



The effects of calving date, weaning date, and duration of fall grazing on the sustainability of beef cow-calf operations in central and southeastern Montana
by Debra Jean Julien

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in
Animal Science
Montana State University
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Abstract:

A bioeconomic computer model was parameterized according to cow/calf production data from 11 southeastern (Northern Great Plains) and 10 central (foothill/mountain) Montana ranches to assist in identifying alternative management practices to improve long-term sustainability. Four two-week changes from the mean breeding dates, weaning dates, and range removal dates for ranches with fixed grazing and stored forage resource bases were simulated. Effects of changes in management dates were analyzed for average weaning weight, calf weight weaned per cow exposed, net income per cow exposed, herd size, break-even steer price, and ranch gross margin for each area. Cattle prices were determined by week from 13-year Montana averages. Input costs were locally established in 1994-5. Five replications were simulated for each combination of breeding date, weaning date, and range removal date in a factorial design. Simulated outputs were analyzed using least squares procedures. Biological and economic efficiency were improved for both areas with earlier breeding date and later weaning date. As weaning date and range removal date moved later into the fall herd size for the Foothill/Mountain and Northern Great Plains areas decreased from 578 cows to a mean 445 and 500 cows to a mean 394, respectively. Northern Great Plains area results suggested that break-even steer price and ranch gross margin were improved by increasing calf weaning age and extending the grazing season, even if herd size was reduced, Foothill/Mountain area results indicated that the greatest ranch gross margin and least break-even steer price were estimated when calves were older and range removal occurred on the median date. (KEY WORDS: Beef cattle, Simulation, Efficiency, Range grazing, Rangeland)

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A thesis submitted in partial fulfillment
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Master of Science

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MONTANA STATE UNIVERSITY
Bozeman, Montana

September 1997

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Michael W. Tess, Ph.D.

M. W. Tess

10/14/97
Date

Approved for the Department of Animal and Range Sciences

Peter J. Burfening, Ph.D.

Peter Burfening

10-14-97
Date

Approved for the College of Graduate Studies

Joseph J. Fedock, Ph.D.

Joseph J. Fedock

10/15/97
Date

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Date October 14, 1987

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ABSTRACT

A bioeconomic computer model was parameterized according to cow/calf production data from 11 southeastern (Northern Great Plains) and 10 central (foothill/mountain) Montana ranches to assist in identifying alternative management practices to improve long-term sustainability. Four two-week changes from the mean breeding dates, weaning dates, and range removal dates for ranches with fixed grazing and stored forage resource bases were simulated. Effects of changes in management dates were analyzed for average weaning weight, calf weight weaned per cow exposed, net income per cow exposed, herd size, break-even steer price, and ranch gross margin for each area. Cattle prices were determined by week from 13-year Montana averages. Input costs were locally established in 1994-5. Five replications were simulated for each combination of breeding date, weaning date, and range removal date in a factorial design. Simulated outputs were analyzed using least squares procedures. Biological and economic efficiency were improved for both areas with earlier breeding date and later weaning date. As weaning date and range removal date moved later into the fall herd size for the Foothill/Mountain and Northern Great Plains areas decreased from 578 cows to a mean 445 and 500 cows to a mean 394, respectively. Northern Great Plains area results suggested that break-even steer price and ranch gross margin were improved by increasing calf weaning age and extending the grazing season, even if herd size was reduced. Foothill/Mountain area results indicated that the greatest ranch gross margin and least break-even steer price were estimated when calves were older and range removal occurred on the median date. (KEY WORDS: Beef cattle, Simulation, Efficiency, Range grazing, Rangeland)

CHAPTER 1

INTRODUCTION

Many ranching enterprises located in the Northern Great Plains and northwestern mountain areas of the United States depend on native pastures for nutritional support of their livestock herds. Sustainable ranching depends on efficient utilization of forage resources and an ongoing understanding of the nutritional capabilities they provide. Decisions for managers of beef cow-calf enterprises must be based on the life cycle nutrient requirements and interactions with the grazing resources available.

To be considered "sustainable" a ranching enterprise must be economically profitable and financially viable to remain in business over an extended period of time, preferably over generations of owners. The ranch would have to be sufficiently profitable to compensate resources involved in production at their opportunity costs. From a financial viewpoint, there must be adequate ranch cash income to satisfy family living costs and service debts. Renewable resources such as native range, farm land, and water need to be maintained or improved in production and quality.

Managerial goals pertaining to cattle production strive to maximize efficiency, minimize waste and losses, maintain or improve the forage base and improve financial status. Cattle enterprises, however, may respond slowly to changes in range forage and herd manipulation. These factors, combined with cyclic environmental patterns, can result in difficulties when determining the long range economic effects of various management decisions.

An effective tool for both cattle production management and livestock research is computer simulation modeling. The computer simulation model can be used as an efficient and inexpensive tool for determining the long range effects of management alternatives. When several decisions are implemented at one time, singular changes can be analyzed for their particular results on the whole. Changes in production can be predicted over a greater span of time, while minimizing the short term effects of environmental and marketing fluctuations, providing a reduction in financial risk to producers.

CHAPTER 2

NORTH AMERICAN BEEF SIMULATION MODELS:
HISTORY AND DEVELOPMENTIntroduction

Since the advent of the computer, researchers have tapped its capability of performing long, complex mathematical equations rapidly, tirelessly, and without error. A single set of equations to define and answer one question could take a researcher days or weeks to decipher by hand, while a series of sets, say those needed to determine daily maintenance and growth of a nursing, pregnant cow on native range for a season, would have seemed insurmountable.

With the evolution of computer models to simulate specific functions, it was a natural progression to combine these efforts to emulate more holistic endeavors or production systems. As in the case of the development of beef simulation models, individual systems were created to describe specific biological functions and over time combined to include whole life cycles. The economics of cattle production, when added to the biological component, evolved into bioeconomic computer

simulations or integrated beef production systems with dynamic and interactive characteristics of real-life production enterprises (Tess, 1995).

Simulation models may be classified as either static or dynamic. Similar to detailed enterprise budgets, static models are mathematical representations of systems based on a series of non-interactive equations. They attempt to account for inputs and outputs over (generally) one year or production cycle (Tess, 1995).

Linear programs simultaneously solve a series of equations and optimally allocate resources to various interactive production functions to maximize an objective function (i.e. enterprise profit). They do not simulate changes in system function over time and generally account for only a limited amount of feedback. However, to obtain a final solution, linear programs must always place constraints on one or more resource inputs (e.g. feed, capital, labor, acreage) (Tess, 1995).

Dynamic models are usually a large and complex set of interactive equations that simulate system performance over a specific time frame. Feedback among system components and changes in system performance over time are simulated in response to input variables. This type of model may be deterministic (i.e., simulate only the mean performance of differing contemporary groups of animals) or may include

stochastic components which simulate individual animal performance including random differences among individuals. When studying the net effects of genetic changes in traits affecting carcass quality on commercial beef production systems the dynamic model is most useful (Tess, 1995).

The following section of this chapter provides a historical view and brief review of the scientific literature which resulted from North American beef simulation models. Due to the volume of literature having used computer simulation to research beef cattle production systems, no attempt is made to be all inclusive, but rather to provide an insight into modeling development.

Historical Review

The first U.S. journal articles dealing with system analysis for beef cattle production were published in 1975 by Long, Cartwright and Fitzhugh at Texas A&M University Agricultural Research Center, McGregor. They used study results from the research center and other published experimental data to develop a deterministic model with linear programming. In a series of three articles they evaluated sources of environmental and genetic variation on efficiency of beef production by cow size and herd management, heterosis and complementarity, and mating plans (Cartwright et al., 1975; Fitzhugh et al., 1975; Long et al., 1975). Cow numbers

varied due to different amounts of nutrients required to raise and maintain cows of different sizes and grow their progeny to a maturity constant slaughter weight.

Long et al. (1975) evaluated the effects of beef cow size on productive efficiency for four straight breeds with three different growth patterns using two sets of production conditions. An optimum solution was determined by maximizing net return to a fixed amount of capital (constrained resource) for feed expenses. Their results indicated small cows were most profitable, followed by medium and large for pasture production with the reverse true for drylot production, however overall small cows were most profitable on pasture.

The crossbred and straightbred progeny of the previous study were used to determine economic and biological effects of hybrid vigor and complementarity in a closed beef production system (Fitzhugh et al., 1975). Comparisons between systems were made for profitability and productivity with a common constrained resource for feed expenditures. Progeny were slaughtered at 110% of similar genotype cow mature weight. Expenses charged against gross income (total live weight production) were feed, fixed per head costs, and 7.5% interest on total investment. Maximum profitability resulted from crossbred mating of the smallest cows with the largest sires for both drylot and pasture production; however, pasture production provided the greatest overall

profitability. When cow size and feed costs were constant, it was more profitable to maintain smaller cows which produced larger crossbred calves.

The simulation model was then used by Cartwright et al., (1975) to evaluate the production efficiency of two-breed, three-breed and two-breed rotational mating systems. Female replacements were produced in each system and calves were fed after weaning to slaughter weights of equal maturity. Results from the simulation indicated that biological efficiency between single crosses and crisscrosses were similar, however net income was increased for 2-way crosses as well as representing an increase on return of investment of 14 to 15% for the Drylot and 9 to 12% for the Pasture. A criss-out-cross system of small cows and large sires further increased net income and return on investment. Net results of the 3-breed system, large sires on either F_1 or crisscross cows, were more favorable than all other crosses.

Although linear programming (LP) had been available for some time, its primary use in animal production was for least-cost ration formulation (Wilton et al., 1974). Five papers were published from 1974 to 1976 in the Canadian Journal of Animal Science by researchers from the Department of Animal and Poultry Science, University of Guelph, Ontario which used linear programming to address whole ranch production systems (Wilton et al., 1974; Morris and Wilton, 1975; Morris et al.,

1976; Morris and Wilton, 1976; Wilton and Morris, 1976). Linear programming was chosen for its useful technique for optimal allocation of resources to maximize an objective, subject to a series of restraints (Morris and Wilton, 1975).

Wilton et al. (1974), extended the LP approach to integrated beef cattle production to include crops, cow-calf, and feedlot enterprises. Researchers described the use of LP in beef production planning on an integrated farm unit, described a set of animal and crop production values (i.e., numbers and weights of various age animals, feed and labor requirements, and crop yields), and illustrated the application of the model. Results of their research were based on small, medium, and large straight-bred cows limited to 100 head. The model included; 1) scheduling of animal annual and life cycle events, 2) animal numbers and ages, 3) weights and growth rates, 4) feed inputs for cattle, 5) labor costs, 6) variable costs of livestock and crop production, 7) crop yields, 8) commodity prices, and 9) interest payments. Comparison of enterprise systems was on the basis of gross margin. Gross margin was defined as the difference between total revenue from meat and crops and the sum of variable costs of production (i.e., hired labor, crops, leased land, purchased feed, and net interest on working capital). Simulated results indicated a higher total gross margin for large cows than for medium or small cows, however these

results did not necessarily reflect similar ranking for biological efficiency.

The simulation model was used in a second research project to evaluate the influence of mature cow weight on economic efficiency in beef cattle production and to estimate economic values for the genetic traits of mature weight, weaning weight, and average daily gain (Morris and Wilton, 1975). Five factors were considered which resulted in 450 possible combinations of values; 1) five mature cow sizes, 2) three farm sizes, 3) three herd sizes, 4) two marketing options, and 5) five beef/feed price combinations. Results from this study were inconclusive. The underlying assumptions of the model were all important to the conclusion, because they determined the interaction between different technical coefficients and constraints. Even if biological efficiency components were defined adequately, biological efficiency did not necessarily rank animals, breeds, or systems in the same order as economic efficiency.

Morris et al. (1976) used the Canadian model, with biological values from the literature, to determine the effects of three mature cow weights, two levels of potential milk yield, and two durations of creep feeding on economic efficiency. Milk yields were compared to different levels of management with varying labor, total land, minimal pasture, and beef:feed ratios. The objective was to maximize farm

gross margins. Simulated results indicated increased cow size always increased farm gross margin, however in general there was no optimum strategy of milk yield and creep feeding for maximal efficiency.

Reproductive performance and mating systems were studied for their effects on farm gross margin in beef production systems (Wilton and Morris, 1976) using the Canadian model described by Wilton et al. (1974). Three mating systems (straightbred, three-breed rational, and terminal cross) were compared at three reproductive rates, two levels of heterosis, two beef:feed price ratios, five mature cow sizes, and three management choices. They concluded that terminal crosses provided larger farm gross margins due to optimal use of farm resources than straight or rotational cross breeding. Their results indicated that comparisons of mating systems are dependent on estimates of heterosis, reproductive rates, beef:feed prices, and resources, as well as basic assumptions used in the model.

Morris and Wilton (1976) used the Canadian model to establish the highest gross margin for three management programs, two reproductive levels, and three mating types. Their model was limited by labor, farm size, and permitted crop sales. For terminal crossbreeding, 2-way cross replacement heifers were purchased at 7 months or as pregnant heifers at 19 months. Results indicated at both reproductive

performance levels terminal crosses of large bulls mated to small crossbred cows had the greatest farm gross margin where 7-month old, 2-way bred heifers were bought and an equal number and age of terminal cross heifers were sold.

In 1976 Smith published results on the effect of sire breeds on the economic efficiency of terminal-cross beef production systems. His approach was to supplement data from a specific experiment with necessary assumptions to quantify the cost of calves entering the feedlot, feedlot costs, and carcass value using a static model (Smith, 1976). The model simulated cow-calf production through retail product for cow and calf profit. Results indicated comparative advantages were high for calves sired by large, growthy sire breeds, especially out of 2-yr-old cows. The growth and carcass merit of the larger sire breeds tended to offset even substantial costs associated with increased calving difficulty.

A series of three research papers were introduced in 1979 for beef production simulated efficiency of Midwestern management systems for cow-calf-feedlot milk production, mature body size and crossbreeding systems (Notter et al., 1979a,b,c). Simulations were conducted with a deterministic, dynamic modified version of the Texas A&M cattle model developed by Sanders and Cartwright (1979a,b) and was used to predict animal performance (Notter et al., 1979a,b,c). The study objective was to discover the optimum size for a beef-

producing animal. Goals included identifying breeds, mating, and management systems which could be combined to minimize production costs under specific conditions.

The objective of the first study was to investigate the effects of level of milk production on biological and economic efficiency for a range of body sizes and the associated effects of relative total digestible nutrient (TDN) costs and total costs per 100 kg of empty body or fat free weight (Notter et al, 1979a). Results indicated that weaning weight per cow exposed was maximum at intermediate milk levels. Cow size interacted with milk production potential (MPP) such that a decline in reproductive rate with increased MPP was less in large cows, and calves which received less milk took longer to reach slaughter weight. In general an increase in MPP that increased weaning rate by increased calf survival generally increased economic efficiency, however increased MPP that reduces weaned weight per cow exposed due to decreased pregnancy rate reduced economic efficiency.

The second study evaluated the total effect of mature body size on the efficiency of beef production (Notter et al., 1979b). Their estimates indicated that, in general, small cows were more economically efficient if cost of TDN was inexpensive and larger cows more efficient if TDN costs were high. Results concluded that effects of breed size on realized economic efficiency of beef production was to be

expected. However, those effects mainly reflected management, pricing, and interaction with size rather than a true biological effect of size.

Evaluation of the total economic efficiency of beef crossbreeding systems was the objective of the third study. It included all sources of costs and returns for the enterprise and purebreds needed to produce female replacements for the crossbred herd (Notter et al., 1979c). Output was measured in cost of TDN required per kg of feedlot EBW. Results indicated systems with individual heterosis were more economically efficient than those without, systems with maternal heterosis were more efficient than those without, and use of large terminal sires with attempts to minimize dystocia were more economically efficient than those not using large sires. At the same sire breed size, rotational crossbreeding systems (with higher heterosis) were more economically efficient than specific crossing systems.

Congleton and Goodwill (1980a,b,c) published a series of three papers on comparisons of simulated breeding plans for beef production. The first research was development of a dynamic model to evaluate the effect of mating plans on productivity and herd age structure. The objective was to compare productivity of different breeding programs in combination with various culling policies. A dynamic component modeled the cow age structure, numbers, and growth

of offspring. Dystocia affected the average herd age, fertility, and early calf mortality when different sized sires were used (Congleton and Goodwill, 1980a).

The second publication used the previously developed model to determine the kg/calf produced per cow bred. Three sire breeds were used on Angus, Hereford, and crossbred cows to compare mating plans for feeder-calf production with light culling (Congleton and Goodwill, 1980b). The model generated numbers and weights of animals, herd size and structure, amount of dystocia, with output compared on a per cow basis. Results indicated Charolais sires and Hereford x Angus dams produced the most kg/calf per cow bred, however matings with Angus cows, producing their own replacements, had the highest gross income per cow. The most productive mating plan was not necessarily the most profitable.

Part three of this study involved additional breeds of sires and more intensive culling for producing feeder-calves. Heavy culling (cow was culled if failed to become pregnant) resulted in a decrease in average herd age, increased dystocia, and a decrease in calves weaned per cow. Results indicated Charolais x Hereford-Angus and Hereford-Angus criss-cross were the most productive combinations, however Charolais x Angus ranked highest for profitability and least for productivity (Congleton and Goodwill, 1980c).

Angirasa (1985) used a biological simulation model interfaced with a linear programming model (Sanders and Cartwright (1979a,b) to determine production efficiency of East Texas cow-calf production. Program options included three choices for forage systems, two calving seasons, and four winter feeding levels. Objectives were to use a systems approach to simulate production of different management practices given several forages, determine carrying capacities, and to compare net returns for each. Results indicated spring calving herds were larger than fall calving herds, however the later produced more live weight sales and generally greater net returns.

The Texas A&M Cattle Production Systems Model (Sanders and Cartwright, 1979a,b) was used by Doren et al. (1985) to extend the information obtained from a biological simulation model to economic interpretation, to better understand how biology and economics interact. Management alternatives included choices of four calving seasons, two or three years of age at first calving, and three levels of supplementation. Results indicated highest production was from 2-yr old cows calving in the fall, however the two most profitable practices involved 2-year old cows and spring calving. Efficiency indicators were felt to be inaccurate guides to relative profitability of management alternatives especially if the magnitude of associated error was large.

Stokes et al. (1986) used the Texas A&M model (Sanders and Cartwright (1979a,b) to evaluate the economic performance of 18 simulated cow-calf herds with differing mature cow size, milk production, and weaning strategy. Costs and returns were calculated for each of the 18 options with net returns also computed for two fixed resource situations. Simulated performance indicated increased output per cow was associated with increased mature size and increased potential milk production. Per hectare cost was least for the large, light milking cows and greatest for small, heavy milking cows. Large, light milking cows had the highest net returns and best economic performance under both weaning policies. Due to declining calf prices, none of the options experienced a positive net income over the simulated 10 year period.

A study was conducted by Marshall and Frahm (1986) to evaluate lifetime productivity of various two-breed cross cow groups when mated to a third bull breed. A deterministic model (static in nature) was used to simulate a terminal crossbreeding, cow-calf-feedlot production system with spring calving and 205 day weaning. The bioeconomic model attempted to account for cow group differences in reproductive performance, nutrient requirements, calf growth rate, calf survival, carcass composition, and cow salvage weights. Relative profitability was compared by gross margin per herd when available land was constrained. Differences among cow

groups resulted in considerable variation in herd composition, replacement rate, and size. The relative advantages and disadvantages of differing groups tended to offset one another, resulting in small to moderate differences in herd gross margin.

In order to be profitable, any farm enterprise must strive to be as economically efficient as possible. Towards that end, McMorris et al. (1986) developed a static model to evaluate cow weight, breeding system and milk yield effects on profitability in beef production. The economic variables were gross margins for each grouping of cows, any changes in rank due to production system, beef-to-feed price ratios, feedlot overhead expenses, overweight carcass discounts, and retail yield premiums. Results from this study indicated that no simple answers were available regarding optimal cow milk yield or weight.

