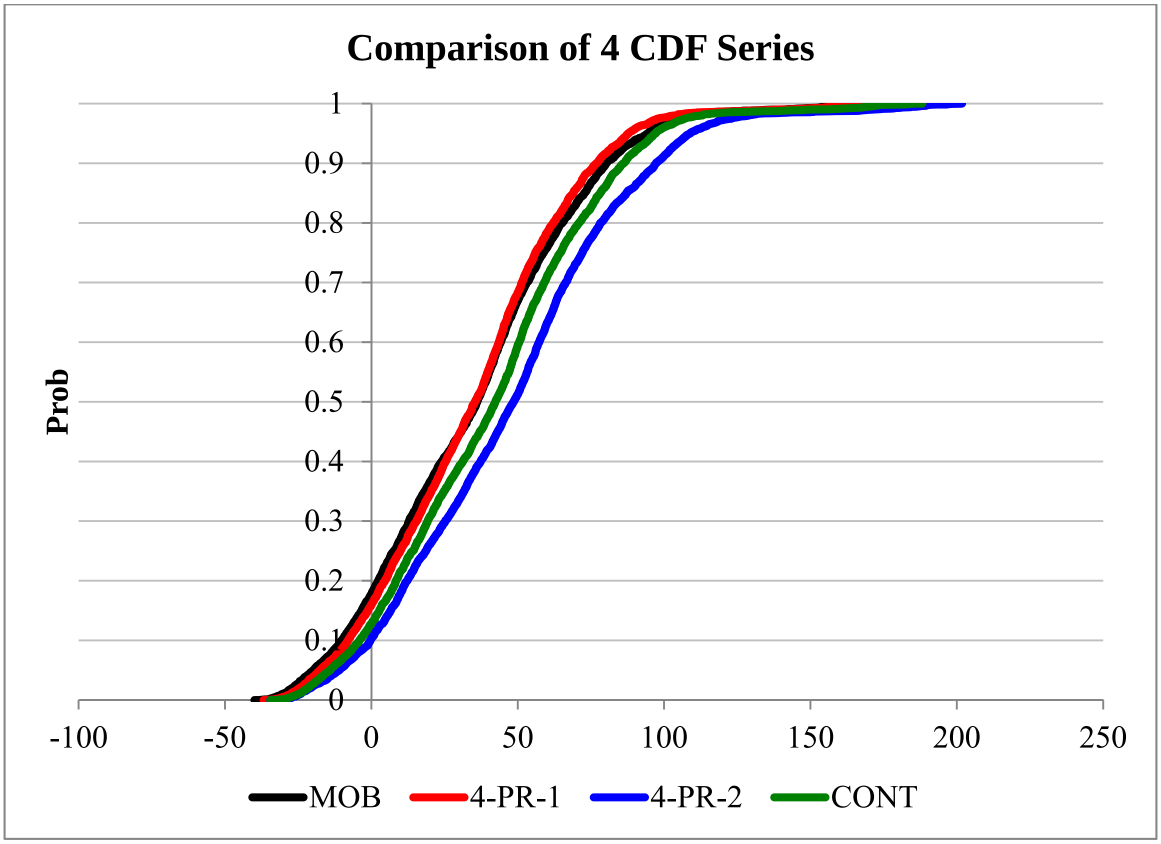
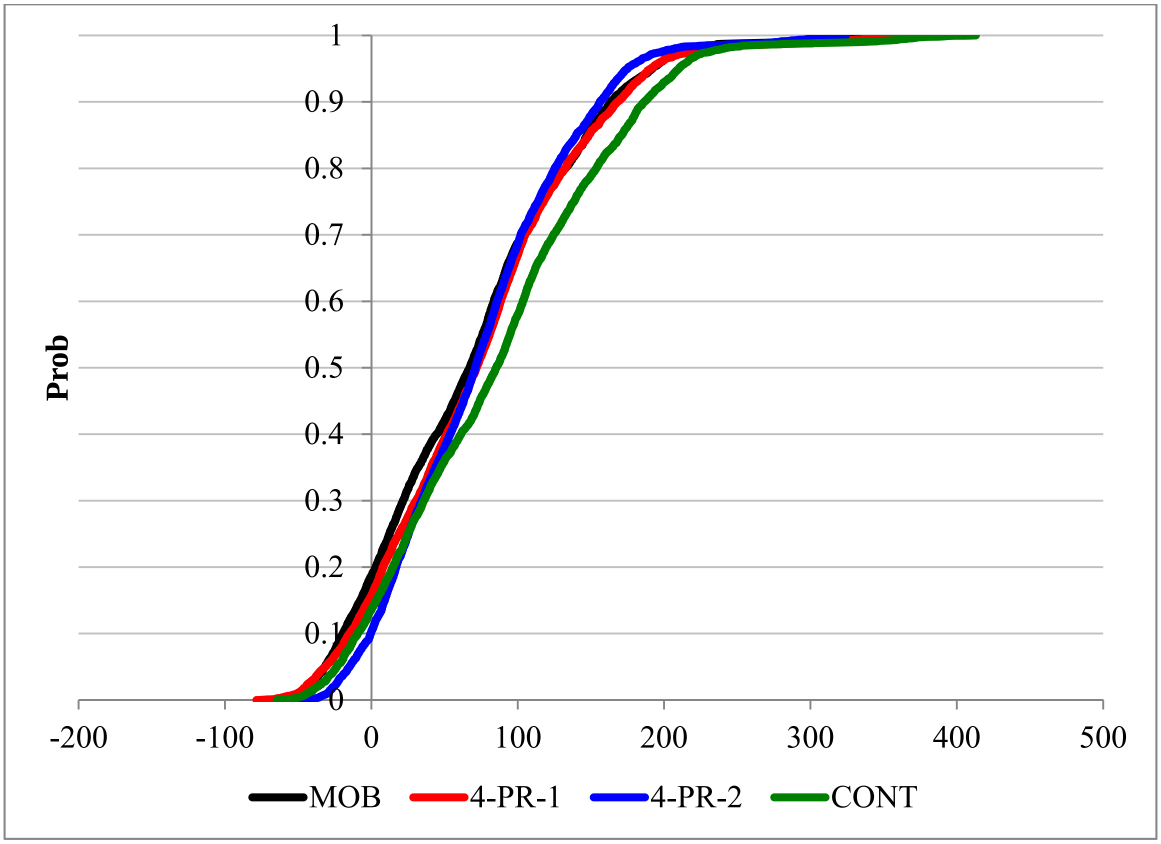


Figure 5-16: Cumulative Distribution Function of Returns to Labor and Management per Acre with a 12.5 % Decrease in Animal Performance



The Simetar© functions SDRF and SERF will rank systems correctly according to risk preferences. According to the SDRF, when there is a 12.5% decrease in animal performance and a producer is risk neutral, 4-PR-2 is the most preferred system per animal. It is followed by CONT, MOB, and 4-PR-1. When the RAC is increased to 1, 4-PR-1 becomes the third most preferred system, followed by MOB. The SERF function predicts the changes in preferences between 4-PR-1 and MOB as soon as a producer becomes risk averse. The preference changes are significantly different compared to a 5% drop in animal performance (Table 5-4). When there was only a 5% drop in animal performance, 4-PR-2 preference actually dropped as risk aversion increased. At 12.5%, it remained the top system no matter the risk aversion level.