The economics of calf production using foreign cattle breeds crosses were studied by Smith et al., (1987a,b) for the parkland area of western Canada and short-grass prairies of Alberta. The objectives for both areas was to compare British and foreign breed cross dams and three-way cross progeny for net farm income per dam. The computer model used simulated beef, forage and grain production farms for each study area and the various management procedures. Dynamic in nature, the model was a multi-year budget-development tool which included

personal and nonfarm financial factors, in addition to technical, biological, and economic factors of cattle, forage, and crop production.

Results for the parkland area of western Canada indicated that Charolais-Angus and Simmental-Shorthorn cross dams were the most profitable while Limousin cross dams were least profitable. Charolais and Limousin sires outranked Simmental and Chianina terminal sires for net farm income per dam (Smith et al., 1987a). For the short-grass prairie area of Alberta, results showed Simmental-Angus cross cows had the highest net farm income per dam when bred to Charolais or Limousin, but not when Chianina was the terminal sire. Charolais and Limousin were the most profitable sires over Chianina and Simmental (Smith et al., 1987b).

Bourdon and Brinks (1987a,b,c) modified the Texas A&M University Beef Production Model (Sanders and Cartwright, 1979a,b) including changes by Notter (1977) to simulate a northern plains range environment. The model was deterministic (dynamic, linked to a linear program) operating on classes of animals by age, sex, month of calving, lactation status, calving difficulty and month of gestation. Over a one year period, it simulated growth, intake, lactation, death loss, fertility, hybrid vigor, and herd dynamics. Three scientific publications resulted from their work, each dealing

with an aspect of simulated biological and economic efficiency of range beef production.

The first study explored growth, milk production, and management systems (Bourdon and Brinks, 1987a). The objectives were to determine the effects of growth and milk production on biological and economic life-cycle efficiency, generate weighting factors for use in determining selection priorities, and to study the interactions of genotype, management, environment, and economics as to how they affected production efficiency. Results from this simulation tended to favor larger, faster growing cattle, rapid early growth, lighter birth weights, increased calf survivability, and backgrounding of calves when costs and prices were average. High feedlot costs favored medium and small cows while high winter costs for the cow herd favored medium to large cows.

Fertility traits were the research subjects for the second paper of this series (Bourdon and Brinks, 1987b). The goals for this study were to compare life-cycle, herd-wide, biological and economic efficiencies of genotypes with differing inherent fertility (age at puberty and maximum probability of conception), determine the relative importance of fertility on production efficiencies, and study the effects of economics and management of herd fertility and production efficiency. Results showed that decreased pregnancy rates implied not a loss of product, but a change in the source of

products - from slaughter heifers to cull cows. Survivability rather than fertility proved the key traits to improve.

The last published paper in this series dealt with culling strategies and nontraditional management systems (Bourdon and Brinks, 1987c). Study objectives used one medium genotype of cow to verify changes of biological efficiency per age structure of a cow herd, determine if economic efficiency could be improved by culling at specific ages, examine the merit of finishing cull cows in a feedlot, and estimate the efficiencies of sex-controlled systems. Simulated results indicated biological but not economic efficiency of lean product production was increased by slaughtering cows at relatively young ages. Increased economic efficiency was attained by adopting strategies that marketed more cull cows when cull cows are relatively valuable in comparison with fed animals.

Smith and Rahnfeld (1988) used data on growth and feed conversion efficiency to evaluate differences in the economic value of feeder calves between breed crosses. A static model, which fed one group of calves per year for a predetermined length of time was used. It simulated producers with a crop enterprise who finish cattle during winter months to utilize labor and farm resources. Slaughter animals were evaluated by live, hot carcass, and lean meat weights. The potential value of feeder calves of similar weight differed between breed

crosses. Carcass grades and yields, rate of gain, and feed efficiency differed between the various crossbred calves. Slower growing or low-yielding carcass calves were less valuable than those crosses which produced calves with high rates of gain and high-yielding and grading carcasses.

The objective of crossbreeding systems is to optimize heterosis and additive breed effects in the entire population simultaneously (Gregory and Cundiff, 1980). To that end, MacNeil et al. (1988) used a static model and data from a four-generation crossbreeding experiment to estimate breed-specific additive and heterotic effects on weaning weight per cow exposed, component traits, and postweaning growth and carcass traits. Findings indicated that cow-calf producers should use both heterosis and breed differences. Gains from using crossbred cows producing crossbred calves over straightbreds showed 3 to 17% improvement in weaning weight per cow exposed.

Linear programming techniques were used by Brennan and Hoffman (1989) to develop a comprehensive computer simulation model of a midwest farm-feedlot production system. A series of cattle feedlot trials provided data for analysis by the model to identify optimal feeding and management strategies to improve overall efficiency and profitability of beef cattle feedlot production. Inputs into the feedlot system, due to changing market prices, were constantly in flux. However, the

results from the simulation model clearly demonstrated the significance of the dynamic interactions between various facets of the feedlot production system and the resulting contribution of overall profitability.

Experimental data was used by Lewis, et al. (1990) to develop a static model evaluating economic criteria involved in backgrounding (extensive) or directly finishing (intensive) calves. Analysis of their data was based on break-even price and overall cost of gain. Results indicated that the price of corn, annual interest rate and feeder cattle price had the greatest overall economic impact on the system. However, due to the additional weight produced with backgrounding calves, this method was more economical than placing calves directly into the feedlot under most price relationships.

Armstrong et al, (1990a) published research on comparisons of four cattle breeding systems for feed intake, weaning weight and net returns. A linear programming model was designed to determine the breeding system which maximized net returns under the various production conditions and constraints on herd size and feed supply. In general, their results found that although dams from larger breeding systems weaned heavier calves, they also consumed the most feed. Neither feed intake nor body size was a simple indicator of net returns.

In a second publication, Armstrong et al. (1990b) researched beef production net returns as influenced by variations in biological and economical parameters. Linear programming was used to determine the best allocation of scarce resources with many alternatives but a specific goal. Their study objective was to measure net returns for different breeding systems and to rank the systems on varied simulated resource constraints, beef to feed price ratios, calving rates, management systems and environments. Findings indicated that comparisons of breeding systems were sensitive to changes in calving rate, environment, management, beef to feed prices and resource constraints.

Green et al. (1991) developed a deterministic model to compare the life-cycle biological efficiency of production to weaning for F_1 cows of two *Bos indicus*-*Bos taurus* crosses with that of two *Bos taurus*-*Bos taurus* crosses, while rearing calves sired by a third breed. The model accounted for known inputs and outputs for a theoretical herd at age equilibrium for one production cycle. Efficiency was evaluated by total cow and calf feed energy input per unit of weaned calf weight output and by per unit of weaned calf plus .55 x cull cow weight output. Simulated results indicated that for the south-central Nebraska environment, *Bos indicus* crossbred cows were favored by 4% over other breed crosses. Costs were lower for earlier terminal cow ages (7 vs 11 yr) due to lower total

feed input in relation to total output value per cow maintained.

A deterministic computer simulation model was used by Werth et al. (1991a) to evaluate the economic efficiency of different durations of breeding seasons in beef production systems. Breeding seasons were 45, 70, or 120 days in length and heifers were bred with the cows or started 21 days prior. The model calculated a net income for one year of production using resources and prices common for cow-calf production in the Sandhills of Nebraska. Findings showed earlier breeding of heifers with high first service conception rates resulted in the greatest expected net income and they produced more kg of calf at weaning during their lifetime. The longer breeding season, if first service conception was low, indicated that selling a light calf, born late, was more profitable than selling a nonpregnant cow and replacing her with a heifer. In this environment, optimized net income resulted from management where herd replacement rates were low with a greater percentage of older cows weaning heavier calves.

In a companion publication, Werth et al. (1991b) combined a stochastic dynamic model for herd reproductive performance with a deterministic cow-herd economic simulation model for management to evaluate performance interaction on net income for a cow-calf operation. Herd performance was determined for three lengths of breeding season with three different

postpartum intervals and first service conception rates. Results showed net income was greatest with moderate postpartum intervals, 70-d breeding seasons, and early breeding for heifers.

Lamb et al. (1992a,b,c, 1993), in a series of four publications, used a deterministic computer model to evaluate five breed mating systems for integrated beef production systems. All breed data was taken from the literature, representing southeastern U.S. beef production, and involved purebred, two- or three-breed rotational crossbreds. Results were reported as total megacalories of metabolizable energy (ME) per kg of steer equivalent weight for biological efficiency and economic efficiency was reported as total input dollars per kg of steer equivalent weight. Inputs included all nonfeed and feed costs.

The first research in this series dealt with the cow-calf segment (Lamb et al., 1992a). Weaned steers and nonreplacement heifers were finished in a feedlot for slaughter. Findings indicated biological efficiency improved 14% and economic efficiency improved 20% with crossbreeding. Crossbreds with Angus and/or Hereford were more efficient biologically and economically. Continental breeds were more economically efficient and British breeds more biologically efficient.

Lamb et al., (1992b) reported on the study of the feedlot segment for the second publication. All feeder calves were purchased at 205 d of age and were independent of the cow-calf segment. Megacalories of ME per kg of weight gained was only for the feedlot time. Economic efficiency was defined as input costs per kg of carcass weight, lean weight and carcass value. For all slaughter end points, crossbred calves improved all efficiencies. Continental breeds combined with British breeds were the most efficient over all.

The third publication in this series researched the integrated system (Lamb et al., 1992c). Findings indicated biological efficiencies were influenced more by the cow-calf segment and economic efficiencies were influenced more by the feedlot segment. Breed combinations that were most efficient in the cow-calf segment were not desirable in the feedlot. Crossbreds of British and Continental origin were consistently more efficient than all others at all end points.

The last publication for this group examined variability in the average carcass performance from the previous research by Lamb et al. (1992a,b,c) and accounted for genetic trends within breeds (Lamb et al., 1993). The 1970 data was adjusted to a 1984 base. Findings showed breed combinations that previously produced underweight carcasses were ranked among the most efficient breed combinations within their mating system when adjusted. Changes in efficiencies occurred within

the cow-calf and feedlot segments, however the integrated system rankings remained relatively unchanged.

The economic and biologic efficiency of three crossbred cow types of similar mature size but producing low, medium, or high milk was studied by van Oijen et al. (1993). A static model was used to compare the three groups by ratio of income to expenses for economic efficiencies, and ratio of calf weight to total feed energy required for biological efficiencies. Estimates showed, with similar mature body weight, the low milk production cows were the most efficient at weaning and slaughter endpoints.

A computer simulation model was developed by Tess and modified by Kolstad to measure economic performance of five strains of composite Beefbooster cattle, three simulated rotational crossbreeding systems, and their resulting change in genetic potential (Kolstad, 1993). The model was deterministic with limited stochastic functions (mostly related to reproduction) and simulated life-cycle performance for an entire herd. Inputs included all variable costs of production for a cow-calf enterprise. Results showed that all rotational strains were more profitable than the composite strains and a younger age distribution improved profitability.

Melton et al. (1994) developed a time-dependent static model reflecting both physical and economic considerations in commercial breed choice which require simultaneous

consideration of multiple facets of cow-calf production processes. Included were resource availability, market prices, prevailing economic trends, multi-product and multi-year nature of beef cow production, breed differences in production and performance, and differences in breed nutrient requirements. The model was illustrated with a 2023.5 ha West Texas Panhandle range ranch. Results indicated small, higher productivity cows were economically preferable over large, slow maturing breeds. However, the simplicity of the model allowed its use with desktop personal computers making it available to producers and extension personnel as a tool for breed selection decisions.

Using data from specialized Beefbooster sire and dam lines, MacNeil et al. (1994) developed a deterministic herd-level model to simulate enterprise profit from 100 beef cows in western Canada. The model was used to derive economic values for specialized sire and dam lines in a vertically integrated crossbreeding system. It examined the sensitivity of economic values to temporal change in economic environment and the effects of different system endpoints on economic values. Findings showed direct and maternal weaning weight had greater relative economic values at weaning than at later endpoints and relative economic values for feed conversion increased as time on feed increased.

Davis et al. (1994a,b) published two papers on life cycle evaluation under cow-calf range production for five biological types of beef cattle. The first research paper explained the rationale and development of the model which specifically used data from a 10-yr study at the Northern Agricultural Research Center, Havre, MT (Davis et al., 1994a). The model was deterministic with stochastic elements (mostly involving reproductive functions). Biological performance was measured by numbers of matings, calves weaned per cow exposed, and calf weight weaned per cow exposed, ME consumed per kg of calf weight weaned or total weight sold, and total dry matter consumed. Economic performance was summarized by break-even steer price, total cost per cow exposed, net profit per cow exposed, and ranch net profit.

The second publication (Davis et al., 1994b) used the model to evaluate the biological and economic performance of the five biological types of beef cattle and to estimate maternal heterosis and maternal breed substitution effects for the performance system. Results estimated that breed groups of moderate mature size and milk production were more profitable than more extreme types for growth and milk production.

Research for data on live animals, involving integrated beef production systems, has become cost prohibitive for most universities and research facilities. However, through the

development and use of computer simulation models, incorporating and building on the results of many smaller studies, investigators will continue to explore more efficient means to improve the beef industry.

CHAPTER 3

SUSTAINABILITY OF WESTERN RANGE
LIVESTOCK PRODUCTION

A concise definition of 'Sustainable Agriculture' has yet to be formulated. This is partly due to differing viewpoints as to what is and what is not sustainable agriculture (Heitschmidt, 1996), as well as acceptance or rejection of any definition is closely joined to individual value systems (Clark and Weise, 1993). In part, it may be because sustainable agriculture is more often viewed as a management philosophy rather than a method of operation (MacRae et al., 1993) that definition becomes difficult.

Sustainable agriculture is broadly defined by Heitschmidt et al. (1996) as ecologically sound agriculture and narrowly defined as eternal agriculture. Agricultural forms which do not require exogenous energy subsidies to function are most likely to be eternal. Grazing of indigenous grasslands is an example of one of the most sustainable forms of agriculture known (Heitschmidt et al., 1996). Ruminants will continue to serve a valuable role in this system. They are well adapted and useful in converting vast renewable resources from

rangeland, which is too poor or erodible to cultivate, into food edible for humans. Nutrients remaining in grazing animal's by-products are utilized in maintaining the rangeland ecosystem and do not become a waste disposal problem (Oltjen and Beckett, 1996). No other form of agriculture is less dependent on external resources such as fossil fuels, pesticides, fertilizers, etc. than the grazing of native rangelands (Heitschmidt et al, 1996).

Bormann et al. (1994) defines sustainable systems as those that exist in the overlap of what the present generation wants for itself and future generations, and what is biologically and physically possible in the long term. The focus is toward merging ecology and economics to ensure what is economically sound in the short-term is ecologically sound in the long-term (Heitschmidt et al, 1996). It is difficult to argue that traditional practices have not been sustainable when many ranches are operated by third and even fourth generation families, however producers are examining traditional management in search of methods to lower costs and improve profitability (Clark, 1994). Although it is difficult to define what is sustainable in livestock production, it is possible to define what it is not. If it is not profitable, it is not sustainable (Busby, 1994).

CHAPTER 4

GRAZING THE NORTHWESTERN UNITED STATES

Forage Base of the Northern Great Plains

The region known as the Northern Great Plains is both definable and unique. Its boundaries include South and North Dakota, eastern Montana, northeastern Wyoming, western Nebraska, and the lower portions of Alberta, Saskatchewan, and Manitoba. Characterized by climactic extremes - short, hot summers; long, cold winters; wind; and highly sporadic precipitation - it is, nevertheless, highly productive range (Goetz, 1988). It is viewed as an area of important livestock grazing that has potentially low input and long term sustainability.

The growing season is short for this area, beginning in mid-April for the southern regions and mid-May for the northern regions. Precipitation at the 49th latitude varies from 12 inches on the western border to 23 inches on the eastern boundary of the Great Plains. The major period of plant growth receives approximately 70 - 75% of the annual moisture (Goetz, 1988).

Forage species of this area may be grouped into three classifications; forbs, browse or shrubs, and grasses. Grasses are members of the family *Poaceae*. Forbs are herbaceous perennial and annual monocots and dicots other than grasses. Browse are perennial woody shrubs and vines used as forage by grazers (Kothmann, 1980). A complete listing of indigenous plants of the Great Plains is given by Goetz (1988).

Each forage class differs in nutrient content and shows characteristic seasonal changes in specific nutrients with advancing maturity. Of the three classes of vegetation, grasses are highest in cellulose and lowest in protein, however they typically lose nearly one-half of their protein content and significantly increase in lignin and cellulose as the growing season advances (Cook and Harris, 1968). Because mostly leaves are grazed, browse species are lowest in cellulose and highest in protein with forbs being intermediate in most respects. As the season progresses lignin and cellulose increase moderately and protein decreases slightly for both shrubs and forbs.

Cattle often graze the Great Plains 12 months of the year and generally calve during the spring season (Ward et al., 1987). Variable precipitation patterns and seasonal progression in this area provide a highly variable nutritional forage basis throughout the year for livestock. Crude protein

may range from less than 4% in winter to over 18% in the spring. Metabolizable energy also varies from 1.4 mcal/kg DM in winter to 2.6 mcal/kg DM during the spring (Adams and Short, 1988). Unfortunately, seasonal patterns of forage quality and quantity do not always match seasonal patterns of livestock nutrient requirements. As fall approaches total forage supply usually has decreased due to prior grazing and plant growth slows and stops; however, livestock nutrient demand continues (Hart, 1991).

According to Adams and Short (1988), although the nutrition of grazing cattle is complex, productivity is determined by three general nutritional factors; 1) availability and concentration of nutrients in range forage diets, 2) quantity of consumed forage, and 3) nutrient requirements of the animal. To coincide cattle production cycles, as closely as possible, with range nutritional cycles most stockmen of the Northern Great Plains utilize spring calving systems. Calving lasts about 60 days beginning in March or early April. During the first 3 - 4 months following calving, protein and energy requirements are the highest of the annual production cycle of the cow. This need parallels the most productive range season for this region (Adams and Short, 1988). Fall and winter provide the lowest values of range nutrition. At this time the cow is not lactating and is

in the last 2/3 of gestation, also her lowest time of nutritional demand (NRC, 1984).

Prairie Range Forage Protein
and Metabolizable Energy

Adams and Short (1988), in an attempt to define the relationship between season of the year and forage quality, developed an annual model for dietary concentration of crude protein (CP) and metabolizable energy (ME) for beef cattle grazing the Northern Great Plains. Their research was based on 78 esophageal fistula collections taken from 1975 to 1985 from four to eight steers grazing native range near Miles City, MT. All months were represented except February and March. The CP values were regressed on date resulting in a significant fifth degree polynomial based on R^2 values (Figure 1).

$$\begin{aligned} \text{CP: } Y = & -274.3423 + 6.37754X - 0.0536825X^2 \\ & + (2.1454696 \times 10^{-4})X^3 - (4.1209498 \times 10^{-7})X^4 \\ & - (3.0624962 \times 10^{-10})X^5 \\ R^2 = & 0.73 \quad P < 0.01 \end{aligned}$$

Contents from the fistula samples showed CP increased rapidly in early spring (April - May), peaked in early June, and then decline as forage matured through summer and fall.

Individual collection dates show CP ranging from 18% in early June to less than 4% by January (Adams and Short, 1988).