Table 5-8: Stochastic Dominance with Respect to a Function per Animal with a 12.5% Decrease in Animal Performance

Efficient Set Based on SDRF at					
	Lower RAC	**0**		Upper RAC	**1**
	Name	Level of Preference		Name	Level of Preference
1	4-PR-2	Most Preferred	1	4-PR-2	Most Preferred
2	CONT	2nd Most Preferred	2	CONT	2nd Most Preferred
3	MOB	3rd Most Preferred	3	4-PR-1	3rd Most Preferred
4	4-PR-1	Least Preferred	4	MOB	Least Preferred

In Table 5-9, CONT is the most preferred system per acre when the ARAC is equal to 0. However, when ARAC increases to .0417, 4-PR-2 becomes the most preferred system per acre (Table 5-10). When the ARAC is increased further to .0833, MOB becomes more preferred per acre than 4-PR-1, but still less preferred than 4-PR-2 and CONT. Preferences changes remain this way as ARAC increase. When the returns to labor and management with a 12.5% decrease in ADG is compared to the returns to labor and management with 5% a decrease of ADG (Table 5-5), important insights can be drawn. First, 4-PR-2 is no longer the least preferred system per acre when a producer is risk neutral; MOB is. However, when the RAC is equal to 1, risk preferences are the same for a 5% and 12.5% decrease in ADG.

Table 5-9: Stochastic Dominance with Respect to a Function per Acre with 12.5% Decrease in Animal Performance

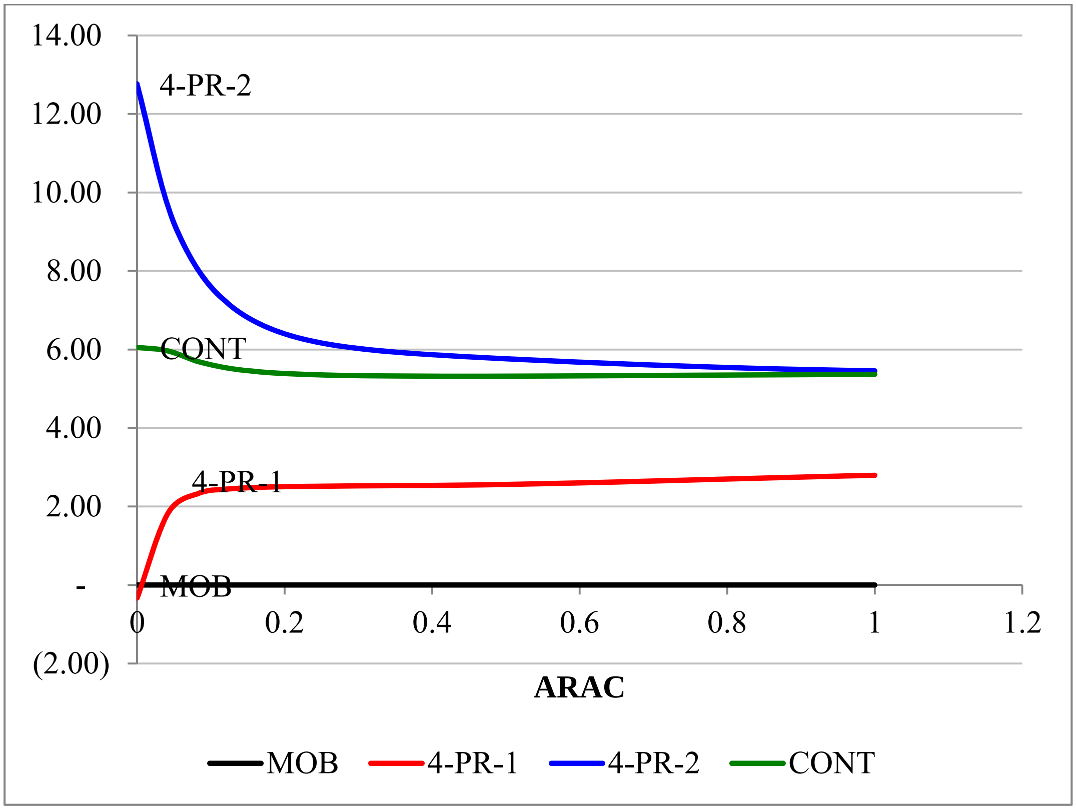
Efficient Set Based on SDRF at					
	Lower RAC	**0**		Upper RAC	**1**
	Name	Level of Preference		Name	Level of Preference
1	CONT	Most Preferred	1	4-PR-2	Most Preferred
2	4-PR-2	2nd Most Preferred	2	CONT	2nd Most Preferred
3	4-PR-1	3rd Most Preferred	3	MOB	3rd Most Preferred
4	MOB	Least Preferred	4	4-PR-1	Least Preferred

Table 5-10: Stochastic Efficiency with Respect to a Function per Acre with a 12.5% Decrease in Animal Performance

	ARAC		
Rank	0	0.0417	0.0833
1	CONT	4-PR-2	4-PR-2
2	4-PR-2	CONT	CONT
3	4-PR-1	4-PR-1	MOB
4	MOB	MOB	4-PR-1

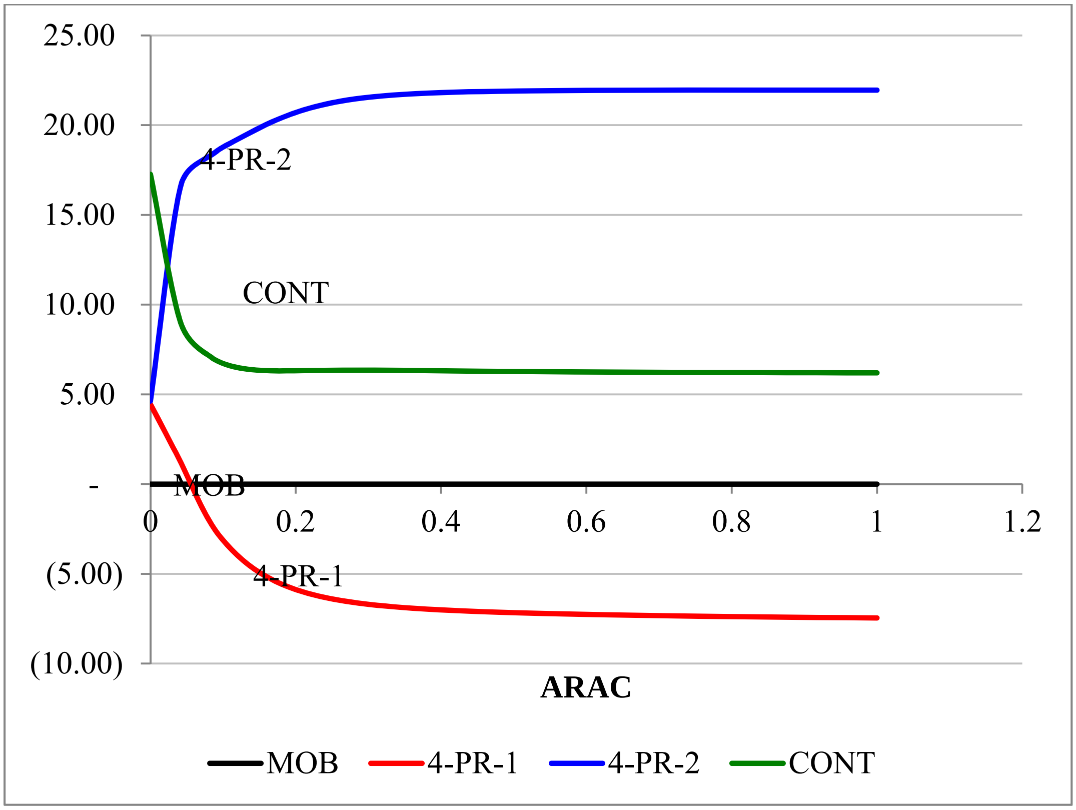
An examination of risk premiums required for producers to be indifferent between systems will help explain the preferences between the systems (Figure 5-17). When ARAC is equal to 0, a producer would need a risk premium of $12.77 per animal and $6.05 per animal to decide to switch from 4-PR-2 and CONT to MOB. However, they would have to receive a risk premium of $0.33 to switch from MOB to 4-PR-1. When risk aversion slightly increases, all systems would need a risk premium to switch to MOB. Another important insight from this graph is the near convergence of 4-PR-2 and CONT. A producer would need to receive a risk premium of $0.09 per head to be indifferent between 4-PR-2 and CONT at an ARAC of 1.

Figure 5-17: Negative Exponential Utility Weighted Risk Premiums Relative to MOB per Animal with a 12.5% Decrease in Animal Performance



When a producer is risk neutral, he would need to receive risk premiums of $4.46, $4.63, and $17.27 per acre to be willing to switch from 4-PR-1, 4-PR-2, and CONT to MOB. As the ARAC increases, the risk premium for 4-PR-2 quickly becomes greater until reaching a max of $21.95 per acre. A producer would need a risk premium of $7.46 per acre in order to switch from MOB to 4-PR-1. One of the biggest differences between the risk premiums needed per acre at a 5% reduction in ADG and at a 12.5% reduction in average daily gain is the risk premium for 4-PR-2 is always positive when there is a 12.5% reduction in ADG (Figure 5-12).

Figure 5-18: Negative Exponential Utility Weighted Risk Premiums Relative to MOB per Acre with a 12.5% Decrease in Animal Performance



25% Decrease in Livestock Performance Analysis

In this section, returns to labor and management will be examined with a 25% decrease in animal's average daily gain (Figures 5-19 and 5-20). The system 4-PR-2 is clearly the better system. This is due to the fact that 4-PR-2 still has the original ADG, while the other systems have gains that are 25% lower. However, the probabilities of having negative returns per animal are .30 or less for MOB, CONT, and 4-PR-1. On a per acre basis, the probability of negative returns is .31 or less. The probability of having returns above $25.00 an acre is over .5 for all systems, even with the 25% decrease in ADG.

The returns to labor and management using the original empirical ADG per system provides key details (Figure 4-8 and Figure 4-9). A 25% decrease in ADG has similar probabilities for returns to labor and management for the CONT system. 4-PR-1 and MOB's original ADG was clearly depressed by more than 25%. The original probability of negative returns for MOB was .81, while it is .30 when ADG is reduced by 25%.

Figure 5-19: Probabilities of Returns to Labor and Management Less Than $0.00 and Greater Than $31.30 per Animal with a 25% Decrease in Animal Performance