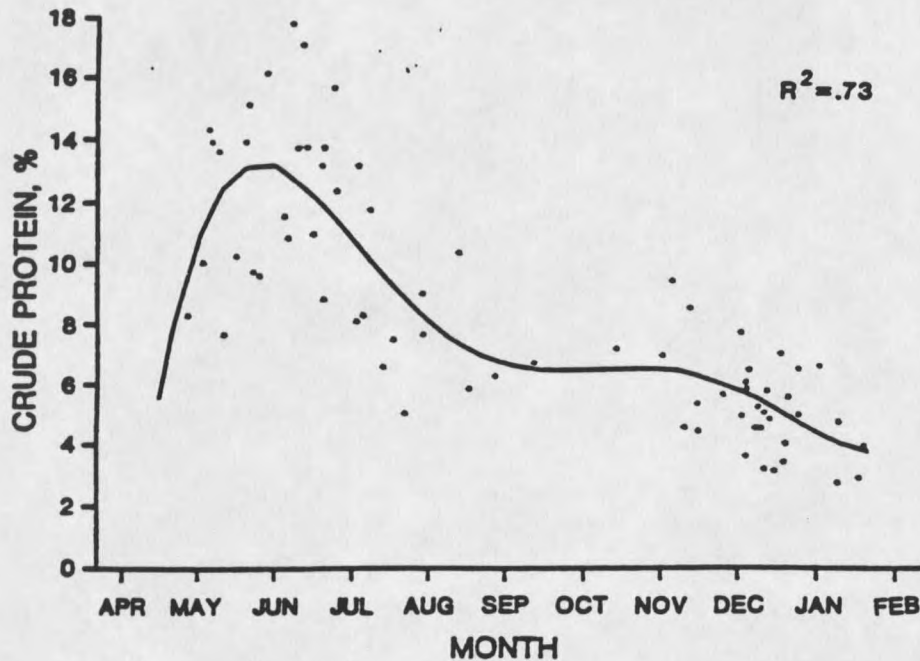


Figure 1. Concentration of crude protein in cattle diets at various times of the year on Northern Great Plains rangeland (from Adams and Short, 1988).

The NRC (1984) subdivides crude protein requirements of cattle into specific metabolic costs or factors. These include 1) metabolic fecal loss, 2) losses from hair, skin, and scurf, 3) endogenous urinary loss, and 4) synthesized protein products including fetal growth, tissue growth, and milk production. Requirements of CP for breeding cows in the second trimester of pregnancy range from 6.9% of dry matter (DM) diet for large, dry, mature cows to 14.2% for small,

superior milking cows. For most average milking 400 to 550 kg range type cattle, an average of 9.5% CP in dietary DM fulfills the needs for the first 3 to 4 months postpartum. Adams and Short (1988) found that these needs are met by a mid-April turnout date through July near Miles City, MT. However, their research shows that by late August CP intake for steers fell below the 7% level and by late December had further declined to less than 6% of dietary DM. Cows can experience a negative protein balance due to a decreased intake of dormant forage from August to October and the lower protein concentration in the diet (Kartchner and Campbell, 1979).

Adams and Short (1988) also regressed ME in vitro digestibility values on date. This resulted in a significant fifth degree polynomial regression equation for dietary metabolizable energy of range forage (Figure 2).

$$\begin{aligned} \text{ME: } Y = & -16.17627 + 0.4089018X \\ & - (3.4456979 \times 10^{-3})X^2 - (1.3862248 \times 10^{-5})X^3 \\ & - (2.6940588 \times 10^{-8})X^4 + (2.0350767 \times 10^{-11})X^5 \\ R^2 = & 0.57 \qquad P < 0.1 \end{aligned}$$

When compared to ME required by confined cattle, grazing animals needs can be up to 40% greater (Havstad and Malechek, 1982). Depending on calving date, energy (ME) supplied by

range forage would meet a lactating cow's requirements during May, June, and July. However, ME would be deficient before spring green up (ie. March and April) and for moderate to high lactating cows during August through October (Adams and Short, 1988). Lack of sufficient ME in the diet to meet lactation, gestation, maintenance, and winter cold stress requirements results in loss of body condition.

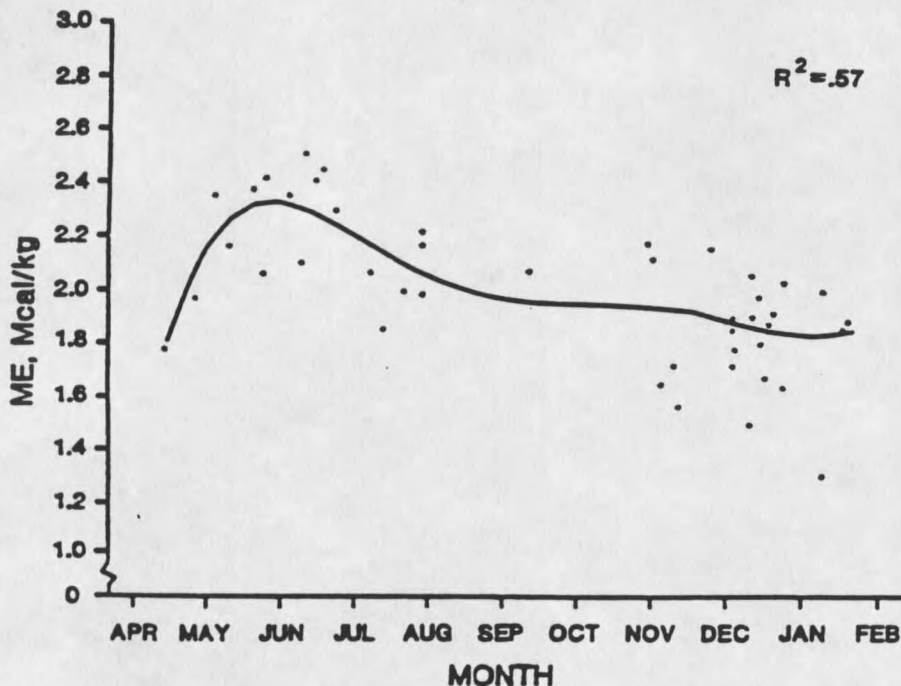


Figure 2. Concentration of metabolizable energy in cattle diets on Northern Great Plains rangeland (from Adams and Short, 1988).

Grazing Foothill and Mountain Ranges

Mountainous grazing areas are usually characterized by a higher percentage of forbs and shrubs to grasses than prairie

sites. Leaves and young stems of shrubs maintain, even after reaching maturity, relatively high levels of crude protein (Cook and Harris, 1968). Plants do not mature as quickly on mountain pastures as opposed to grasslands with earlier greenup. This may be partially due to canopy cover shade slowing maturity rates (Holechek et al., 1981). The same cover may reduce any effects of late summer precipitation and the resulting fall plant regrowth experienced by prairie ranges (Holechek and Vavre, 1982).

Holechek and Vavre (1982) found that during summer grazing periods cattle on forest had higher dietary intakes ($P < .05$) than cattle on grasslands. This was the result of less advanced plant phenology and higher contents of shrubs and forbs in the diet. Ralphs and Pfister (1992) found 48 to 83% forbs in cattle diets of forb dominated communities while grass range use was 11 to 32%. Similar results were reported at Oregon's Starkey Experimental Forest and Range Site. Thirty nine percent of summer diets on mountain forest range were composed of forbs and shrubs whereas grassland diets were 20% forbs and shrubs (Holechek et al., 1982). Compared to grass leaves and stems, forbs and shrubs result in faster rumen turnover, decomposition, and digestion. Intake may also increase in forest and mountainous areas due to shade and decreased heat stress promoting more grazing time (Holechek et al., 1981; Holechek and Vavre, 1982).

Holechek et al. (1982) using esophageal fistulated cows and Holechek and Vavre (1982) utilizing total fecal collections from steers found forest range intake, on a DM basis, to be 1.50 to 2.39% of body weight and 1.60 to 2.50% of body weight with a mean of 2.1%, respectively. The lowest rates represent late summer mountain range values. When averaged across seasons 2% of body weight provided a reasonable estimate of daily dry matter forage intake (Holechek et al., 1982).

Forest diets contain more crude protein in early and late summer and provide greater gains than grasslands. Holechek et al., (1981) using pregnant heifers found concentrations of crude protein maintained acceptable levels with little seasonal variation in ration content. During 1976 to 1978 averages were 12.87% CP in late spring, 11.07% in early summer, 12.10% in late summer and 11.57% CP in fall diets. Research from foothill/mountain areas of Utah by Cook and Harris (1968) found sagebrush-grass ranges provided 14.6% ingested CP in June and July and 8.9% in August and September. In the same study, aspen grazing areas had 13.2% ingested CP during June and July and 11.4% CP during August and September. Crude protein levels below 7% of forage DM do not meet the needs of rumen microbes (NRC, 1984), however crude protein never fell below 8% in these studies (Holechek and Vavre, 1982; Holechek et al., 1981; Cook and Harris, 1968).

For forest and mountain ranges digestible energy rather than crude protein may be the first limiting nutrient (Holechek et al., 1981). Esophageally fistulated Angus x Hereford yearling heifers were used to determine diet quality of mountain grazing in the Blue Mountains of northeastern Oregon. Averaged across years (1976-80), digestible organic matter was 65.7% in late spring, 55.5% in early summer, 55.7% in late summer, and 53.3% in fall (Holechek et al., 1987). Cook and Harris (1968) noted a decline in percent TDN as grazing season progressed on Utah mountain ranges. Average digestible nutrient intake of cattle showed 49.5% TDN early in the season, 48.8% TDN mid-season, and 46.6% late season. The NRC (1984) notes a 454 kg average milking ability cow requires 56.6 % TDN in 20.2 lb of dry matter intake.

Under suggested stocking rates, forage maturity rather than availability most often determines cattle intake and nutritional status (Holechek et al., 1987). Diets decrease in quality as the season progresses with little fall regrowth in forested ranges (Holechek and Vavre, 1982). If regrowth occurs on grasslands in the fall it will surpass forest grazing land in organic matter digestibility and cattle gains. Consumption of more mature shrubs during late summer and fall may decrease dietary organic matter digestibility. Where possible, utilization of grasslands in early spring and fall with summer grazing of forest and mountainous areas may

provide the best nutrition and gains for cattle (Holechek et al., 1981; Ralphs and Pfister, 1992).

Factors Affecting Range Grazing

Cattle Intake and Selectivity of Grazed Forages

Several factors affect intake and digestibility of range forage. The most apparent and studied are changes in plant chemical composition associated with advancing maturity (Kartchner and Campbell, 1979). Other factors include animal body size, stage of animal production, availability of supplementation (Allison, 1985), cold (Adams, 1990), heat, water availability and consumption, hours of light (Fox, 1987), and forage abundance (Cook and Harris, 1968). Cattle are also selective grazers with individual preferences for palatability (Cook and Harris, 1968) and nutritional quality of forage (Kothmann, 1980).

Hand clipped sampling provides data on range nutrition from potentially available forage, but does not allow for the selectivity between plants or plant parts preferred by grazing livestock. Selective grazing alters botanical and nutritive composition of forage ingested as compared to that available as a whole from range. Sheep and cattle often graze plant species and plant parts higher in protein than the average available herbage (Theurer et al., 1976; Kothmann, 1980;

Sindelar, 1987). Research has attempted to assess animal selectivity through the use of esophageal fistulas and rumen canulas implanted in domestic livestock (Theurer et al., 1976; Adams and Short, 1988; Grings et al., 1995).

Research conducted over a five-year period with cattle grazing Nevada range documented shifts in composition of feed intake from year to year. Rumen fistula forage samples disclosed grass and browse contents varied from 68 to 93% and 0 to 24% of the diet, respectively. On a yearly basis, forbs ranged from 4 to 17% of the diet. Annual precipitation determined availability of grasses and preferred forage, influencing the yearly change in diet composition (Bohman and Lesperance, 1967). Kothmann (1980) proposed that average forage quality on many ranges is inadequate for livestock production and that selective grazing by livestock allows for economic sustainability.

Intake of cattle grazing prairie range may vary as much as 1 to 4% of their body weight (Cordova et al., 1978). The NRC (1984) cites the voluntary organic matter intake of cattle on winter range in the Central Great Plains as 45 to 60 g/kg $W^{0.75}$ (Rittenhouse et al., 1970; Scales et al., 1974; Yates et al., 1982) while the summer intake for the same area varies from 70 to 85 g/kg $W^{0.75}$ daily (Streeter et al., 1968; Powell et al., 1982; Yates et al., 1982). Holechek and Vavre

(1981) in grassland research found dry matter forage intake to range from 1.56 to 2.54% of body weight with an average of 2.07%.

Calf Grazing Selectivity

Data collected from esophageal or rumen fistulated suckling calves, dams, and steers indicate that nursing calves select diets higher in protein than their older counterparts (Peischel, 1980; Ansotegui, 1986; Grings et al., 1995). In a two year study at Ft. Keogh near Miles City, MT Grings et al. (1995) found that 4 and 5 month-old calves selected forage diets 21% greater in CP ($P < 0.01$) and 5% less in NDF ($P < 0.06$) during June and July than mature steers. However, by September - October there were no differences between the two ages.

Ansotegui (1986) conducted a two-year study with rumen cannulated calves and cows at Red Bluff Research Ranch, a foothills area, near Bozemen MT. Calves selected diets higher in CP in July 1985 and September 1984-5 and diets higher in NDF during July 1884-5 and August 1985. Averaged across year and month, calves diets were 17% greater in CP, 8.5% greater in NDF, and 3.8% greater in ADF than cows diets for July through September.

Using esophageally-fistulated, one-month-old, nursing calves and 1 to 5 year-old steers grazing the Kansas Flint

Hills during 1977-8, Peischel (1980) found calves selected a higher quality diet than steers. Averaged across month (May - Oct.) and year, calf diets were 11.7% greater in CP than steers. Calves gross energy ingested was greater than steers during May through July, equal in August, and less in September and October. Consumption of NDF was less for calves May and June, equal for July, and greater for August, September and October.

Suckling calves select higher quality forages in early summer than older cattle and similar diets later in the grazing season (Grings et al., 1995). This may be caused by calves having more time to be selective of plant parts with greater nutritive value while nursing, however with declining milk intake and a greater need to forage later in the season (Ansotegui, 1986) the capability of selection decreases as available herbage quality declines with advancing maturity (Grings et al., 1995).

Stocking Rates

Range condition and amount of available forage must be considered in meeting nutritional requirements of grazing cattle (NRC, 1984). Intake is reduced if the quality or quantity of range forage is inadequate for cattle needs (Holloway et al., 1979). Heavy grazing increases the usage of low quality forage, reduces animal intake (Kothmann, 1980),

and reduces the average daily gain of stocker calves, lactating cows and suckling calves (Vallentine, 1990).

Table 1 demonstrates long-term heavy, moderate, and light grazing effects on mixed-prairie rangeland from a 25-year study conducted at Miles City, MT. Annual stocking rates from 1933 to 1957 averaged 25 acres/cow for heavy use, 34.5 acres/cow for medium use, and 43.1 acres/cow for light use. At the end of the study summer range condition climax was 29% under heavy, 39% under moderate, and 60% under light grazing. Results from 1938 to 1945 indicated heavy grazing reduced average weaning weights 30 lb compared to moderate or light grazing. Data from 1950 to 1957 showed heavy grazing reduced average weaning weights by 50 lb over moderate grazing and 70 lbs over light grazing. The corresponding average percent calf crop differences were 63, 85.6 and 91.4 respectively (Vallentine, 1990).

Heavy grazing of rangelands over a period of years reduced weaning weights and summer yearly gains by 30 - 50%, reduced body weight and condition of breeding females, reduced conception rates and percent calf crops by 10 - 15% unless supplements were fed (Vallentine, 1990). Shoop and McIlvain (1971) based on Oklahoma grazing studies concluded that for the long-term moderate grazing was more profitable than heavy grazing and more financially stable in the short-term.

Table 1. Evaluation of Long-term Stocking Rates on Mixed-Prairie Rangelands at the Fort Keogh Livestock and Range Research Laboratory, Miles City, Montana, 1932-1957^a (from Vallentine, 1990).

Years	Grazing intensity	Stocking level ^b	Weaning weight (lb./calf)	Weaning weight (lb./acre)	Calf crop weaned (%)	Average hay fed cow (lbs.)	Weight of cows weaning calves, Nov. 1 (lbs.)	End of Study			
								Range condition (% climax)		Utilization key species (%)	
								Summer units	Winter units	Summer units	Winter units
1933-1936	Heavy	23.1 acres/cow	248	8.1	75.0						
	Moderate	30.5 acres/cow	297	7.7	79.0						
	Light	38.8 acres/cow	300	6.1	79.0						
1938-1945	Heavy	23.1 acres/cow	395	14.0	82.0	1068	955				
	Moderate	30.5 acres/cow	427	12.6	90.0	436	1030				
	Light	38.8 acres/cow	423	9.7	89.0	470	1070				
1950-1957	Heavy	29.3 acres/AUY	348	9.3	63.0		939	29	50	77	60
	Moderate	42.5 acres/AUY	408	8.2	85.6		1032	39	58	60	52
	Light	51.7 acres/AUY	420	7.4	91.7		1023	60	56	51	46

^aFormerly U.S. Range Livestock Experiment Station; grazing treatments yearlong but on paired summer and winter grazing units; the three time periods represent three different groups of Hereford cows; the 1933-1936 period was terminated because of drought, the latter two because of age of cows. Adapted from Woolfolk and Knapp (1949); Reed and Peterson (1961); Houston and Woodward (1966).

^bStocking levels include combined acreage of paired summer and winter units.

External and Environmental
Factors Affecting Forage Intake

Water is required for maintenance and growth (Fox, 1986). Non-lactating cattle consume an average of 3 parts water to 1 part dry matter up to 4.4° C environmental temperature. Need for water consumption increases proportionally with increased temperature (Winchester and Morris, 1956). Utley et al. (1970) found that dry matter intake is reduced when water availability is restricted. For free roaming cattle, distance to water, palatability, availability, and freezing in winter can reduce intake. Water consumption is variable and influenced by factors concerning the composition and rate of gain, activity, diet, feed intake, pregnancy, lactation and environmental temperatures (NRC, 1984).

Hours of daylight appear to affect intake and rate of gain or loss in cattle. Decreased light stimulates decreases in grazing time (Fox, 1986). Extremes in cold or heat may further depress grazing while increasing expended energy for maintaining norms in body temperature (Adams and Short, 1988). Adams et al. (1986) found as ambient air temperatures declined from 32° to -40°F a linear decline occurred in daily grazing time. Further reduction of grazing time resulted with increased wind speed accompanied by a reduction (up to 50%) of forage intake. Cold stress increases the ME requirement an

additional 1 - 3% for each degree Celsius below the animals lower critical temperature (NRC, 1984).

Internal Factors Affecting Forage Intake

Pregnancy, especially close to parturition, affects forage intake of cattle. Competition arises for space in the body cavity between the rumen digesta and the growing fetus. Voluntary intake of pregnant cows decreases two percentage units per week during the last month prepartum (ARC, 1980). NRC (1984) suggests a 12 to 13% decrease in intake during this time, followed by rapid increases in consumption postpartum.

Adams and Short (1988) used a combination of nutritional data provided by range forage intake studies, data on milk production from crossbred cows located at Ft. Keogh near Miles City, MT., and NRC (1984) requirements for a 500 kg lactating cow to determine needed forage intake for this area. Lactation resulted in an April forage intake increase of nearly 100% over maintenance requirements to meet CP demand (Figure 3) and 52% for ME (Figure 4). At this time a cow nursing a calf is unable to consume adequate forage to meet her body's needs. By October increased need for lactation over maintenance demand had declined to 30% for CP and 25% for ME.

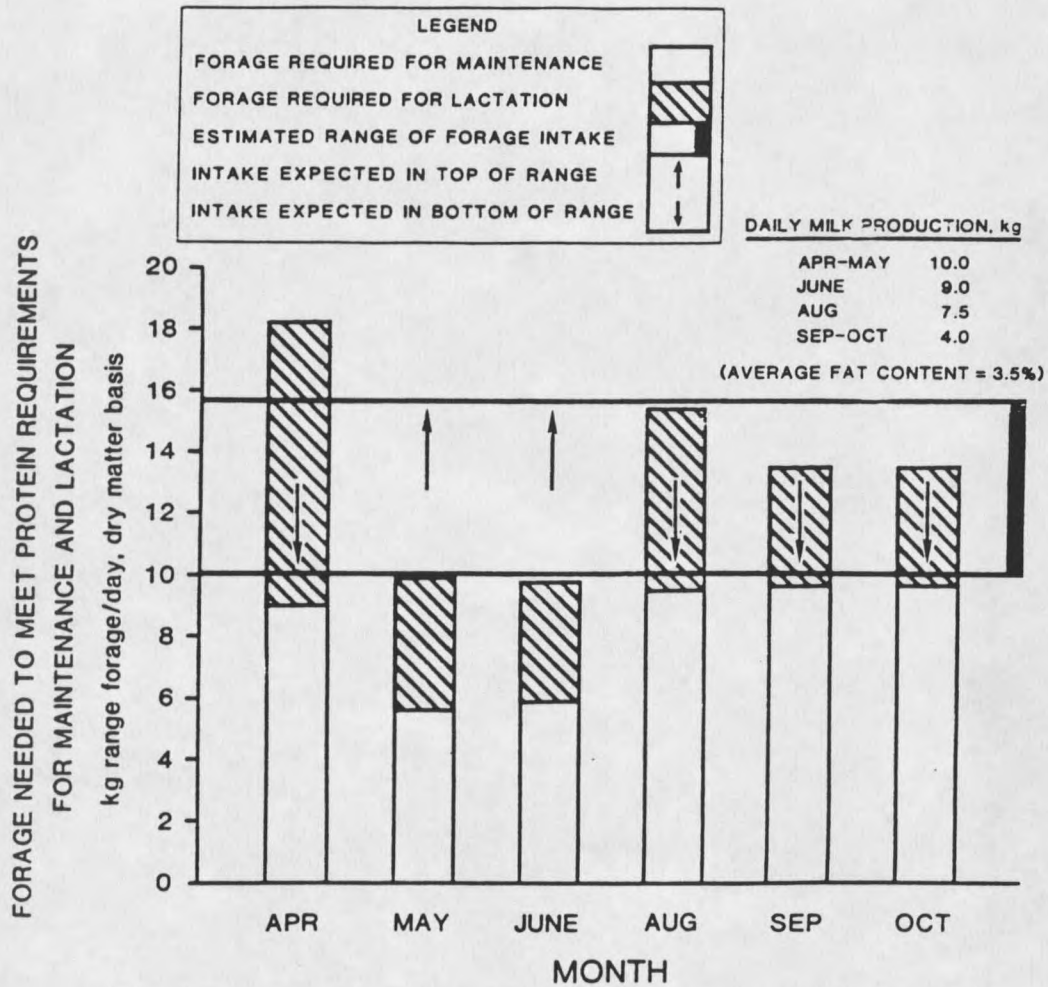


Figure 3. Range forage required to meet the protein requirements of a 500 kg lactating cow at various times of the year (from Adams and Short, 1988).

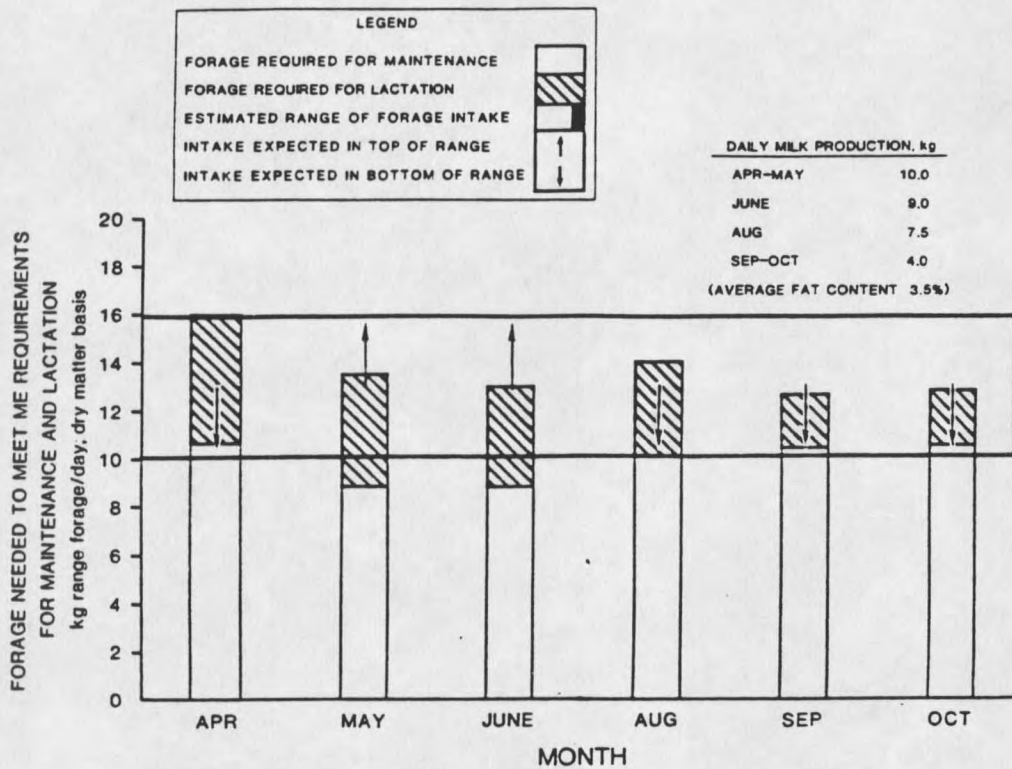


Figure 4. Range forage required to meet the metabolizable energy requirements of a 500 kg lactating cow at various times of the year (from Adams and Short, 1988).

Calving and Weaning Dates

Calves weaned per cow exposed (Brownson, 1976; Dziuk and Bellows, 1983) and weight of calves weaned per cow exposed (Lawlor et al., 1984; Deutscher et al., 1991) are two methods to evaluate reproductive efficiency, annual trends in herd performance, as well as potential income. Maximizing reproductive efficiency in a range environment requires using available resources to best advantage (Dziuk and Bellows, 1983; Bagley et al., 1987). Matching range nutrition, breeding and calving dates, weather (Brownson, 1976), winter supplementation and feeding (Bellows and Short, 1978) and cow condition (Richards et al., 1986) at calving to maximum advantage may provide the greatest production efficiency (Bellows, 1988).

Limited calving seasons are commonly recommended to best match herd nutrition requirements to range forage production and efficient use of labor resources (Marshall et al., 1990). Extended calving seasons lead to less uniform weaning weights for the calf crop, require more labor, and more cows to be culled due to previously late calving and failure to rebreed (Selk et al., 1988; Azzam et al., 1990; Marshall et al., 1990; Short et al., 1990). Deutscher et al. (1991) found an April calving season to be as productive as a March calving season in the Nebraska Sandhills when calves were weaned at similar ages. Comparing 30, 45, and 70-day breeding seasons however,

resulted in longer breeding seasons being more productive ($P < .05$) with calf weight weaned of 162, 172, and 186 kg, respectively.

Calving as early as climatic conditions will allow, increases the age at weaning and corresponding weight. It is estimated for each late day to calving costs 1.5 lbs of calf weaned or 32 lbs per estrus cycle (Brownson, 1976). Marshall et al. (1990) studied the economic effects of early calving and subsequent reproductive performance in two- and three-year-old cows. Their results indicated that despite increased feed costs associated with early calving cows (producing older calves at weaning), they were biologically and economically more efficient and rebred earlier than cows calving later in a limited season.

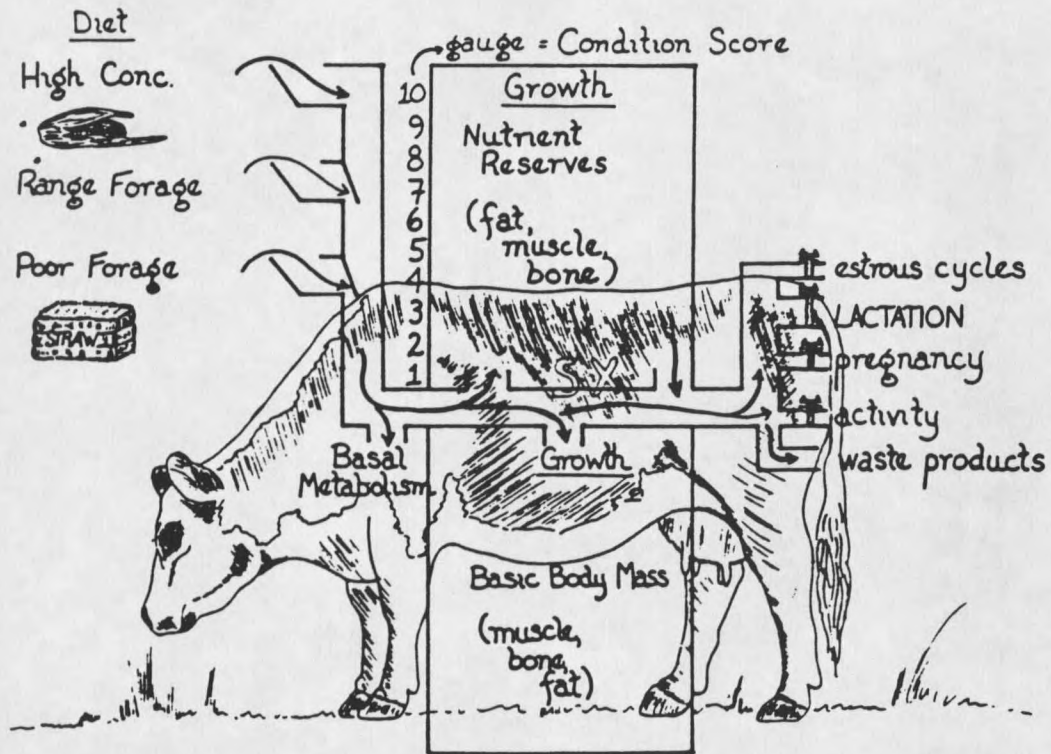
Calves become ruminally active at 45 to 60 days and are selective grazers, often selecting diets higher in protein and energy than older member of the species. If older calves are turned out on range in the spring their diets are improved by the early quality of nutrition provided by the range (Ansotegui, 1986; Adams and Short, 1988).

Late born calves may not be capable of utilizing range forage until it has decreased in nutritional value and palatability (Brownson, 1976; Adams and Short, 1988). This may result in greater dependence on the dam for milk at a time when the mid-gestation cow needs to improve her condition

before winter (Short et al., 1996). The attempt to meet all her demands late in the grazing season may cause an increase in loss of condition during the winter, a lighter weight calf, and increased percentage of calving losses the next spring (Corah et al., 1975; Fredeen et al., 1988). Calving interval can be effected if too much condition is lost resulting in failure to rebreed and a decrease in weaning weight per cow exposed (Richards et al., 1986; Fredeen et al., 1988). Weaning date may be critical for cows with high milk production to ensure they do not become thin before the fall-winter grazing period (Adams et al., 1993).

Range Nutrition and Calving Interval

Lowering costs of beef production could substantially increase profitability of cow/calf operations if the amount of harvested forage fed could be decreased while maintaining or improving cow performance. Extending fall and winter grazing on rangeland is one method to reduce inputs of harvested forages (Adams et al., 1994). However, Northern Great Plains rangeland often does not provide adequate protein and/or energy to meet nutritional needs of pregnant cows at this time (NRC, 1986; Adams and Short, 1988). Figure 5 illustrates the general strategy a cow uses in partitioning nutrients (energy) to various body functions (Short and Adams, 1988). The ability of beef cattle to use low quality forage as an energy



The approximate order of priority for partitioning of nutrients:

1. Basal metabolism
2. Activity
3. Growth
4. Basic energy reserves
5. Pregnancy
6. Lactation
7. Additional energy reserves
8. Estrous cycles and initiation of pregnancy
9. Excess reserves

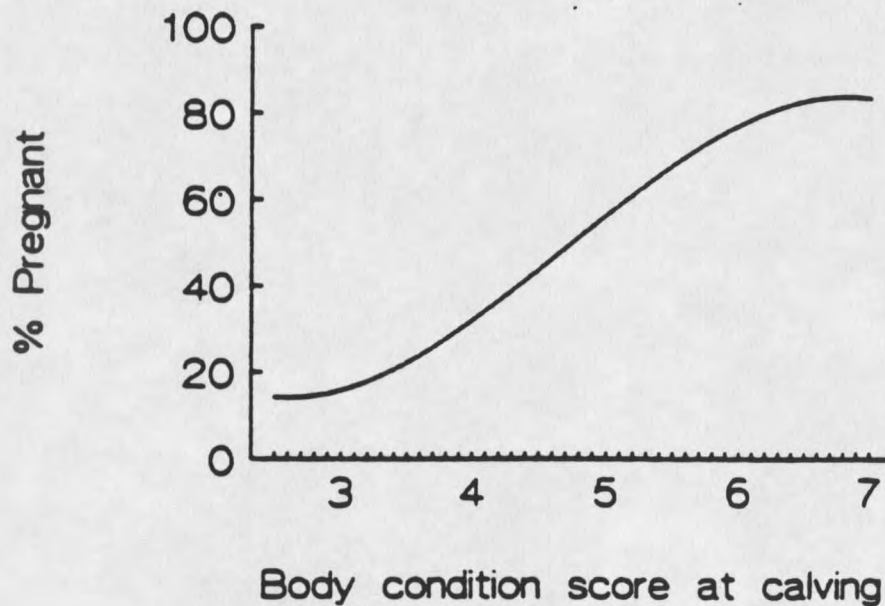
Figure 5. Partitioning of nutrients in a cow with nutrient intake varying in quantity and quality (from Short and Adams, 1988).

source can also develop problems do to diet quality directly effecting production levels (Adams and Short, 1988). As a result, managers must decide how best to utilize low cost range forage without sacrificing reproductive capability.

A primary limiting factor for production efficiency in cattle is reproduction, (Dzuit and Bellows, 1983) an important determinant of cow/calf profitability (Dickerson, 1970). A reduction of optimal reproductive performance increases the production cost per cow exposed (Wittum et al., 1990). Greatest potential production loss occurs if cows fail to become pregnant (Wiltbank et al., 1961). Postpartum anestrus interval (PPI, time between calving and estrus) determines the likelihood of conception during the breeding season (Wiltbank, 1970). One major factor influencing PPI is level of nutrition (Corah et al., 1975; Bellows and Short, 1978; Richards et al., 1986; Sasser, et al., 1988; Randel, 1990; Short et al., 1990) and its effects on the condition of cows prior to parturition (Dziuk and Bellows, 1983; Richards et al., 1986; Selk et al., 1988; Osoto and Wright, 1992).

Body condition score (BCS) is the most effective means to monitor nutritional status (Richard et al., 1986; Randel, 1990; Short et al., 1990). Precalving BCS and BCS at start of breeding season were found to be the most accurate predictors of pregnancy by Selk et al. (1988). A cubic response best described the relationship between precalving BCS and

pregnancy rate ($P < .07$) in their data (Figure 6). Cows with BCS between 4 and 6 were impacted the most (positively or negatively) by a change of one unit of BCS than cows either thinner or fatter.



$$Y = 1.28 - .986(\text{PBCS}) + .248(\text{PBCS}^2) - .016(\text{PBCS}^3)$$

Figure 6. Influence of precalving body condition score (PBCS) on pregnancy rate (from Selk et al., 1988).

Richards et al. (1986) investigated postpartum nutrition as an influence on PPI. Results indicated that postpartum nutrition management had no effect on PPI. However, cows with $\text{BCS} \geq 5$ returned to estrus earlier than cows calving at $\text{BCS} \leq 4$ ($P < .01$) averaging 12 days earlier across treatments. Their data showed that cows on a low prepartum energy diet, i.e., those calving with low BCS, exhibit estrus later in the

postpartum period regardless of level of energy offered postpartum. This study concluded that BCS at calving is the most significant determining factor related to re-establishment of cyclic ovarian activity in the beef cow. Osoro and Wright (1992) supported these conclusions and found body condition at calving a major determinant of reproductive performance. Cows with higher BCS had shorter calving intervals. Table 2 describes the levels and attributes of each BCS (Richards, et al., 1986).

Dziuk and Bellows (1983) and Richards, et al. (1986) suggest a minimum body condition score of ≥ 5 at calving to ensure body stores of nutrients adequate for postpartum reproductive performance (Randel, 1990). The effect of nutrition, as expressed by BCS, on postpartum reproduction is more important at precalving than after calving (Figure 7). Although postcalving improvements in nutrition show a decrease in PPI the greatest effects are at low (< 6) precalving BCS (Short et al., 1990) and when feed intake precalving was low. Richards et al. (1986) also noted that cows ($BCS \leq 4$) which gained weight 40 to 60 days prior to breeding had improved pregnancy rates over cows that continued to lose weight postcalving. Cows with $BCS < 5$ decreased in potential fertility and attempts to correct precalving nutritional problems by increasing BCS after calving were difficult and expensive.

Table 2. System of body condition scoring (BCS) for beef cattle (from Richards et al., 1986).

GROUP	BCS	DESCRIPTION
THIN CONDITION	1	EMACIATED - Cow is extremely emaciated with no palpable fat detectable over spinous processes, transverse processes, hip bones or ribs. Tail-head and ribs project quite prominently.
	2	POOR - Cow still appears somewhat emaciated but tail-head and ribs are less prominent. Individual spinous processes are still rather sharp to the touch but some tissue cover exists along the spine.
	3	THIN - Ribs are still individually identifiable but not quite as sharp to the touch. there is obvious palpable fat along spine and over tail-head with some tissue cover over dorsal portion of ribs.
BORDERLINE CONDITION	4	BORDERLINE - Individual ribs are no longer visually obvious. The spinous processes can be identified individually on palpation but feel rounded rather than sharp. Some fat cover over ribs, transverse processes and hip bones.
	5	MODERATE - Cow has generally good overall appearance. Upon palpation, fat cover over ribs feels spongy and areas on either side of tail-head now have palpable fat cover.
OPTIMUM MODERATE CONDITION	6	HIGH MODERATE - Firm pressure now needs to be applied to feel spinous processes. A high degree of fat is palpable over ribs and around tail-head.
	7	GOOD - Cow appears fleshy and obviously carries considerable fat. Very spongy fat cover over ribs and around tail-head. In fact "rounds" or "pones" beginning to be obvious. Some fat around vulva and in crouch.
FAT CONDITION	8	FAT - Cow very fleshy and over-conditioned. Spinous processes almost impossible to palpate. Cow has large fat deposits over ribs, around tail-head and below vulva. "Rounds" or "pones" are obvious.
	9	EXTREMELY FAT - Cow obviously extremely wasty and patchy and looks blocky. Tail-head and hips buried in fatty tissue and "rounds" or "pones" of fat are protruding. Bone structure no longer visible and barely palpable. Animal's motility may even be impaired by large fatty deposits.

Marston et al. (1995) also concluded that prepartum protein or energy supplementation had more positive influence than postpartum. Research on gestating range cows fed supplements from November 8 until calving March 3, also resulted in energy (90%) providing a greater rebreeding rate than protein (80%, $P < .002$). Energy supplemented cows produced calves 1 kg heavier at birth ($P < .03$) and 6 kg heavier at weaning ($P < .06$) than those fed protein.