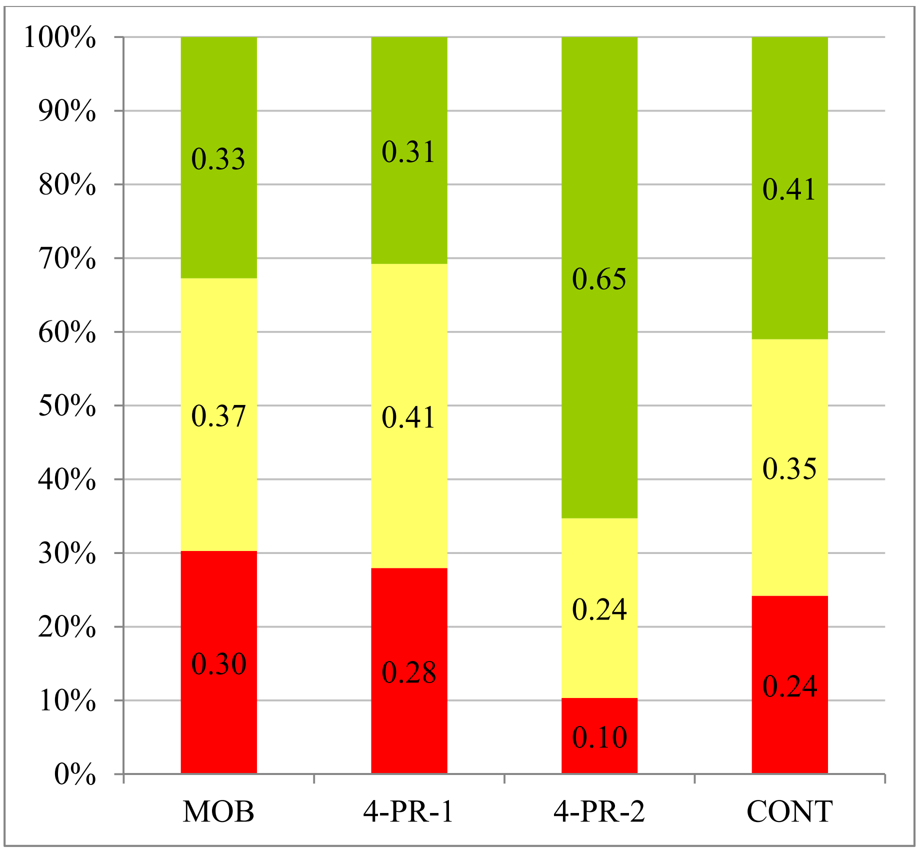
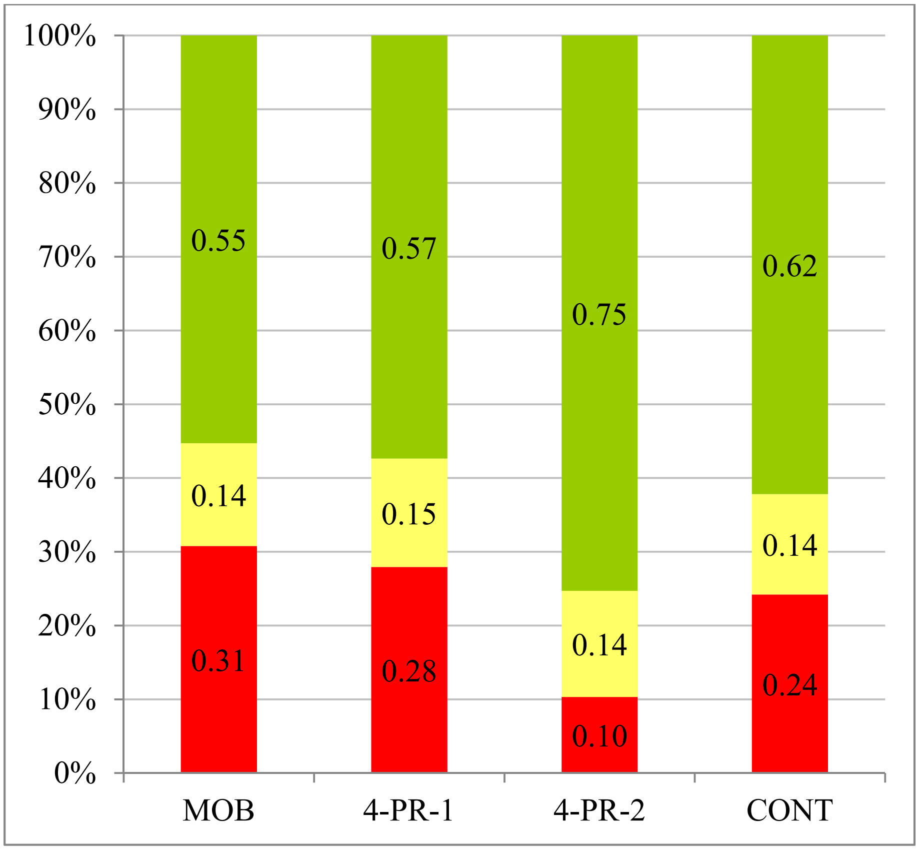


Figure 5-20: Probabilities of Returns to Labor and Management Less Than $0.00 and Greater Than $25.00 per Acre with a 25% Decrease in Animal Performance



The CDF show that 4-PR-2 is clearly the dominant system on both per acre and per animal basis when ADG is reduced by 25% (Figure 5-21 and Figure 5-22). However, the system is slightly more dominant on a per animal basis. Even with a 25% decrease in ADG, the probability of large negative returns is very low. At a probability of just over 0, a loss of $50 per animal and less than $100 per acre are possible. More analysis is necessary in order to accurately represent the systems. Around half of the distribution for MOB, 4-PR-1, and CONT lies between $0.00 and $50.00 return per animal. The returns per acre distribution are slightly less vertical than the returns per animal.

Figure 5-21: Cumulative Distribution Function of Returns to Labor and Management per Animal with a 25% Decrease in Animal Performance

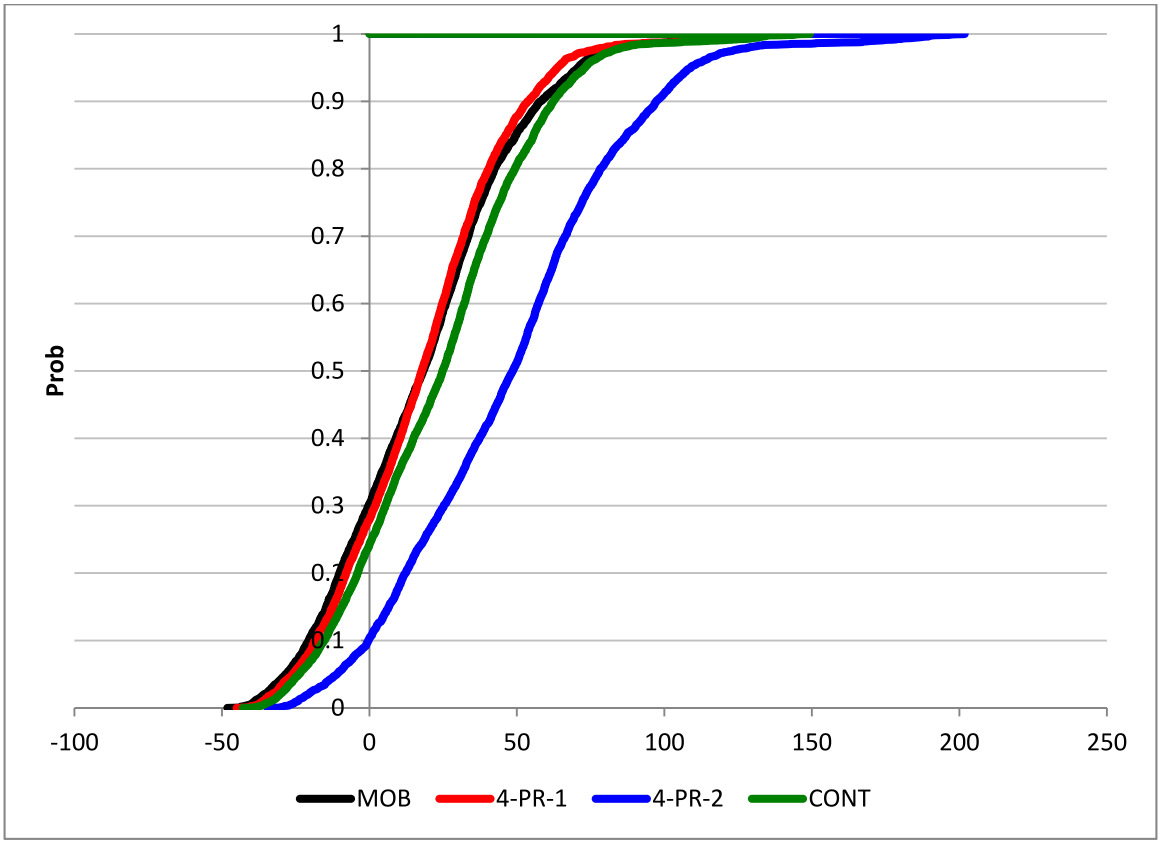
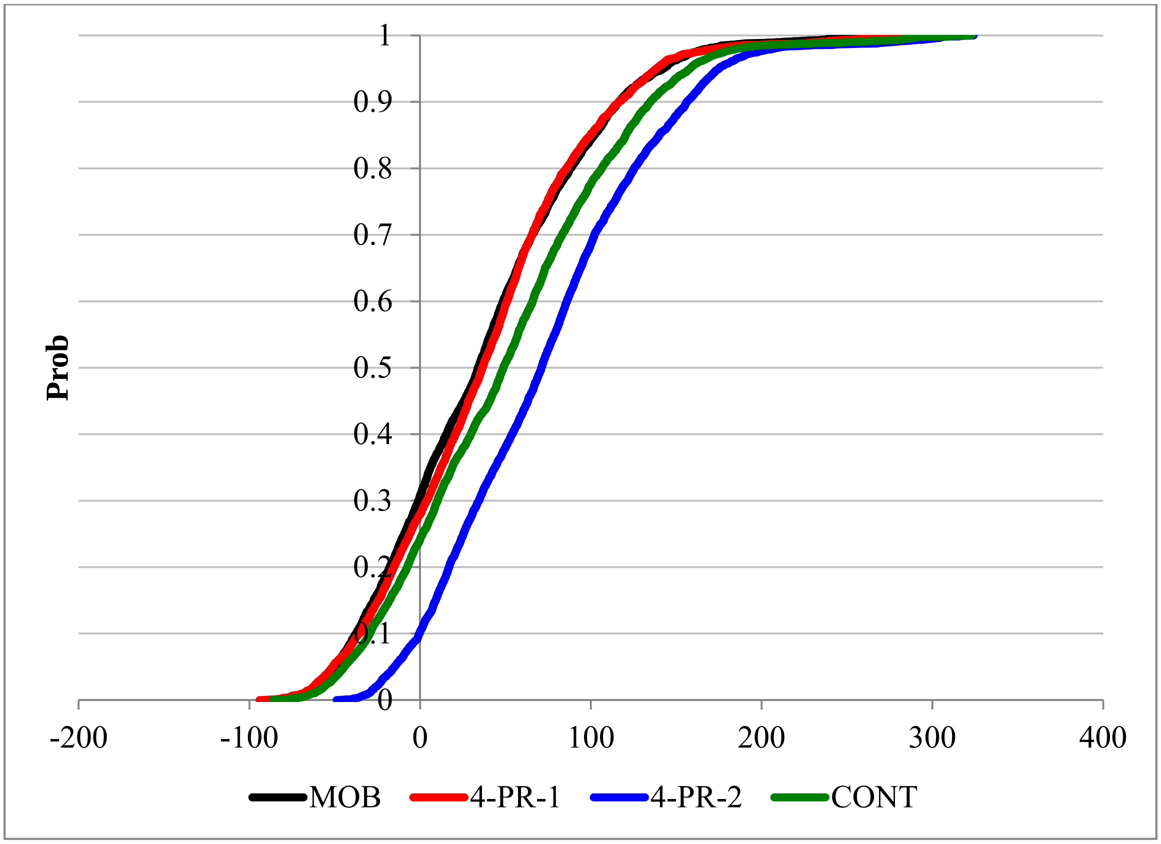