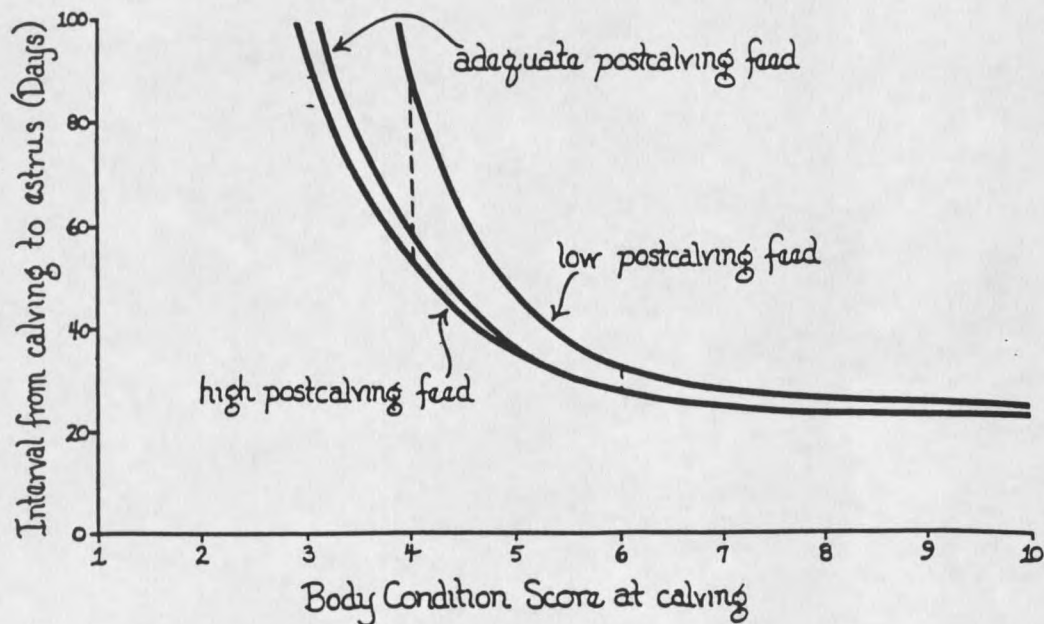


Figure 7. Relationship of interval from calving to estrus (PPI) and body condition score (BCS) as affected by levels of postpartum diets (from Short et al., 1990).

Feeding of supplements and management practices such as manipulating weaning dates can improve beef production on rangelands (Adams and Short, 1988). Non-supplemented cattle foraging on fall-winter rangelands in the Northern Great

Plains commonly lose weight and body condition (Ward et al, 1987). Because interval from calving to first estrus and pregnancy is closely related to body condition it is a critical consideration when formulating fall-winter feed management procedures. Consequently, it is most advantageous to manage cows during late summer and early fall so that body condition is maintained at a moderate level (Adams and Short, 1988).

Optimum profitability in cow-calf production is a combination of interrelated factors. Time of calving and weaning, stocking rates, time and duration of range forage use, and plane of nutrition all affect one another and the reproductive capability of a herd. For producers, attempting to determining the most efficient use of available resources while manipulating multiple management decisions becomes a time consuming task. However, the use of computer simulation modeling is an efficient and effective tool to aid ranchers in realizing the potential outcome of various decisions before they are actually implemented.

CHAPTER 5

OBJECTIVES

This thesis was conducted in conjunction with the Sustainable Agriculture Research and Education Project (SARE) entitled "Specifying and Analyzing Whole-Ranch Systems for Sustainable Range Livestock Production in Environmentally Sensitive Areas". The project "...is designed to enhance the long - term sustainability, profitability, and competitiveness of U.S. agriculture. The long range goal of the program is to provide an abundance of food and fiber in a way that is environmentally sound and sustainable for generations to come".

The objectives of the research described herein were to use computer simulation to model the mean current cow/calf production of identified sustainable ranches in a foothill/mountain area and Northern Great Plains area of Montana and analyze alternative management practices for increased profitability.

Managerial decisions concerning when to calve, wean, and use range resources to best advantage affect overall ranch

profitability. Increasing time cattle spend on range and later calving decrease the needed quantity of expensive stored forages. Calves born early and weaned late provide higher weights and therefore more revenue per cow exposed. When the range resource is seasonal and limited, questions arise as to how many cow-calf pairs can be maintained, when should calving and weaning occur, how would decisions on each single issue effect the outcome of the others, and which combination would provide the greatest income.

Ranches recognized a sustainable (defined in materials and methods) in both foothill-mountain regions and mixed short grass prairie regions of Montana were identified and characterized. Data collected from these ranches were used to parameterize a model of current cattle production systems representative of ranches in each region. The computer simulation model was then used to determine the effects of manipulating cattle calving dates, weaning dates, and the duration of fall grazing on calf weaning weights, utilization of raised and purchased forage, break-even steer prices (annual costs of production), average calf weaning weight, herd size, and ranch gross margin.

CHAPTER 6

MATERIALS AND METHODS

Simulation Model

The bioeconomic beef production computer model used for this project was written by M. W. Tess (1995) and modified by B. W. Kolstad (1993). It is dynamic (changes over time increments) with deterministic equations for growth and metabolism and reproductive functions represented by stochastic functions. The model estimates individual animal performance daily over a lifetime and performance of a number of individuals as a herd annually. Additional information of the model's attributes and parameters are described by Kolstad (1993).

Surveys were taken in 1993 for beef cattle production on Montana ranches located in Fergus and Petroleum Counties (foothills/mountain region) and Carter and Fallon Counties (Northern Great Plains region) and used to parameterize simulated ranches. Ranches were selected for participation on a non-random basis and qualified for the study if: 1) they were the primary source of family income, and 2) provided a net return above operating costs including a positive net

return to family supplied resources and equity capital (Johnson, personal com). Research associates administered structured questionnaires at each ranch concerning livestock production and other farming, social, and ecological endeavors (Johnson et al., 1994a,b). An in depth report of economic and financial sustainability from this survey has been provided by Johnson et al. (1994a,b). To protect participants confidentiality, data from area ranches were averaged to produce a simulated ranch representative of all but specific to none. Mean data (external) from each location were matched for input and output of ranch means by the model. Cow/calf inputs included genotype, mating system, cow yearling and adult weight, milk production, percent dystocia by age group, and average years of production,

Managerial inputs consisted of dates of turnout and removal from range grazing, type and number of vaccinations, type and amount of stored or supplemented forages, breeding and calving dates, weaning date, cows to bull ratio, herd size, cull rates, percentage of cow and calf death losses, number of replacement heifers, and management groups.

Forage inputs included annual amount and chemical composition (i.e., protein (CP), metabolizable energy (ME), neutral detergent fiber (NDF), and rumen degradable protein (RDP)) of range, hay production, and supplements fed by

management group. Calves were allotted a grazing ratio for selectivity of plants over those selected by older cattle.

Economic inputs to the simulation model were 1994 sale prices for all classes of livestock at date of weaning and all marketing costs. Also included were variable costs associated with range and aftermath grazing, supplemental feeding, veterinary services and vaccinations, bulls, livestock taxes, opportunity costs, and labor. Fixed costs for ranch enterprises were not included in the study.

Input produced by the computer simulation program (internal) were individual selection of replacement heifers, actual number of cattle dead or sold, production weights and body composition, expenses due to incidence of dystocia, and cost and quantity of feed types consumed annually.

Simulated outputs used in this study included average calf weaning weight, herd size (number of cows carried under a constrained range resource), net income per cow exposed (net income averaged over all cows bred), weaning weight per cow exposed (weaning weight averaged over all cows bred), break-even steer price (measures cost of production per unit of steer-equivalent weight sold), and ranch gross margin (gross income less variable livestock production costs).

Model Application

As stated previously, the model was parameterized to each production area, to simulate the mean 1994 management practices of these cow/calf operations. Ranches were not chosen randomly, but were selected according to criteria denoting their ability to be and remain sustainable for the long term.

The application of the computer model was to manipulate the breeding dates (BD), weaning dates (WD), and dates of range removal dates (RR) currently used to determine management combinations which would potentially increase profitability and thus increase the likelihood of ranch sustainability. Changes consisted of dates 28d and 14d prior to the current (included) dates and 14d and 28d past for all BD, WD, and RR. The Julian Calendar was used for all dates and data entry and is listed in Appendix E.

Five replications of 125 different combinations were simulated. If performed in an actual beef cow/calf production system it would have required 625 average (climatic) years, an impractical and impossible task. However, through the use of computer simulation such information can be made available in a more timely manner.

Common Simulation Inputs

Livestock Parameters

Cattle genotype was considered to be of mixed breeding (2 to 3 breed crosses). Cows were culled if they failed to conceive or lost a calf. All cull animals were sold at weaning. Through the various culling and death losses used by the model very few cows remained in the herd to the maximum age. Those that did remain were sold in year 13 as culls and were not counted in total cows exposed.

Cost of dystocia was calculated at \$15.00 (additional labor costs) per incident. Calculations for percent dystocia by age and calf and cow mortality are discussed in detail by Kolstad (1993) as well as lactation and feed parameters. Calf birth weights were unavailable, hence a value of 36 kg was used for both areas.

Several ranches in both areas raised sheep as well as cattle. The computer model presently utilizes only cattle, so sheep were classified by sex, age, and function (Lacey et al., 1991) into equivalent cattle units and added to each ranches total cattle numbers. Some ranches were feeding additional steers and/or heifers to January 1 past weaning. No information was available as to the exact time of sale for these animals, therefore steers were considered to be kept until spring turnout and heifers until fall as extra bred

yearlings. Both were added in proportion to size, sex, and time on the ranch to the total annual herd numbers.

Management Cost Inputs

Veterinary costs were determined by majority rule. If 50% or more of the producers used a practice or inoculation it was also used by the "simulated ranch" for each area. If it was less than 50% it was excluded. Prices shown for heifers include a second inoculation for those heifers kept as replacements (50%) which also allows for a small amount of waste. Prices reflect 1994 Montana veterinary services and retail ranch supply companies.

Additional non-feed expenses included brand inspection fees of \$.35 per head and check-off fees of \$1.00 per head at time of livestock sale. Shipping costs were determined from the center point of each area to the closest regional market and commissions percentages were specific to each market.

Shrink, not a direct expense but rather a decrease in income, was included when figuring marketing costs. Calves and cull animals are weaned and shipped in rapid succession in both areas and were subject to the resulting shrink calculated on time and distance traveled to area markets. For a three hour ride and wait prior to sale, an estimated 5% shrink was calculated for calves and 3.5% for heifers, cull cows and bulls (GP Beef Cow/Calf Handbook, GPE-4002).

Interest costs on ownership capital were calculated at 10%. Opportunity costs for livestock investment were 5%. Values determined by average market prices for yearlings, 2-yr olds, cows, and bulls and were \$500.00, \$700.00, \$700.00, and \$2,500.00, respectively. Breeding stock was taxed (property tax) at \$1.20 for replacement heifers, \$5.53 for 2-yr olds, \$6.08 for cows and \$10.94 bulls.

Labor costs for livestock production was determined by total labor cost times percent of income generated by livestock production. For instance, if a ranch had \$100,000.00 of gross income of which \$75,000.00 was from livestock sales then 75% of the hired labor was credited to livestock production. If \$20,000.00 was paid in labor then \$15,000.00 was divided by the herd number to ascertain labor cost per head.

Fixed Forage Base

Annual AUM's of range forage required by the mean herd was determined by the simulation model for each area. Available AUM's were then fixed at that level. This allowed for increased cow numbers to be run on range if the grazing season was shortened and decreased numbers if lengthened. For the purposes of this study it was assumed that weather and precipitation was average for the area and water was available for the duration of all range grazing.

Stored hay was allocated to management groups according to dietary need. Young growing heifers were fed alfalfa, 2-yr old heifers were fed alfalfa or alfalfa/grass, and older cows alfalfa/grass hay with straw in close proportion to what the mean ranch produced. Stored forage was also fixed to the requirements of the mean herd. Additional hay was purchased or sold as needed according to herd numbers. Alfalfa was priced at \$77.00/ton, grass hay at \$71.50/ton, and straw at \$38.50/ton for 1994 as reported in area agricultural periodicals.

As previously indicated calves are selective grazers and select higher quality forage than cows (Peischel, 1980; Ansotegui, 1986; Grings et al., 1995). Calf selectivity was set at 1.15% of cattle diets. This figure was within parameters cited in the literature and allowed the simulation model to provide weaning weights which matched those indicated by producers.

Supplemental Feeding

The majority of ranchers in both areas used a winter supplemental feeding program. Surveys indicated that grain or range cubes of <15% protein content and the metabolizable energy equivalent of barley were used. Selection of a 14% protein range cube was used for the simulation. Bulk delivery 1994 prices at Montana retail feed suppliers was \$158.40 t and

analysis was according to 90% dry matter of contents listed. Nutritional information is provided in Table 3.

Table 3. Supplemental Feed - Analysis of 14% CP Range Cube

CONTENTS	ME/DM	NDF/DM	CP/DM	RDP/DM
Barley - 91%	3.11	.21	.108	.75
Soy Bean Meal 9%	3.04	.08	.477	.75
14% Cubes 100%	3.104	.1983	.141	.75

1994 Livestock Market Valuation

The majority of surveyed ranches sold weaned calves through forward contracts. Those prices were not available so area market reports were used. Weekly livestock sale prices from 1982 through 1994, as reported by the USDA Livestock Reporting Commission in Billings, MT were analyzed by least squares procedures (SAS, 1987) to formulate weekly prediction equations by year. Weaning and annual sale of all classes of livestock took place in the same week. Figures 8 and 9 show estimated prices for 450, 550, and 650 lb (204, 250, and 295 kg) steers ($R^2 = .965238$, $P, .0001$) and heifers ($R^2 = .970565$, $P, .0001$) for weeks 36-52 of 1994.

Sale prices for yearling, 2-yr old, and cull cows were estimated by sampling price differences between these and 550 lb (250 kg) steers from area livestock publications for the fall of 1994. Results indicated indexes of .809, .622, .546

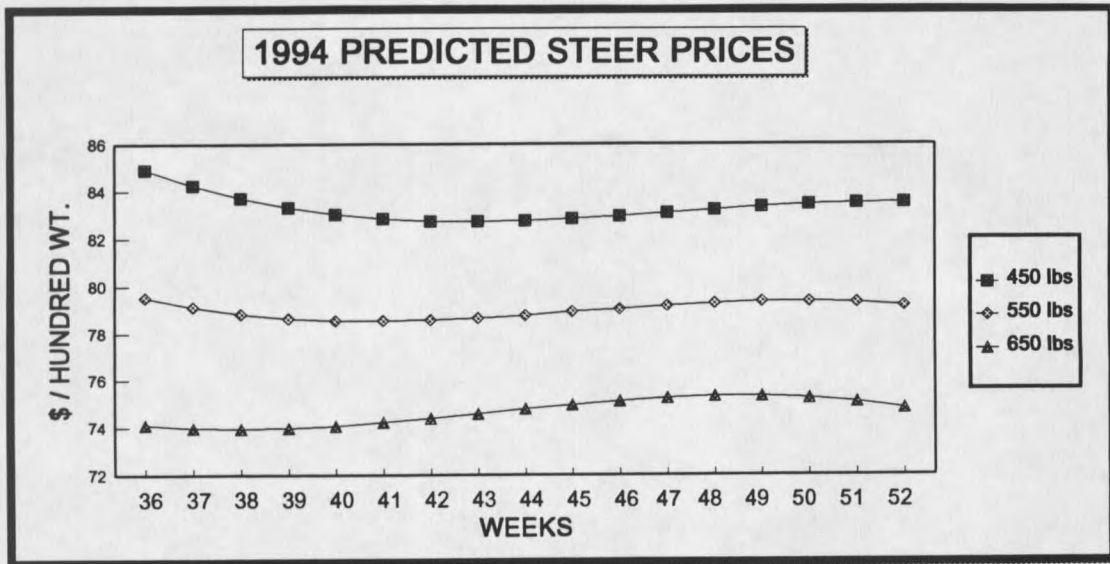


Figure 8. Predicted Steer Prices - 1994.

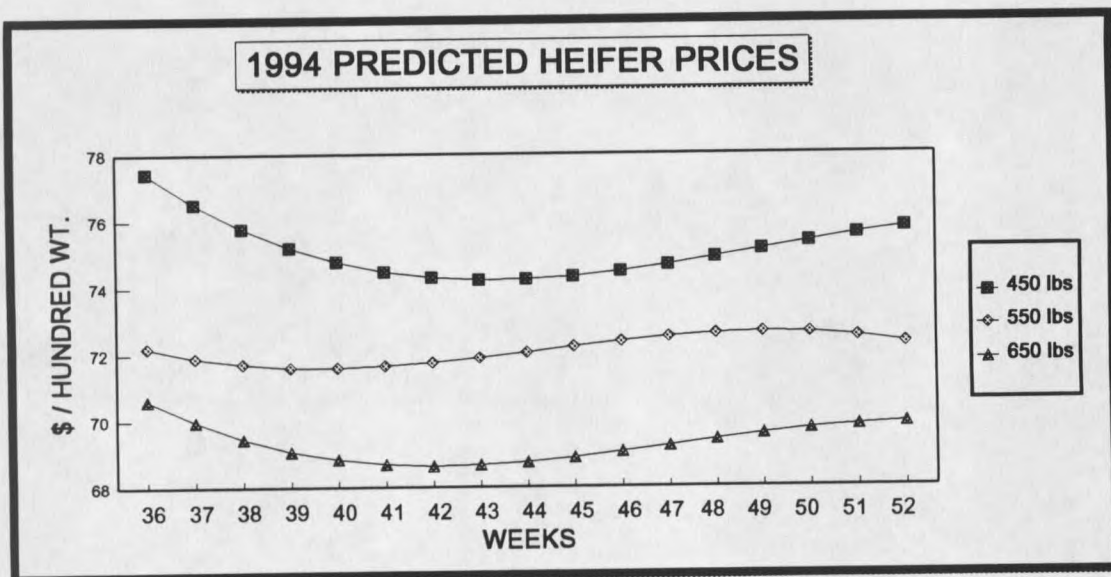


Figure 9. Predicted Heifer Prices - 1994.

for yearling , 2-yr old, and cull cows to steer prices, respectively.

Price slides for heifers and steer calves, resulting from increased or decreased weight from 550 lb (250 kg) at weaning, were determined by comparing class prices of 450 lb (204 kg) and 650 lb (295 kg) calves. Slides were calculated separately for each sex, week of sales and direction of movement.

Bull purchase price was set at \$2,500.00. Resale of cull bulls, after an average 4 years of use, was determined from the USDA Montana Livestock Reporting Service at Billings, MT from 771 kg yield grade #2 quotes. Cull value equaled 771 kg X \$1.20/kg or \$925.00 per head. Depreciation was \$394.00 annually. It was calculated by purchase price less salvage divided by 4 years of service.

Northern Great Plains Region - Mean Ranch Input

This study area consisted of Carter and Fallon Counties located in the southeastern corner of Montana. It comprises 1.3 million hectares (3.2 million acres) of which 90% is devoted to range livestock production. It is defined by Goetz (1988) as part of the Northern Great Plains (NGP) mixed and short grass prairie region. Annual precipitation is 36 cm, elevation ranges from 762 m to 1067 m, and temperatures vary

from 43 °C in summer to -46 °C in winter (Larry Brence, County Extension Agent, private comm., 1997).

Eleven ranch cooperators participated in this survey. All were members of the Carter-Fallon Forage Committee, an ad hoc committee formed by ranchers to address ranch management issues (Johnson et al, 1994b).

Alternative Management Dates

Data from Carter and Fallon Counties produced the following dates which were used for alternative management decisions (Class variables). Mean breeding date (BD) for both heifers and cows was d 160 (June 9). Alternative dates also used were d 132 (May 12), d 146 (May 26), d 174 (June 23), and d 188 (July 7). Mean weaning date (WD) and range removal date (RR) were d 307 (Nov. 3), where as d 279 (Oct 6), d 293 (Oct 20), d 321 (Nov. 17) and d 335 (Dec. 1) representing alternate choices.

Livestock Production

The survey indicated that cow herds consisted of about half black and Black Angus breeding and approximately 25% Hereford. Remaining breeding, all less than 10% each, included Gelbvieh, Red Angus, Saler, and Simmental. Bull breeds used in the herds were also Black Angus and Hereford in similar proportions. Minor breeds included Gelbvieh (15%),

Red Angus, Saler, Simmental, and a small percentage of Charolais.