Figure 5-22: Cumulative Distribution Function of Returns to Labor and Management per Acre with a 25% Decrease in Animal Performance



The ranking of risk preference per animal did not change from when ADG was reduced by 12.5% to when it was reduced by 25% (Table 5-8). MOB became the least preferred system per animal as soon as a producer became risk averse. The most preferred system per acre is 4-PR-2 no matter the RAC. This is a change from a 12.5% decrease in ADG, where CONT was the most preferred system at an ARAC of 0. However, in both cases when ARAC is equal to .0833, MOB overtakes 4-PR-1 to become the third most preferred system.

Table 5-11: Stochastic Dominance with Respect to a Function per Acre with a 25% Decrease in Animal Performance

Efficient Set Based on SDRF at					
	Lower RAC	**0**		Upper RAC	**1**
	Name	Level of Preference		Name	Level of Preference
1	4-PR-2	Most Preferred	1	4-PR-2	Most Preferred
2	CONT	2nd Most Preferred	2	CONT	2nd Most Preferred
3	4-PR-1	3rd Most Preferred	3	MOB	3rd Most Preferred
4	MOB	Least Preferred	4	4-PR-1	Least Preferred

Finally, risk premiums give some of the best insights to each system. At an ARAC of 0, 4-PR-2 system would need a risk premium of $29.74 per animal to be indifferent between it and MOB (Figure 5-23). The risk premiums between MOB, CONT, and 4-PR-1 changed slightly from the amount needed when ADG was reduced by 12.5%. At a 25% decrease in ADG, a producer would need a smaller risk premium to change from CONT to MOB. As absolute risk aversion increases to one, a producer would need a risk premium of $13.63 per animal to be indifferent between 4-PR-2 and MOB and $8.37 to be indifferent between 4-PR-2 and CONT.

On a per acre basis and when ADG is reduced by 25%, for the first time 4-PR-2 needs a risk premium to switch to any other systems (Figure 5-24). The range of risk premiums is also more concentrated for 4-PR-2 and 4-PR-1 at the 25% decrease of ADG compared to the 12.5% decrease in ADG, $5.06 and $4.40 to $11.92 and $17.32, respectively. Without the consideration of risk, a producer would need a risk premium of $37.23 per acre to be indifferent between 4-PR-2 and MOB and $14.34 per acre to be indifferent between CONT and MOB. As the ARAC approaches 1, a producer would need $41.62 per acre in order to be different between MOB and 4-PR-2. The highest rent value in the budgets was $25. Therefore, the value to the risk premium exceeds the cash rental rate of the land.

Figure 5-23: Negative Exponential Utility Weighted Risk Premiums Relative to MOB per Animal with a 25% Decrease in Animal Performance

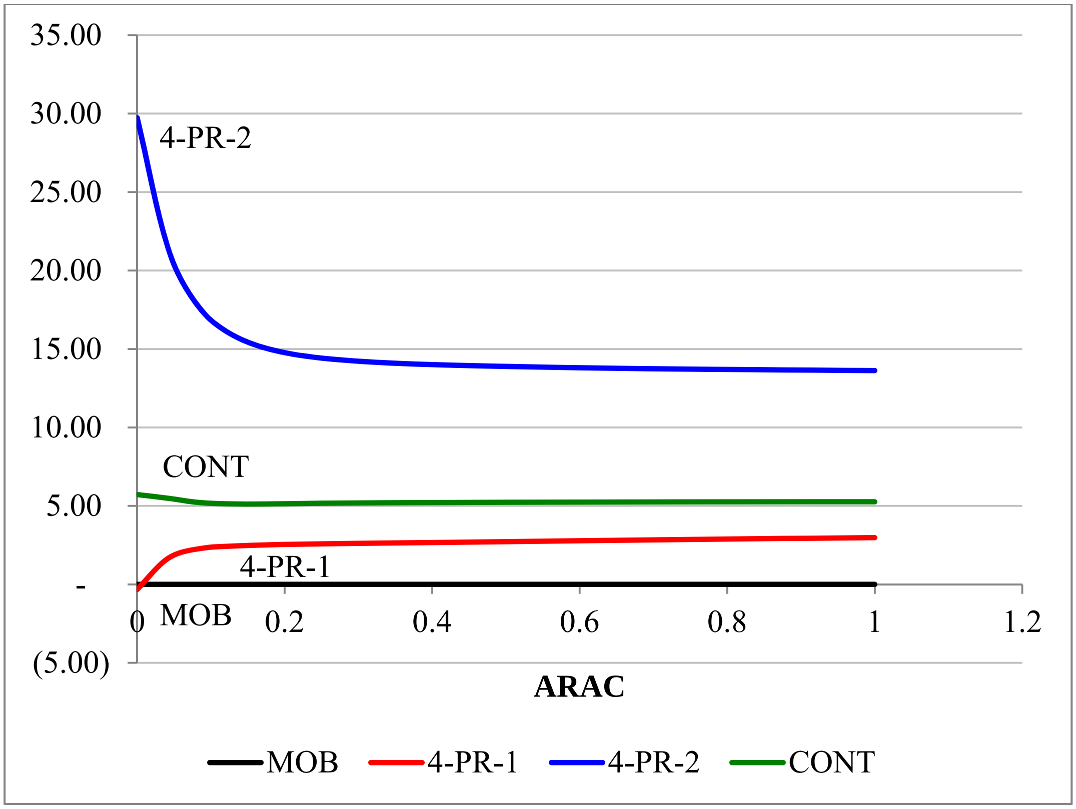
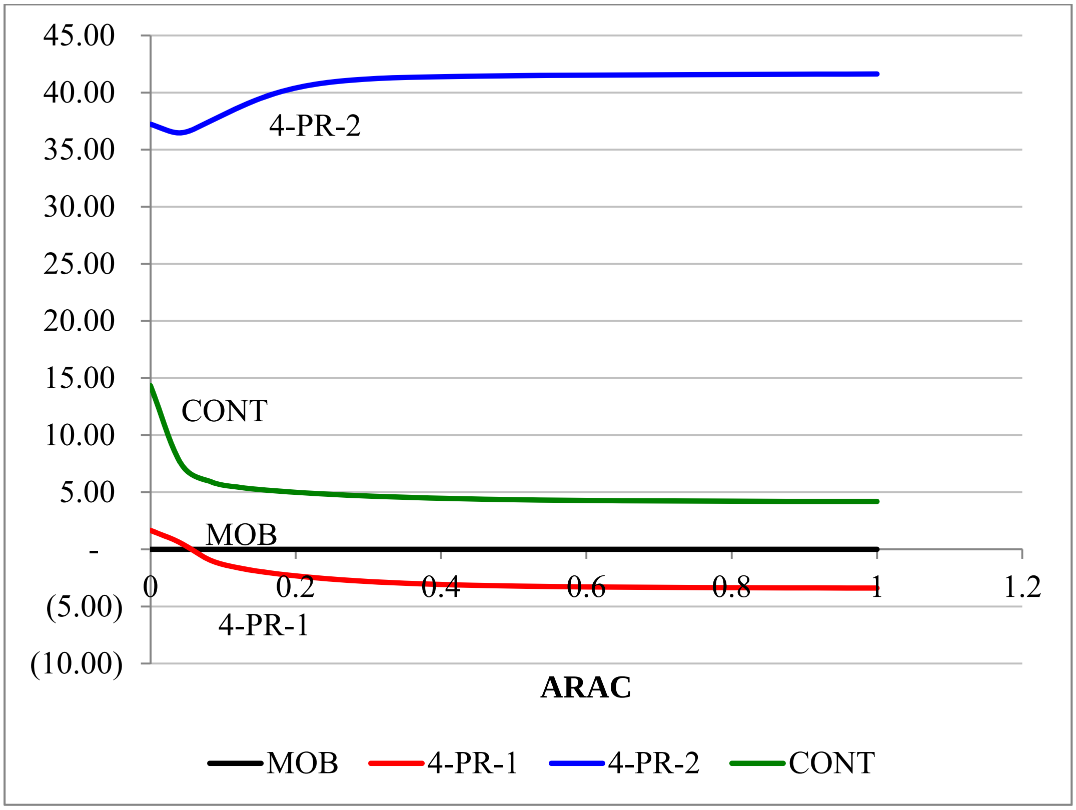


Figure 5-24: Negative Exponential Utility Weighted Risk Premiums Relative to MOB per Acre with a 25% Decrease in Animal Performance



Summary

When the adjustments are made to ADG in order to account for the ability of management to mitigate large decreases in animal performance, important results emerge. First, on a per animal basis, at a five percent decrease in ADG, the CONT system is most preferred and 4-PR-2 is the second most preferred, followed by MOB and 4-PR-1. When risk aversion increases, MOB becomes the least preferred system. If the systems experience a 12.5% or greater decrease in ADG, then 4-PR-2 is the most preferred system and remains no matter the RAC. Therefore, on a per animal basis, a producer has incentives to CONT graze if management can keep reduction in ADG low. As ADG falls further, producers have the incentives to graze using a 4-PR-2 system. The risk premium needed to be indifferent between systems is relatively small per animal. Even though the CONT system was the most preferred system per animal when ADG has a five percent decrease, 4-PR-2 is still preferred when risks are considered. Management changes could keep the system more profitable.

On a per acre basis, CONT system is the most preferred system with a five percent decrease in ADG. As risk aversion increases, the 4-PR-2 system quickly becomes the most preferred system. MOB is the third most preferred system. When there is a 12.5% decrease in ADG, CONT is still the most preferred, but 4-PR-2 is close behind it. MOB is the third most preferred system, but quickly falls to last as risk aversion increases. At a 25% decrease in ADG, 4-PR-2 is the most preferred system and does not change as risk aversion increases. MOB behaves the same as the 12.5% decrease scenario.

The major implication of these results are that 4-PR-2 is still the best system, which would align with the original empirical and original stochastic analysis. Thus, even with the steps the MOB producers take in order to help preserve ADG, it might not be enough. However, a good manager would realize that 4-PR-2, the most preferred system, has the second highest number of moves between the four systems. Increasing management knowledge about additional moves could have additional benefits for animal gain.