Cow/calf production and replacement heifer numbers are presented in Table 4. Lactation curve figures were set to peak production of 11.5 kg on day 42. A conception rate of 65% per cycle provides a 96% pregnancy rate for the 65 day breeding season. Heifers were bred 3.5 days earlier and 2 days longer than older cows. Days for both groups were averaged since separate breeding dates were not obvious. Average age at weaning was taken from the end of the first 1/3 of calving until the day of weaning, 206 days.

Table 4. Simulated Northern Great Plains ranch cattle production

INPUT DATA	MEAN
CATTLE PRODUCTION	
No. of Cows	215
No. of Replacements	45
No. of Bred Heifers	46
No. of Additional Cattle	24
No. of Cow Equiv. from Sheep	93
Total Cows	423
Average Cow Wt.	527 kg
Culled Cows	.14%
Pregnancy Rate	.96%
Herd Death	.01%
Breeding Dates	
Begin	June 9
End	Aug 15
No. of Days	65
Percent Calf Losses	.04%
Weaning Date	Nov. 3
Average Weaning Age	206 days
Weaning Weights	
Steers	245 kg
Heifers	236 kg
No. of Cows per Bull	26

Forage Production

Table 5 shows forage attributes of the simulated ranch. Aftermath grazing occurred on fields which were cut for hay production. The majority of hay production was on a dryland basis and provided a single cutting per year. Nutritional quality of this aftermath grazing was considered to be the same as alfalfa/grass hay which would be fed when grazing forage declined. Straw was added to the forage base for 2-yr old and older cows during the winter months.

Table 5. Mean Northern Great Plains simulated ranch forage production.

INPUT DATA	MEAN
FORAGE BASE	
Hectares of Range	4452
Deeded	2088
Government	1463
Other	901
Hectares of Pasture	27
Hectares of Hay	321
Tons of Hay Produced	799 t
Tons/Hectare	2.50 t
Tons of Grass	72 t
Tons of Alfalfa	182 t
Tons of Alf/Grass	545 t

The proportion of types of hay fed was matched as closely as possible to the nutritional needs of various classes of livestock. Replacement, yearling, and 2-yr old heifers prior to range turnout were fed alfalfa hay, while older cows were fed alfalfa/grass hay and alfalfa/grass/straw (mixed) hay.

The stored forage base was fixed to the needs of the mean herd: 214 t of mixed, 352 t of alfalfa/grass, and 178 t of alfalfa hay was available. Prices for each type of forage were \$69.30, \$71.50, and \$77.00 t, respectively and straw was priced at \$38.50 t. Prices were attained from area news and livestock publications for 1994.

Composition of the stored forage base was provided by Ellis Williams, Extension Agent for Carter and Fallon Counties (Personal Comm., 1995). Nutritional specifications of each forage type are shown in Table 6.

Table 6. Nutritional Hay Specifications - Northern Great Plains area.

TYPE	ME/DM	NDF/DM	CP/DM	RDP/DM
Alfalfa				
Mid-bloom	2.10	.46	.17	.75
Grass Hay - Dry Land				
Winter Rye	2.20	.66	.081	.52
Crst. Wheat	1.92	.61	.100	.70
Brome Grass	2.03	.61	.146	.75
Even Mix	2.05	.63	.109	.66
Alfalfa/Grass				
50/50 Mix	2.08	.54	.140	.70
Straw				
Wheat	1.48	.700	.036	.60
Oats	1.63	.700	.044	.60
Barley	1.45	.800	.043	.60
Average	1.52	.733	.041	.60
Straw/Alfalfa/Grass Mix				
6.8%/93.2%	2.04	.556	.133	.70

(From: NAC, 1971; ARC, 1980; NRC, 1984; NRC, 1989.)

Due to the averaging of data, small gaps appeared between ending one forage supply and beginning another. Those days were divided by 2 and the mean date was used. Alfalfa was fed to replacement heifers, yearlings, pregnant yearlings, and 2-yr olds prior to calving in the amount of 6.10, 7.75, 8.17 and 13.3 kg respectively. During fall and spring older cows were fed 13.6 kg of alfalfa/grass hay with 13.6 kg of alfalfa/grass/straw during the winter months.

Supplemental Feeding

Dates which begin and end supplemental feeding and amounts are listed in Table 7 for each management group.

Table 7. Simulated Supplemental Feeding Dates - Northern Great Plains area

INPUT DATA	MEAN DATES	AMOUNT
Supplemental Feeding (14% CP Range Cake)		
Replacements		
Begin	Nov. 3	1.60 kg
End	Dec. 31	
Yearlings		
Begin	Jan. 1	1.55 kg
End	April 30	
Begin	Dec. 11	1.70 kg
End	Dec. 1	
2 Yr. Olds and Cows		
Begin	Jan. 1	1.15 kg
End	April 14	
Begin	Dec. 11	1.15 kg
End	Dec. 31	

Range Grazing Nutrition

Range nutrition for protein and metabolizable energy was taken from data gathered at the Ft. Keogh USDA Agricultural Research Center, Miles City, MT (Figures 1 and 2). This site is located 70 miles NW of the center of Carter and Fallon Counties and is considered by Goetz (1988) to be part of the same area of the NGP region. Previously described fifth degree polynomial regressions derived from this research were adapted (Appendix F) to parameterize the quality of range forage over the grazing season (Adams and Short, 1988). Consumption was based on 2% of cow body weight.

Survey data shows approximately 4452 hectares of range providing 10.5 hectares per animal or 3 hectares animal month. The fixed range forage base, as determined by the mean simulation computer run, was set at 3,060 AUM's.

Marketing Costs

The closest regional livestock market for this area is located in Belle Fouché, SD and lies approximately 125 miles southeast from the center of the study area. Trucking costs for 1994 were quoted at \$2.00 per loaded mile from area businesses, or \$250.00 per trip with 22,268 kg of payload. Price per kg of livestock shipped was \$.011227.

Belle Fouché, SD Livestock Auction Yard charged a set commission of \$9.20 for calves under 227 kg and \$9.80 for

calves over 227 kg and yearlings, \$11.80 for cull cows and 2-yr olds, and \$16.80 for cull bulls. Commission percentages were entered into the simulation by sales cost / average sale weight. Yearlings, cull cows, and bulls consistently averages near .01%, however calves varied considerably and commissions as a percentage of average sales weight were entered.

Herd Health and Interest Costs

Health services, products, and expenses are listed in Table 8 and reflect those used by the majority of area producers. Annual bull fertility tests, vitamin E, trichomoniasis, and E-coli inoculations are not commonly used.

Labor Costs

Hired labor costs on a per animal basis was derived from the survey balance sheets and showed a livestock figure of \$6.91. Average dollars spent on hired labor was \$2,922.00 per ranch covering 423 head.

Foothill/Mountain Region - Mean Ranch Input

Fergus and Petroleum counties, located in central Montana, comprised this study area. It consists of 1.68 million hectares (4.1 million acres) of which 871,142 million hectares (52%) is used for range livestock production. Annual precipitation averages 30 to 46 cm and elevation ranges

Table 8. Veterinary and Health Costs - Northern Great Plains Area

ITEM	PER DOSE	STEERS	HEIFERS	YR. HEIFERS	2 YR HEIFERS	COWS	BULLS
Prevention							
IBR/BVD	\$1.00	\$1.00	\$1.50	\$1.00	\$1.00	\$1.00	\$1.00
Blackleg	0.25	0.25	0.38	0.25	0.25	0.25	0.25
Lepto/Vibrio	0.50		0.25	0.50	0.50	0.50	0.50
Wormer	2.38		0.75	2.00	2.83	2.83	3.50
Grubs/Lice	0.83		0.40	0.70	0.83	0.85	1.00
Flies	1.30	1.30	1.30	1.30	2.60	2.60	2.60
Bangs	1.25		0.75				
Preg Check	1.25			1.25	1.25	1.25	
Implants	0.95	0.95	0.95				
Vit A & D	0.24	0.12	0.18	0.24	0.24	0.24	0.35
Vet Travel				0.15	0.15	0.15	
I.D. Tags	0.75	0.75	0.75	0.75	0.25	0.25	0.25
Fees							
Taxes				1.20	5.53	6.08	10.94
Interest				25.00	35.00	35.00	125.00
Sub Total	\$11.15	\$4.37	\$7.21	\$34.34	\$50.43	\$51.00	\$145.39
Sick Pen							% needed
Pneumonia	12.06	0.24	0.24				2
Scours	5.40	0.27	0.27				5
Pink Eye	6.85	0.34	0.34	0.34	0.34	0.34	5
Mastitis	5.50			0.17	0.17	0.17	3
Ret Placenta	5.00			0.15	0.15	0.15	3
Misc.	7.00			0.21	0.21	0.21	3
Total		\$5.22	\$8.06	\$35.21	\$51.30	\$51.87	
Bulls Expense	Depreciation (\$394.00) plus Health Expense (\$145.39) = \$539.39 annually						

between 688 to 2545 m. Temperature extremes vary from 43 °C in summer to -40 °C in winter (Dave Phillips, County Extension Agent, private comm., 1997). Johnson et al. (1994b) paraphrased Saunderson and Chittenden (1937) in describing this area as one of detached mountain ranges, foothills and level or rolling benchlands and basins with cattle ranches mainly located around and in rough land and secondary mountain areas.

Ten ranch cooperators, all members of the Fergus County Integrated Resource Management Program, were surveyed for this study. (Johnson et al., 1994b).

Alternative Management Dates

Data from Fergus and Petroleum Counties produced the following dates which were used for alternative management decisions (Class variables). Mean breeding date (BD) for cows was d 196 (May 16) and heifers was d 126 (May 6). Alternative dates also used for cows were d 108 (April 18), d 122 (May 2), d 150 (May 30) and d 164 (June 13). Heifer alternative breeding dates were d 98 (April 8), d 112 (April 22), d 140 (May 20) and d 154 (June 3). Information on graphs used heifer breeding dates for entire herd reference. Mean weaning date (WD) and range removal date (RR) was d 291 (October 18), with alternative dates represented by d 263 (September 20), d 277 (October 4), d 305 (November 1) and d 319 (November 15).

Livestock Production

As indicated by the survey cow herds were primarily black and Black Angus breeding (60%) with about 20% each of Simmental and Hereford. Bulls used for breeding were mostly Simmental (55%) and Black Angus (30%) with Charolais, Hereford and Gelbvieh each making up less than 10%.

Table 9 describes the attributes of the cow/calf production for this study area. A conception rate of 70% per cycle provided a 96% pregnancy rate for a 60 day breeding season. Heifers were bred ten days earlier and breeding ended 15 days earlier than with older cows. Sixty six heifers were chosen annually for replacements or 16% of the adult herd. Peak lactation was set at 12.6 kg on day 42. Average weaning age was 216 days.

Forage Production

The forage parameters of the simulated ranch are shown in Table 10. Over half of hay production was from irrigated fields and provided two cuttings annually. Aftermath grazing occurred during the fall and winter with the mean computer run defined 194,000 kg of available forage. All simulations were set to +/- 5000 kg of this figure for quantity of aftermath grazing after which cattle were fed stored hay. Straw was added to the winter diet for 3 yr old and older cows.

Table 9. Simulated foothills/mountain ranch cattle production.

INPUT DATA	MEAN
CATTLE PRODUCTION	
No. of Cows	326
No. of Replacements	60
No. of Bred Heifers	48
No. of Additional Cattle	42
No. of Equiv. from Sheep	7
Total Cows	483
Average Cow Wt.	567 kg
Percent Culled Cows	12 %
Percent Pregnant	96 %
Percent Herd Death	01 %
Breeding Dates	
Cows	
Begin	May 16
End	July 15
No. of Days	60
Heifers	
Begin	May 6
End	June 30
No. of Days	55
Percent Calf Losses	.03
Weaning Date	Oct. 18
Average Weaning Age	216
Weaning Weights	
Steers	282 kg
Heifers	270 kg
No. of Cows per Bull	25

The stored forage base was fixed to the needs of the mean herd: 291 t of mixed (alfalfa/grass/straw), 385 t of alfalfa/grass, and 242 t of alfalfa hay was available. Prices of forage were \$67.10, \$71.50, and \$77.00 t, respectively with straw priced at \$38.50 t.

Table 10. Mean foothills/mountain simulated ranch forage production.

INPUT DATA	MEAN
FORAGE BASE	
Hectares of Range	2660
Deeded	1759
Government	279
Other	622
Hectares of Pasture	51
Hectares of Hay	240
Tons of Hay Produced	964 t
Tons/Hectare	4.01 t
Tons of Grass	11 t
Tons of Alfalfa	476 t
Tons of Alf/Grass	477 t

Dave Phillips, Extension Agent for Fergus and Petroleum Counties (personal comm., 1995) provided information for the composition of the hay base. Table 11 describes the nutritional specifications of each forage type.

Alfalfa hay was fed to replacement heifers, yearlings and 2-yr heifers prior to calving at the rate of 7 kg, 9 and 10 kg, and 12 kg per day, respectively. Post-calving 2-yr olds and older cows were fed alfalfa/grass hay during spring and fall at 13.2 kg per day and alfalfa/grass/straw mix during the winter at 12.2 and 12.5 kg daily, respectively.

Supplemental Feeding

Mean dates and amounts of supplemental feeding for each management group are shown in Table 12.

Table 11. Nutritional Hay Specifications - Foothills/mountain area.

TYPE	ME/DM	NDF/DM	CP/DM	RDP/DM
Alfalfa				
Early/Mid-bloom	2.17	.40	.18	.75
Grass Hay - Irrigated				
Smooth Brome	2.03	.61	.146	.75
Regar Mdw. Brome	2.17	.65	.16	.75
Tall Fescue	2.21	.57	.124	.75
Orchard Grass	2.35	.61	.159	.75
Wheat Grass	2.21	.61	.13	.75
Int. Wheat Grass	2.00	.61	.13	.75
Average	2.16	.61	.14	.74
Alfalfa/Grass				
50/50 Mix	2.17	.505	.16	.743
Straw	1.52	.733	.041	.60
Straw/Alfalfa-Grass Mix				
12.5%/87.5%	2.10	.511	.12	.727

(From: NAC, 1971; ARC, 1980; NRC, 1984; NRC, 1988)

Table 12. Simulated Supplemental Feeding - Foothills/Mountain area.

INPUT DATA	MEAN DATE	AMOUNT
Supplemental Feeding (14% CP Range Cubes)		
Replacements		
Begin	Oct. 18	.80 kg
End	Dec. 31	
Yearlings		
Begin	Jan. 1	.80 kg
End	May 2	
Begin	Nov. 15	.62 kg
End	Jan. 1	
2 Yr. Olds and Cows		
Begin	Feb. 11	.52 kg
End	May 11	

Range Grazing Nutrition

Information on mountain/foothill range nutrition was not available for an entire grazing season. To parameterize input data for the simulation results were used from several grazing studies conducted at higher elevations in the northwestern U.S. (Cook and Harris, 1968; Peischell, 1980; Ansotegui, 1986; Holechek, et al., 1987; Adams and Short, 1988.). Figures 10, 11, and 12 show graphed regression equations of DM crude protein, metabolizable energy, and neutral detergent fiber levels used for area input, respectively. Simulation equations are shown in Appendix F.

Survey range data indicate 2660 hectares of available range providing 5.6 hectares per animal or 1 hectare per animal month. As determined by the base simulation computer run, the fixed forage base was 3640 AUM's.

Marketing Costs

Billings, MT is the closest regional livestock market for this area, located 110 miles to the southwest of the center of the two counties. Trucking rates for 1994 were quoted at \$2.00 per loaded mile or \$220.00 per 22,268 kg payload. Price per kg of livestock shipped was \$.009879. The Public Auction Yards charge a commission of 2.25% inclusive of all yard fees.

Figure 10. Concentration of Crude Protein in cattle diets at various times of the year on Foothill/Mountain Range.

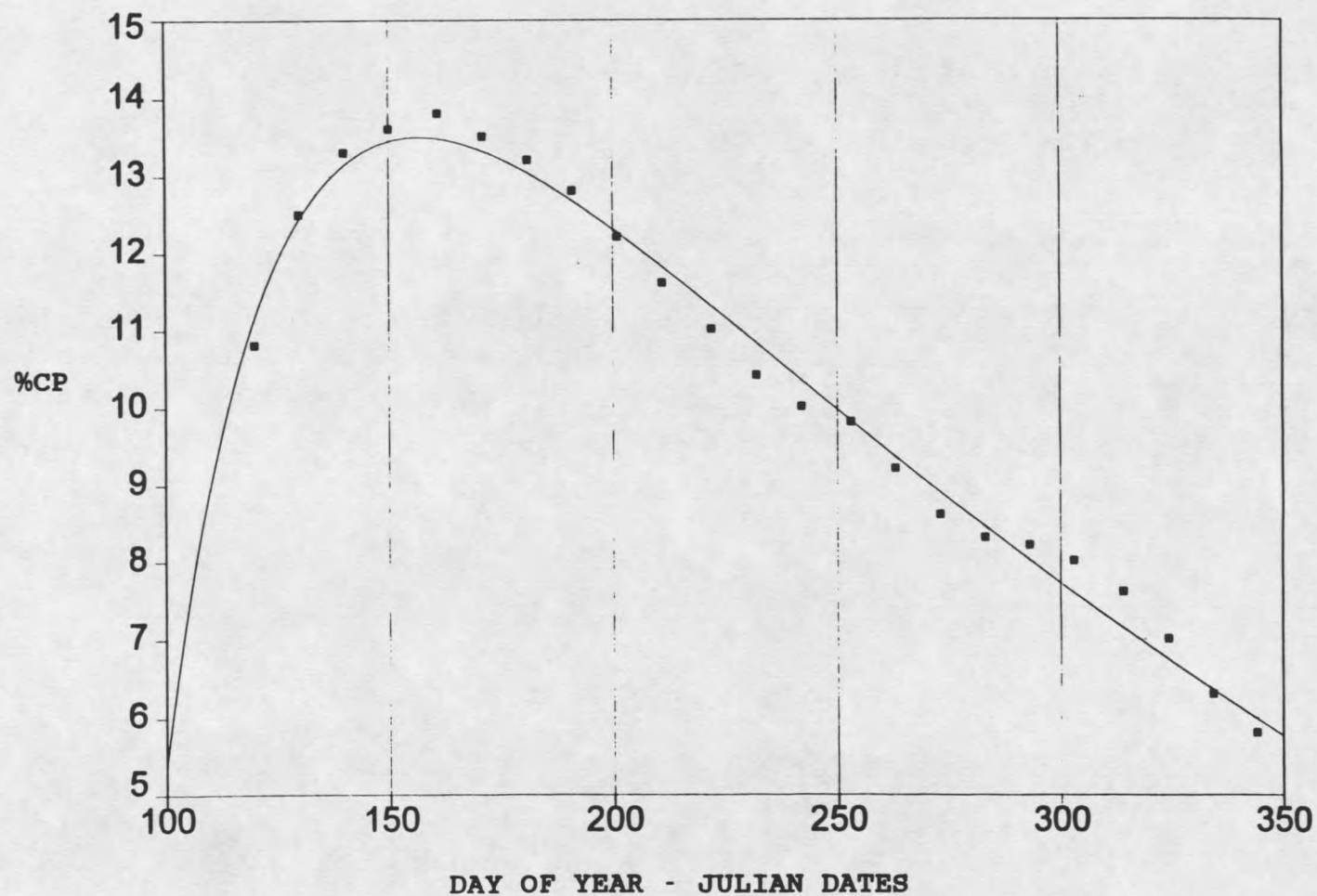


Figure 11. Concentration of Metabolizable Energy in cattle diets at various times of the year on Foothill/Mountain Range.