Chapter VI: Summary and Recommendations

The profitability of grazing systems have long been determined by three major factors which include: labor cost, infrastructure cost and the animal's average daily gain. Ultimately, a producer will choose a grazing system based on the profitability and the risk associated with the system. In this study, four major grazing systems were examined, each replicated twice. The first one was a 120 paddock mob grazing system (MOB). Livestock visited each of the 120-paddocks once during the grazing season. The second system consisted of 4 paddocks which were grazed once during the season (4-PR-1). The third was also a four-paddocks system, except that the cattle grazed each pasture twice during the season (4-PR-2). The final and fourth treatment was a single pasture grazed continuously over the season (CONT).

The objectives of the study were met throughout the thesis. The first objective was to determine the profitability of MOB grazing and other traditional grazing systems. The next objective was to determine the risk of each system and the preference rankings of each system based on different levels of risk. The third objective used this risk information to assign risk premiums to each grazing system. Finally, the profitability and risk were examined for each system using different levels of animal performance due to changes in management.

Which scheme is the proper grazing system has long been debated. Briske et al. (2008) reviewed numerous grazing studies, mostly throughout the U.S. but also other parts of the world, and found that livestock performance in continuously grazing systems was usually better or equal to rotational grazing systems. In 2011, Briske et al. went further and explained that behind the better performance for continuously grazed system were protocol changes. Researchers change systems when events like drought occur. Therefore, the animal performance can no longer be attributed solely to the system (Briske et al, 2011). Other studies by Rogler (1951), McCollum III et al. (1999), and Manley et al. (1997) also found continuous systems to be superior to rotational grazing.

Teague et al. (2008) and Norton (1998) argued the problem with grazing system studies is scale. The systems do not accurately portray a commercial ranch since they are replicated in very small portions. A commercial ranch has many different plant communities, soils types, and terrains in each pasture. In scientific studies, these factors are controlled. What happens in small pasture grazing studies may not be true for larger pasture studies. Other studies by Walton et al. (1981) and Jacob et al. (2006) found that rotational grazing benefits the soils. Forages in the rotational grazing systems had higher nutritional value, which led to improved animal performance.

Another important aspect of grazing systems is the stocking rates. Smart et al. (2010) and Hart and Ashby (1998) found that as grazing pressure increases, the individual animal's performance will decrease. However, the gain per acre increased as grazing pressure increased. Smart et al. (2010) did not find an optimal stocking rate, whereas Hart and Ashby (1998) found the optimal stocking rate was slightly higher than the moderate stocking rate. In the study, the moderate stocking rate was 23.0 heifers-days ha^{-1}.

Derner et al. (2007) found that the amount of early season moisture a grazing system receives is as important as the type of grazing system itself. This study was an important theoretical foundation used for empirical distribution of the individual animal's average daily gain. Finally, local producers added some important insight into mob grazing of less than five acres at a time. A producer must also be aware of how the animals are handling the system. If cattle start to decline in body condition, one must alter the system.

This five-year study started in 2010 on the UNL Barta Brothers research ranch near Rose, Nebraska. Part of the research was to investigate how mob grazing affected soil properties compared to other types of grazing systems. Factors examined in the research were net primary production, trampling, harvest efficiency, utilization, species composition, forage quality, animal performance and animal activity. From this data, the animal performance (average daily gain) and stocking rates were used to perform economic analysis.

In the first year of the study, a large number of animals mysteriously died. Therefore, animal performance data was not included for 2010. Each system had different size pastures and varying number of animals within the system. This was done in order to maintain different stocking rates between the systems. In the first two years of the study, the MOB system had very poor animal performance compared to 4-PR-2 and CONT.

The average daily gain (ADG) and stocking rates were used to set up budgets for each system. The budgets were evaluated on both a per animal and per acre basis to find the returns to labor and management, total cost, total revenue, and labor and infrastructure costs. Next, this information was evaluated using mean, standard deviation, coefficient of variation, and mini-max to rank systems in order. This analysis ranked MOB and 4-PR-1 systems lower than 4-PR-2 and CONT.

In order to gain more insights into the profitability and risk of each system, stochastic variables were added to the budgets. The ADG became stochastic through a multivariate empirical distribution. The selling price was calculated from a uniform distribution and a price slide according to Dhyuyvetter and Schroeder (2000). Finally, the animal unit month (AUM) cost vector was given a triangle distribution. Next, the returns to labor and management were simulated 1,000 times for each replication in each system in each year. So, the total data points per system were 8,000, making 32,000 data points overall.

In the stoplight analysis, the probability of MOB having negative returns was 0.81. The system 4-PR-2 had a probability of negative returns at 0.11. This was true for both a per animal basis and a per acre basis. In the cumulative distribution function (CDF), the line representing MOB was located to the left of the other system for most of the distribution, which signifies the lower desirability of the system. On a per animal basis, MOB was the least preferred system no matter the level of risk aversion. A risk neutral producer would rank MOB the least preferred system on a per acre basis (Table 6-1). However, when risk aversion is increased to .0417, MOB overtakes 4-PR-1 and becomes the third preferred system.

A risk premium is the monetary value a producer would need to receive to be indifferent between two systems. A producer would need a risk premium to switch to MOB grazing on a per animal basis. The highest risk premium was at an absolute risk aversion coefficient (ARAC) of 1 for 4-PR-2 and was $91.53 per animal. A risk neutral producer would need a risk premium to switch from any other system to MOB on a per acre basis. However, as ARAC increases, the producer would then need $34.10 an acre to switch from MOB to 4-PR-1. The system 4-PR-2 risk premium increased to $192.73 per acre to be indifferent between the two systems. The risk premium is very large here due to the differences in the probabilities of negative returns to labor and management.

The sensitivity of the returns to labor and management were then examined. The literature suggest that as stocking rates increase, the individual animal rates of gain decrease while the overall animal gain per acre increase (Smart et al., 2010). In order to test this idea in an economic context, the ADG from 4-PR-2, the base system and lowest stocking rate, was used as the ADG for all systems. However, the rate of gain was decreased by 5%, 12.5%, and 25%. The three different decreases were chosen in order to observe how profitability and risk change when animals' performances are affected. Again this was examined on both a per animal and a per acre basis. The major reasoning behind testing the sensitivity was to see if changes in management to help improve animal performance could increase the preference of a given system.

A per acre analysis tells the most important story (Table 6-2). At a 5% decrease in animal performance, 4-PR-2 is the least preferred system and MOB is the third most preferred. The reason 4-PR-2 is the least preferred system is the fact that it has the lowest stocking rate. The overall gain per acre is greater than the decreased gain per animal using different stocking rates. As risk aversion increases, 4-PR-2 becomes the most preferred system. Finally, at 25% decrease in animal performance the risk preferences of the original stochastic dominance of returns to labor and management (Table 6-1) and the newly adjusted stochastic dominance of returns to labor and management (Table 6-2) share the same ranks.

Table 6-1: Stochastic Dominance with Respect to a Function per Acre

Efficient Set Based on SDRF at					
	Lower RAC	**0**		Upper RAC	**1**
	Name	Level of Preference		Name	Level of Preference
1	4-PR-2	Most Preferred	1	4-PR-2	Most Preferred
2	CONT	2nd Most Preferred	2	CONT	2nd Most Preferred
3	4-PR-1	3rd Most Preferred	3	MOB	3rd Most Preferred
4	MOB	Least Preferred	4	4-PR-1	Least Preferred

Table 6-2: Stochastic Dominance with Respect to a Function per Acre with Adjusted ADG

Efficient Set Based on SDRF at 5% Decrease in Animal Performance					
	Lower RAC	**0**		Upper RAC	**1**
	Name	Level of Preference		Name	Level of Preference
1	CONT	Most Preferred	1	4-PR-2	Most Preferred
2	4-PR-1	2nd Most Preferred	2	CONT	2nd Most Preferred
3	MOB	3rd Most Preferred	3	MOB	3rd Most Preferred
4	4-PR-2	Least Preferred	4	4-PR-1	Least Preferred
Efficient Set Based on SDRF at 12.5% Decrease in Animal Performance					
	Lower RAC	**0**		Upper RAC	**1**
	Name	Level of Preference		Name	Level of Preference
1	CONT	Most Preferred	1	4-PR-2	Most Preferred
2	4-PR-2	2nd Most Preferred	2	CONT	2nd Most Preferred
3	4-PR-1	3rd Most Preferred	3	MOB	3rd Most Preferred
4	MOB	Least Preferred	4	4-PR-1	Least Preferred
Efficient Set Based on SDRF at 25% Decrease in Animal Performance					
	Lower RAC	**0**		Upper RAC	**1**
	Name	Level of Preference		Name	Level of Preference
1	4-PR-2	Most Preferred	1	4-PR-2	Most Preferred
2	CONT	2nd Most Preferred	2	CONT	2nd Most Preferred
3	4-PR-1	3rd Most Preferred	3	MOB	3rd Most Preferred
4	MOB	Least Preferred	4	4-PR-1	Least Preferred

Through the entire analysis one important theme kept recurring, 4-PR-2 and CONT outperformed both MOB and 4-PR-1. The system 4-PR-2 was the most favored using the original budget information and the simulated budget information. However, the sensitivity analysis showed that if there is only a small decrease in animal performance, a CONT system would be preferred. This means that a producer should either choose a moderate level of management or almost no management. The added cost of MOB along with the lower animal performance rendered the system undesirable.

Recommendations & Implications

The study frame for MOB grazing may have been too short. If the system leads to additional beneficial agronomic traits, such as improve soil or plant health, that were not yet realized, then the true economics of the system has yet to be realized. These benefits would be expressed in higher forage quality, which would in turn help boost animal performance. Additional research should be done on price slide and cattle weights; it is possible to have the price of beef increase over the grazing period. In this study, the selling price was always lower than the buying price. This does not have to happen; a more accurate mode of modeling the selling price would be accommodating. A better record of actual costs within the system would help make the budgets more realistic.

A further study should look at the harvest efficiency of MOB and the sensitivity of animal performance. The study would find the feasible region that would align the harvest efficiency, changes in animal performance, and certain beef prices. This would give producers more information in order to help them manage mob grazing systems. The research would give the producers a target zone and an idea of much animal performance can be affected.

Further research could also be done looking at compensatory gain and mob grazing. This would give insights if producers would be able to benefit from retained ownership of animals as they go into a feedlot setting. The animals would have increased gain and could have potential benefits to the owner. However, this economic hypothesis needs to be investigated further.

The results of the study have some important implications. Although MOB grazing was not as desirable as 4-PR-2 the livestock benefited from multiple moves. A producer wanting to adopt a mob grazing system should start with a 4-PR-2 system and adjust towards the mob system while keeping a close eye on animal performance. Along the same lines, the producer could also lower the stocking rate. Another important implication is that just because a producer switches to a rotational grazing system, does not mean their cattle will automatically perform better. The CONT system was ranked higher than 4-PR-1 and MOB throughout the analysis. When changing a system a producer will also have to make the appropriate management changes. Finally, it is important to seek information about systems such as MOB before implementing in an operation. This would help lessen the learning curve and help mitigate risk.

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Glossary

Animal performance- How much weight an animal gains per day, or how much weight is gained by the animals per unit of land (Smart et al., 2010).

Animal unit (AU)- It is equal to one mature cow of approximately 454 kg, either dry or with calf up to 6 months , or their equivalent consuming about 12 kg of forage on an oven dry–basis (Smart et al., 2010).

Average daily gain- The amount of weight an animal gains each day (Smart et al,. 2010)

Bioeconomic efficiency measure- a consolidated measure of management effectiveness. Some factors considered were rate of gain, body condition score, etc. These measures were all grouped into one variable with the assumption that these variables would accurately reflect how well management preforms (Wilson et al., 1987).

Continuous grazing (CONT)- A grazing system in which livestock are allowed to graze on one tract of land for the entire duration of the grazing season.

Deferred rotational grazing- A grazing system in which one paddock is not grazed until plants have had full opportunity to complete life cycle (Manley et al., 1997).

Disappearance- another name for harvest efficiency (Redden, 2014)

Four pasture one time through (4-PR-1)- Is a rotational grazing system in which the original pasture is split into four paddocks and livestock are moved through the four paddocks one time throughout the grazing season.

Four pasture two times through (4-PR-2)- Is a rotational grazing system in which the original pasture is split into four paddocks and livestock are moved through the four paddocks twice throughout the grazing season.

Gain per hectare- The total amount of weight gained per hectare. Calculated by total amount of weight gained by animals divided by the number of hectares in the parcel (Smart at el., 2010)

Grazing efficiency- The proportion of forage consumed by livestock to the total that disappears due to all other activities (Smart et al., 2010).

Grazing pressure index- The animal-to-forage relationship measured in terms of animal units per unit of weight of forage over a period of time (Smart et al., 2010).

Harvest efficiency- The proportion of forage consumed by livestock compared to the total forage produced (Smart et al., 2010)

Heifer-days ha^{-1}-the number of days an animal grazes on a particular hectare (Hart & Ashby, 1998)

Length of grazing cycle- The length of time in a calendar year during which animals graze on a given tract (Batabyal et al., 2001).

Livestock performance-in cow/calve operations performance is judged by conception rates, calving rates, weaning rates, and weaning weight. (Wilson, 1987).

Stocking rate- The number of animal units per unit of land (Batabyal et al., 2001).

Time-controlled grazing- A grazing system in which livestock is moved once a week. It is more aggressive than rotational grazing, but not as intensive as mob grazing (Manley et al., 1997).

Utilization- The proportion of the current year's production that is consumed or destroyed by grazing animals (Smart et al., 2014).