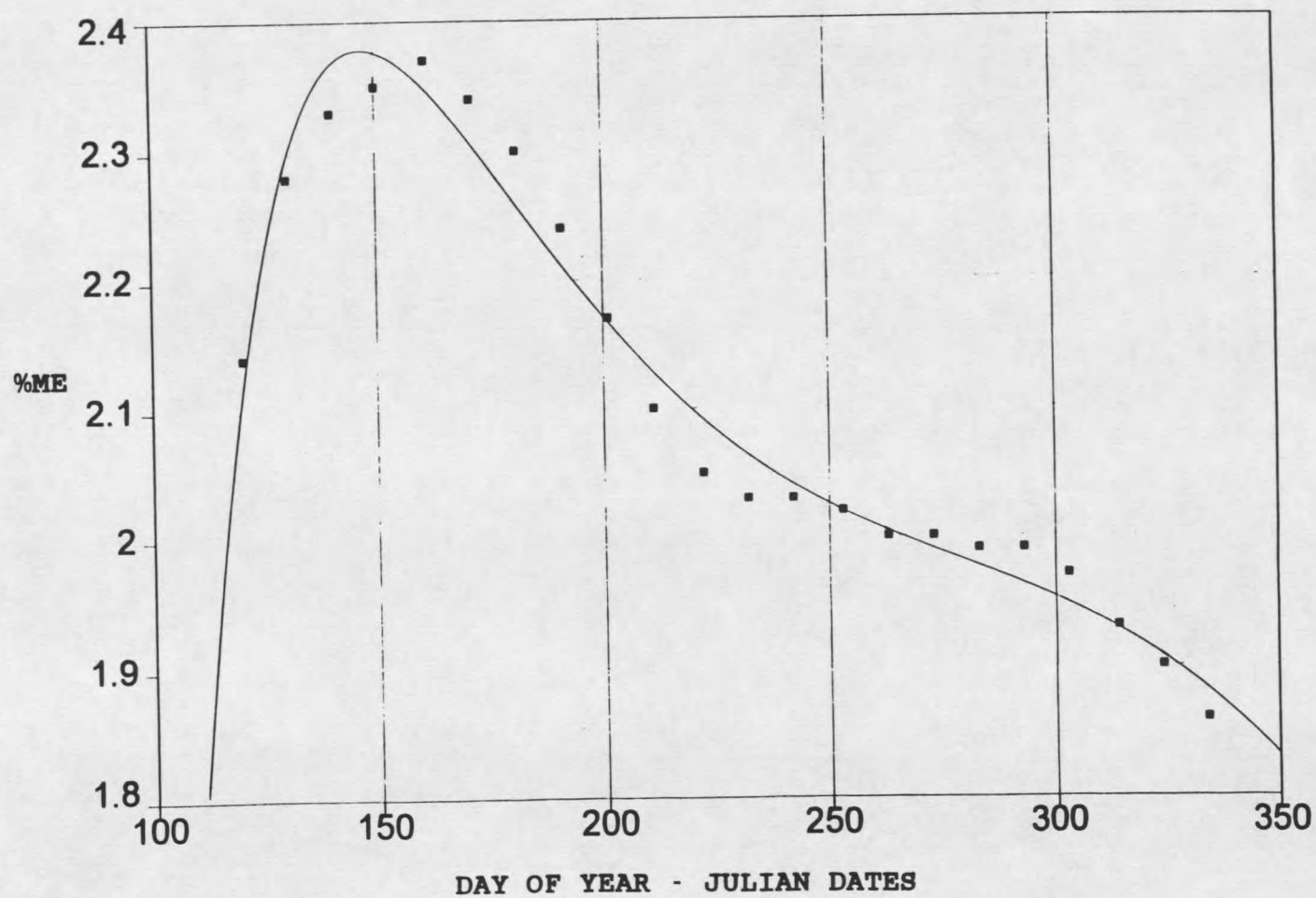
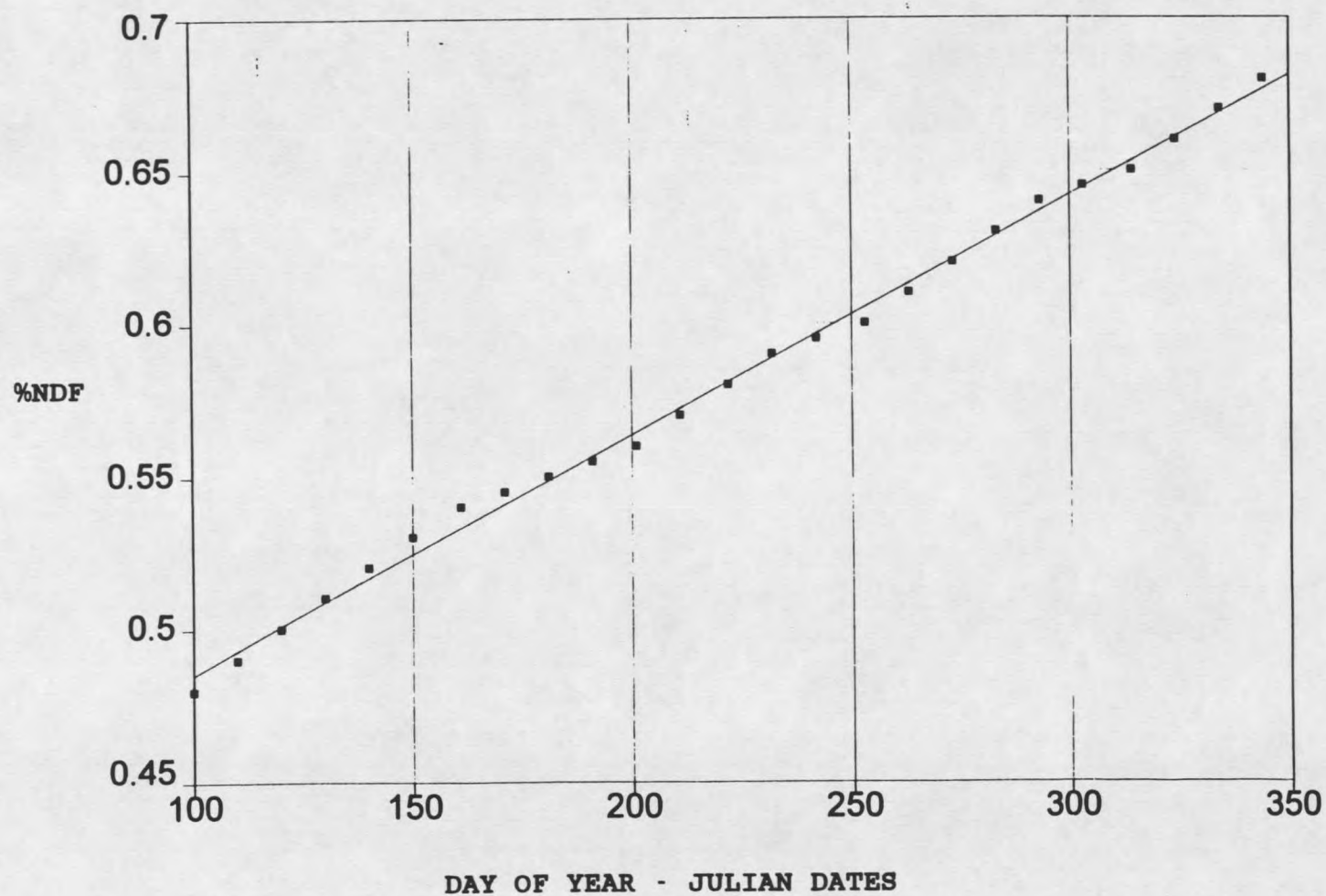


Figure 12. Concentration of Neutral Detergent Fiber in cattle diets at various times of the year on Foothill/Mountain Range.



Herd Health and Interest Costs

Table 13 describes the health products and services used by the majority of producers in this area. Vitamin E, wormers, and inoculations for trichomoniasis were not commonly used.

Labor Costs

Four of the 10 ranches showed expenses for hired labor. The average figure for labor associated with livestock production was \$5,947.00 or \$12.31 per head.

Statistical Design

The statistical design used for this study was a 3 X 5 factorial with five replications for each combination. Simulated data generated by the computer model was analyzed using the General Linear Model procedure of SAS (1987). Duncan's Multiple Range Test was used for comparison of means. The initial model considered all classes, two and three way interactions, providing 125 degrees of freedom with 500 degrees for error. Sources were considered significant for $P < .05$ and less.

Traits analyzed in this study included average calf weaning weight, herd size, net income per cow exposed, weaning weight per cow exposed, break-even steer price, and ranch gross margin.

Table 13. Veterinary and Health Costs - Foothill / Mountain Area

ITEM	PER DOSE	STEERS	HEIFERS	YR. HEIFERS	2 YR HEIFERS	COWS	BULLS
Prevention							
IBR/BVD	\$1.00	\$1.00	\$1.50	\$1.00	\$1.00	\$1.00	\$1.00
Blackleg	0.25	0.25	0.38	0.25	0.25	0.25	0.25
Lepto/Vibrio	0.50		0.25	0.50	0.50	0.50	0.50
E. coli	0.60	0.60	0.60				
Grubs/Lice	0.83		0.40	0.70	0.83	0.85	1.00
Flies	1.30	1.30	1.30	1.30	2.60	2.60	2.60
Bangs	1.25		0.75				
Preg Check	1.25			1.25	1.25	1.25	
Implants	0.95	0.95	0.95				
Vit A & D	0.24	0.12	0.18	0.24	0.24	0.24	0.35
Vet Travel				0.15	0.15	0.15	
Fert. Test	18.50						18.50
I.D. Tags	0.75	0.75	0.75	0.75	0.25	0.25	0.25
Fees							
Taxes				1.20	5.53	6.08	10.94
Interest				25.00	35.00	35.00	125.00
Sub Total		\$4.97	\$7.06	\$32.34	\$47.60	\$48.17	\$160.39
Sick Pen							% needed
Pneumonia	12.06	0.24	0.24				2
Scours	5.40	0.27	0.27				5
Pink Eye	6.85	0.34	0.34	0.34	0.34	0.34	5
Mastitis	5.50			0.17	0.17	0.17	3
Ret Placenta	5.00	0.21	0.21		0.15	0.15	3
Misc.	7.00			0.21	0.21	0.21	3
Total		\$6.03	\$8.12	\$33.06	\$48.47	\$49.04	
Bulls Expense	Depreciation (\$394.00) plus Vet (\$160.39) = \$554.38						

CHAPTER 7

RESULTS

Northern Great Plains Region

Table 14 shows the ANOVA of the dependent variables for each class and class combination.

Average Calf Weaning Weight

The analysis of variance for average calf weaning weight (AWW) revealed two two-way interactions. Figure 13 represents the interaction between WD and RR. Average calf weaning weights were greatest for calves removed from the range early but weaned late. The decline in AWW, for all weaning dates, as range removal moved later into the season was due to a slower rate of gain for calves remaining on range under declining nutritional conditions versus those on aftermath grazing or stored forages prior to weaning.

Breeding date and range removal interaction is shown by Figure 14. Estimates show earlier BD and RR increased average calf weaning weight. For all BD, average weaning weight declined as RR moved to later into the fall. A review of the output data indicated cows with later weaned calves had declining percentages

Table 14. Analysis of Variance - Northern Great Plains

Source	df	AWW	P	WWCE	P	HS	P	BESP	P	NICEX	P	RGM	P
BD	4	89278	0.0001	63684	0.0001	38723	0.0001	2.1994	0.0001	51433	0.0001	9.891E+09	0.0001
WD	4	56141	0.0001	39697	0.0001	19186	0.0001	1.0452	0.0001	27650	0.0001	5.195E+09	0.0001
RR	4	1109	0.0001	857	0.0001	219539	0.0001	0.2641	0.0001	10804	0.0001	1.794E+09	0.0001
BD x WD	16	2	0.6270	32	0.5506	40	0.0003	0.0093	0.0001	36.74	0.2741	1.688E+07	0.0001
BD x RR	16	5	0.0001	41	0.2879	242	0.0001	0.0014	0.0510	38.47	0.2309	2.903E+07	0.0001
WD x RR	16	296	0.0001	178	0.0001	1674	0.0001	0.0008	0.4794	36.5	0.2805	1.0590E+07	0.0253
WD x BD x RR	64	2	0.0512	26	0.9239	12	0.7832	0.0007	0.8454	23.44	0.9160	4.383E+08	0.9196
R-Square		0.998		0.960		0.994		0.971		0.959		0.96	

df - Degrees freedom; AWW - Average weaning weight; WWCE - Weaning weight per cow exposed; HS - Herd size; BESP - Break-even steer price; NICEX - Net income per cow exposed; RGM - Ranch gross margin.
P - P value

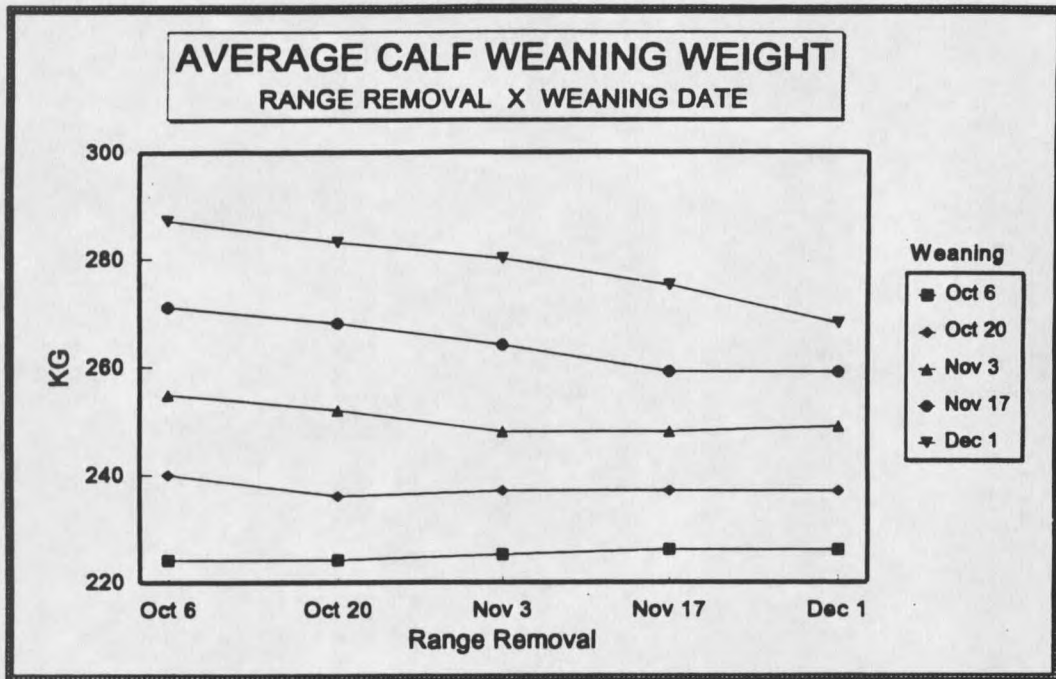


Figure 13. Average Calf Weaning Weight - Range removal and weaning date interaction (Northern Great Plains).

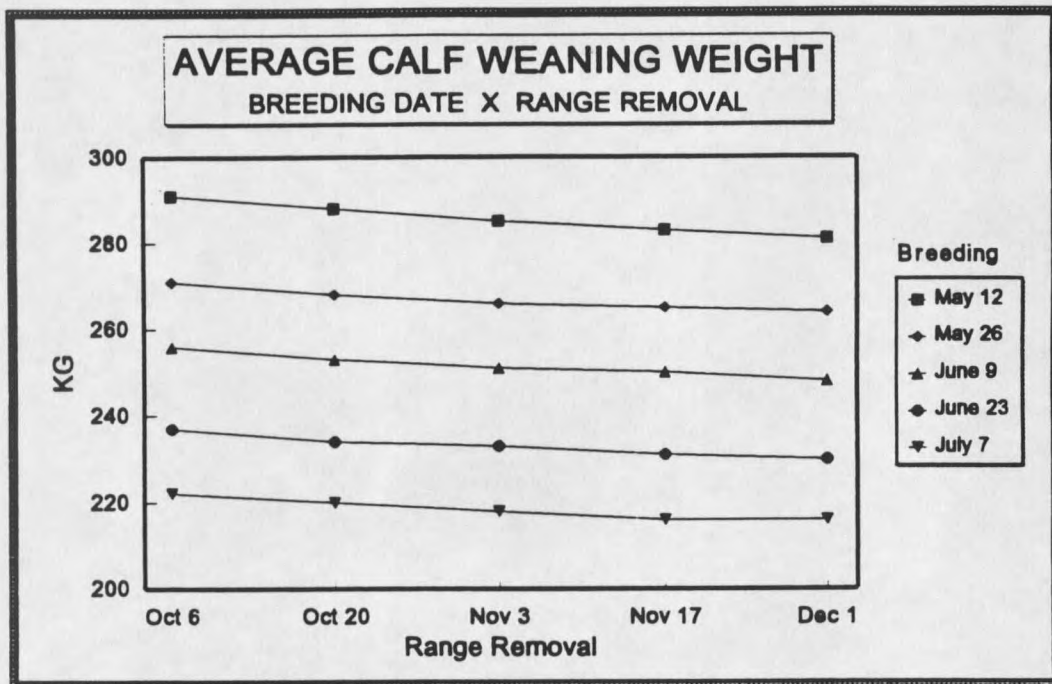


Figure 14. Average Calf Weaning Weight - Breeding date and range removal date interaction (Northern Great Plains).

of body fat and increased postpartum intervals. A decrease in age of calf at weaning was also noted. A decline in the cows' body condition may explain the slight decrease in AWW as RR was extended.

Weaning Weight per Cow Exposed

Results for weaning weight per cow exposed (WWCE) showed one two-way interaction and the effect of breeding date. Figure 15 illustrates the breeding date regression for WWCE. As the breeding date is moved further into the spring WWCE steadily decreased. Calves born earlier in the spring had greater weaning weights.

The interaction between WD and RR resulted in a decrease in WWCE for all weaning dates as range removal was extended later into the fall (Figure 16). Later weaning combined with decreasing nutritive value of the range forage resulted in increased calving intervals and a decrease in weaning weight per cow exposed. This was attributed to a weaning and calving time decrease in body condition score of the cows. To investigate this result further, input data was rerun with an increase in amount of fall supplementation and/or starting the feeding supplementation earlier which increased cow BCS and WWCE (data not shown).

Herd Size

With constrained resources, herd size decreased for all weaning dates as RR was extended later into the season (Figure

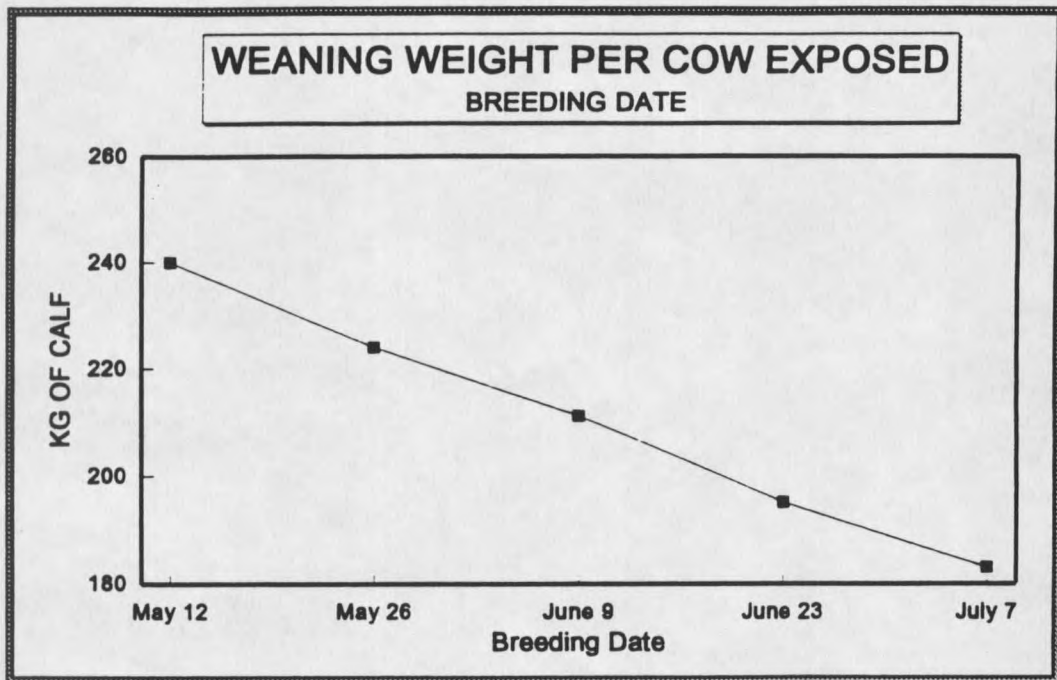


Figure 15. Weaning Weight per Cow Exposed - Breeding date (Northern Great Plains).

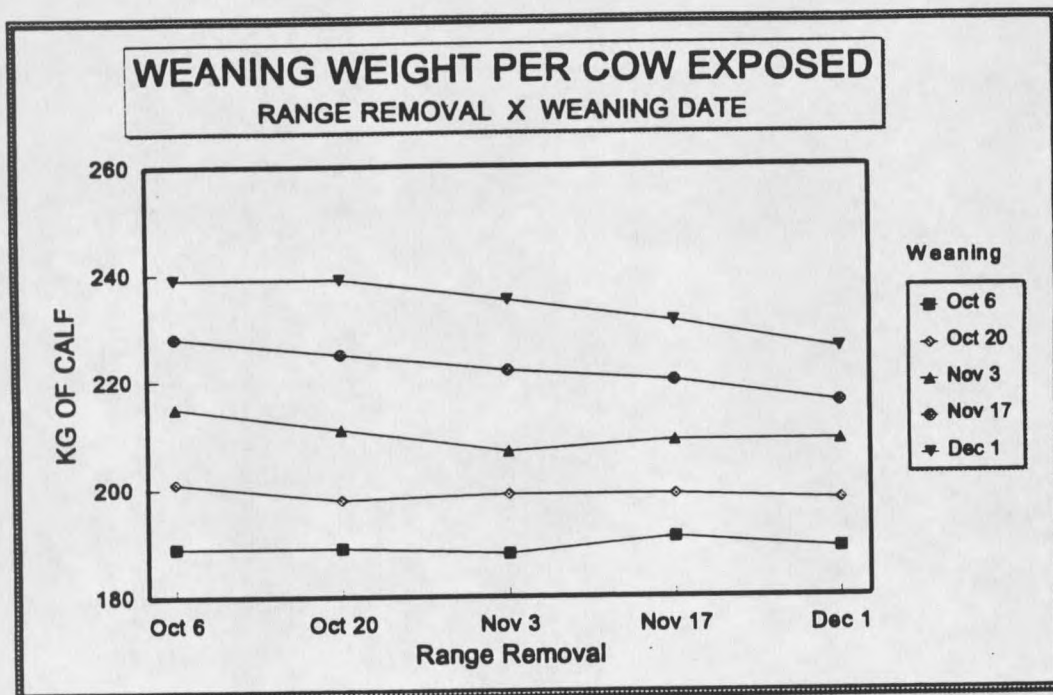


Figure 16. Weaning Weight per Cow Exposed - Range removal date and weaning date interaction (Northern Great Plains).

17). Herd size was approximately 500 cows for all WD for the earliest range removal date. However, herd size decreased with the length of time cows remained on range and calves remained with their dams competing for range forage. Herd size also decreased for all breeding dates as range removal was extended further into the fall (Figure 18). The earlier calves were born the greater the competition with mature cows for use of the limited available forage. As range removal was extended later into the fall herd size decreased depending on the age (and thus size) of the calves and the length of time spent on the range. The breeding date and weaning date interaction also revealed a decrease in herd size for all breeding dates when weaning date was extended later into the fall (Figure 19). The youngest calves (born late and weaned early) provided for the largest herd size, while oldest calves weaned latest resulted in the smallest herd size. Younger calves provided less competition than older calves for the limited range resource.

Break-even Steer Price

Break-even steer price represents the sale price needed to recover total fixed and variable production costs for all livestock classes at a steer weight equivalent rate (\$/kg).

Analysis of break-even steer price resulted in the effect of range removal and one two-way interaction. Means for BD x WD (Figure 20) showed earliest breeding dates with a \$.40/kg

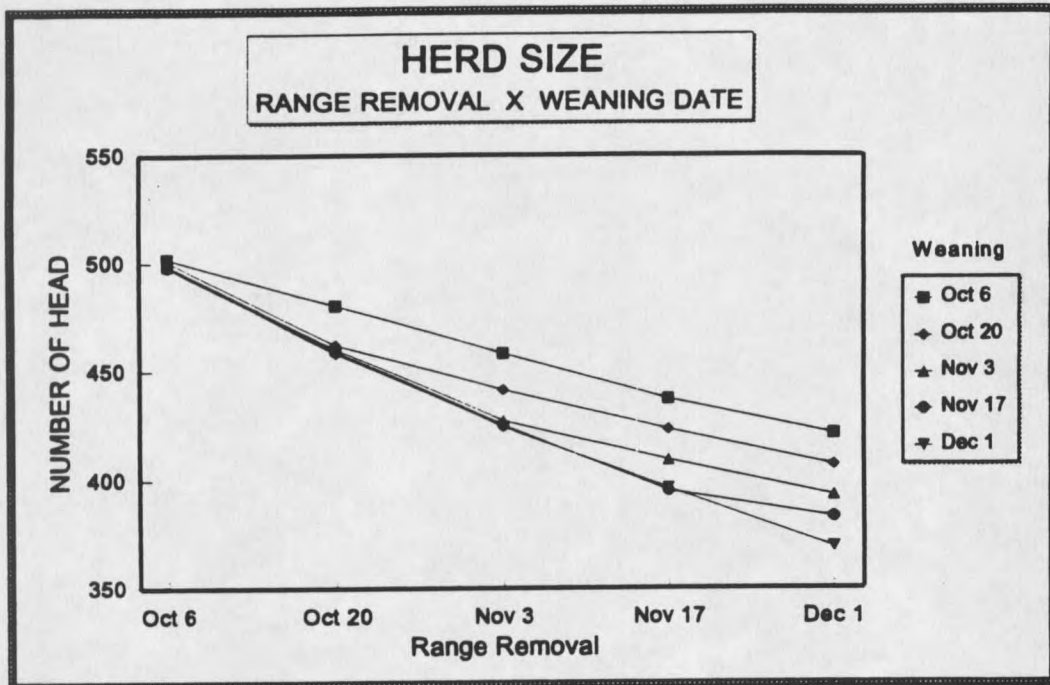


Figure 17. Herd Size - Range removal date and weaning date interaction (Northern Great Plains).

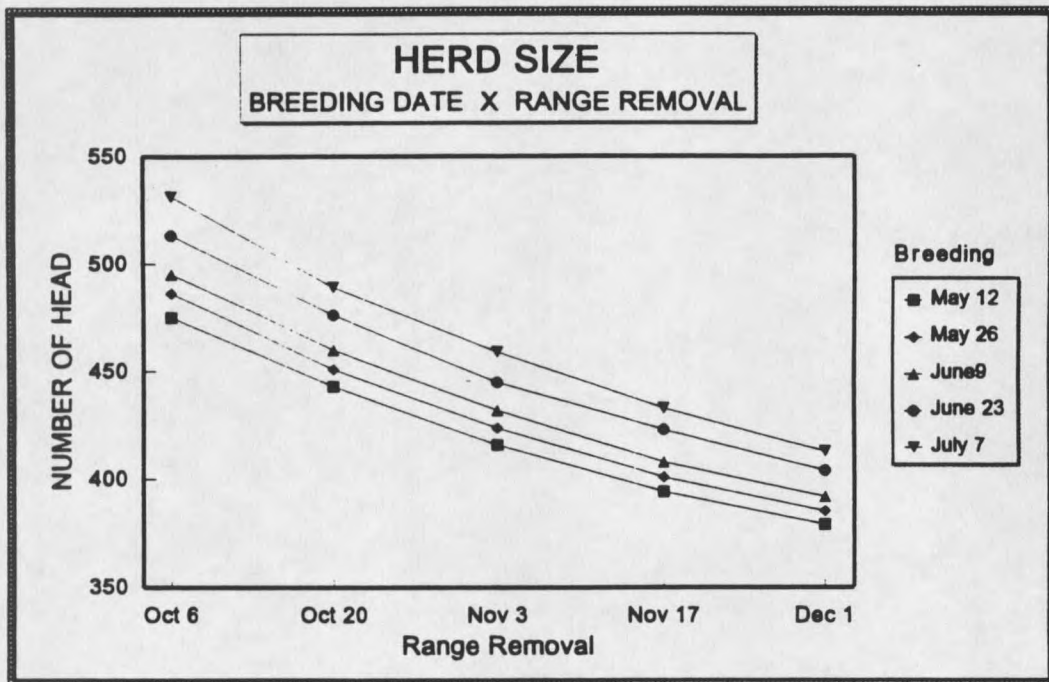


Figure 18. Herd Size - Breeding date and range removal interaction (Northern Great Plains).

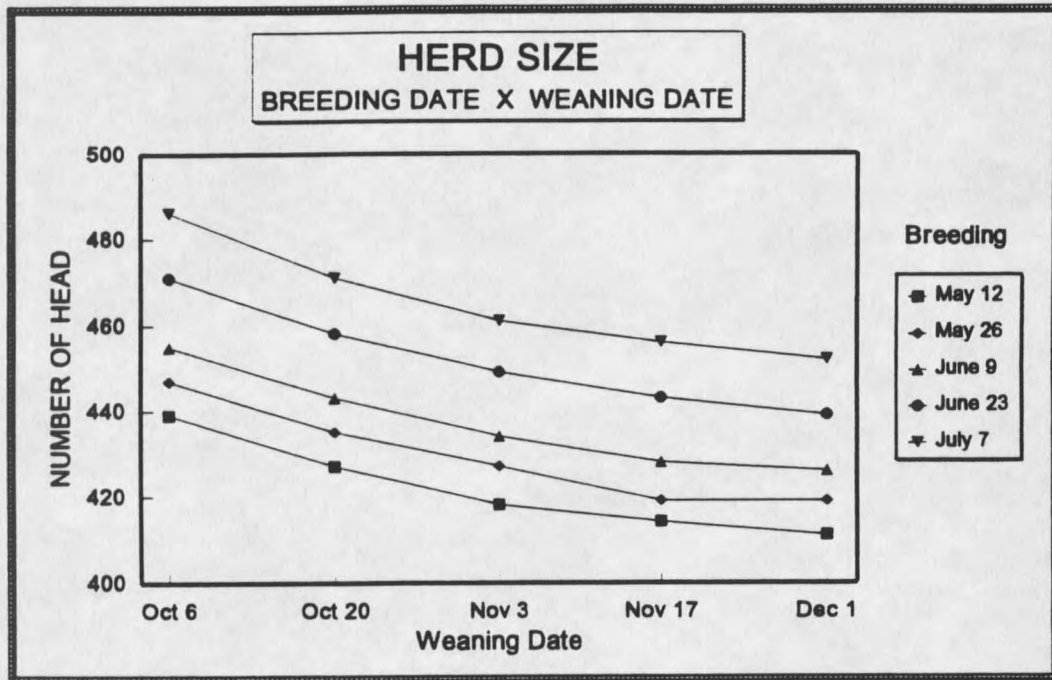


Figure 19. Herd Size - Breeding date and weaning date interaction (Northern Great Plains).

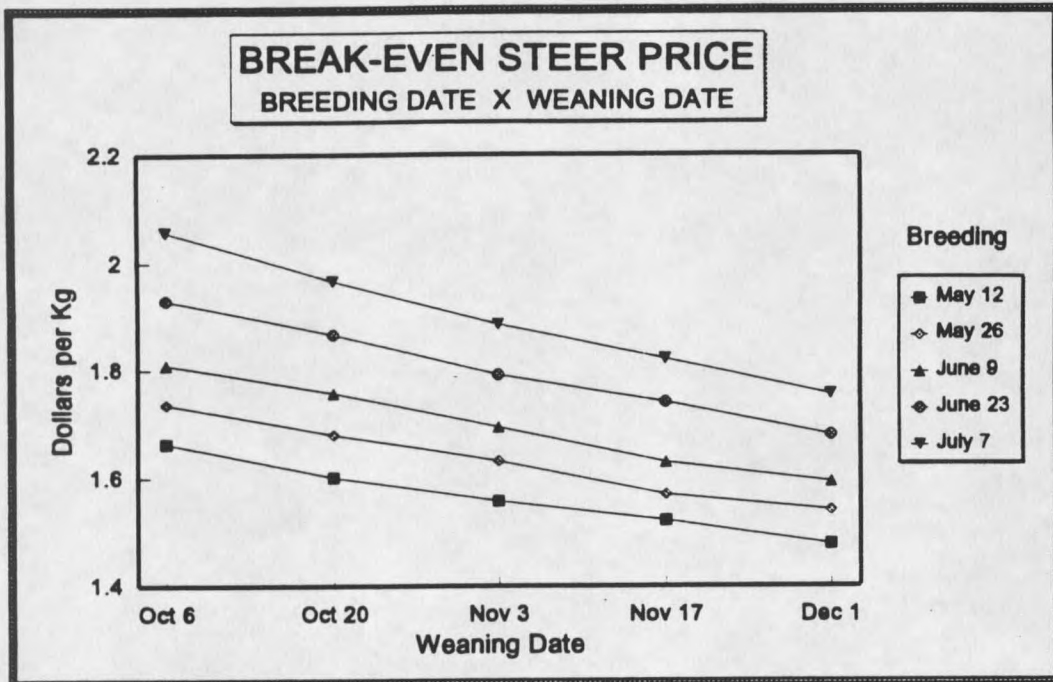


Figure 20. Break-even Steer Price - Breeding date and weaning date interaction (Northern Great Plains).

advantage over the latest when weaning date was the earliest. When WD moved to the end of the fall season, latest and earliest breeding dates decreased by \$.31/kg and \$.18/kg respectively. Calves born later and weaned earlier in the season were lighter in weight requiring an increased sale price to meet production costs.

As range removal was moved further into the fall break-even steer price declined (Figure 21). Earliest and latest RR differed by .12 \$/kg and indicated an extended range grazing season improved efficiency.

Net Income per Cow Exposed

As range removal moved from October 6 to December 1 net income per total cow exposed (NICEX) increased (Figure 22). Increased use of range forage and decreased use of costly stored forages improved economic efficiency. Weaning date also improved NICEX as calves were removed from dams later into the fall (Figure 23). Later weaning increased calves' age and weight and improved returns per calf. Figure 24 indicates that as breeding date moved later into the spring NICEX decreased. Later born calves were younger and weighed less when weaned and were less efficient than earlier born calves.

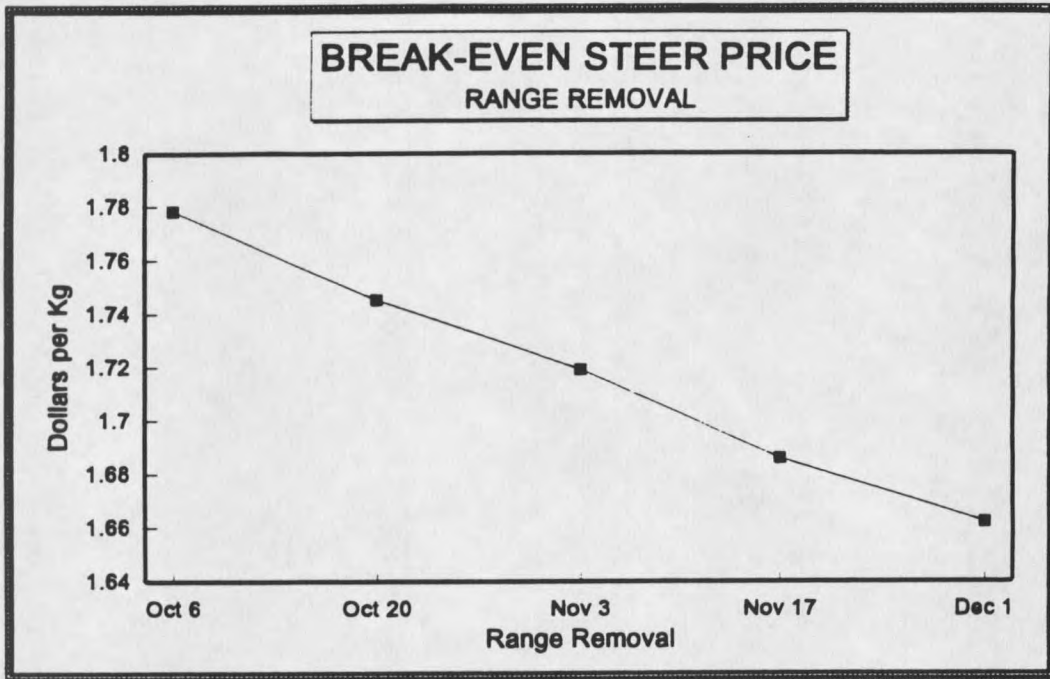


Figure 21. Break-even Steer Price - Range removal (Northern Great Plains).

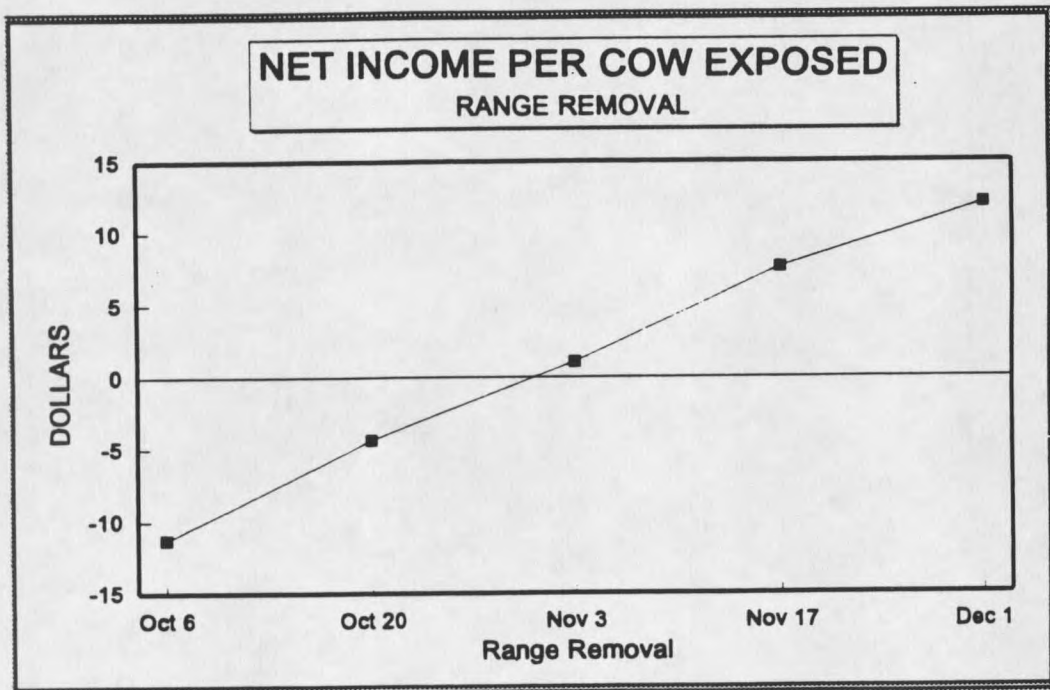


Figure 22. Net Income per Cow Exposed - Range removal (Northern Great Plains).

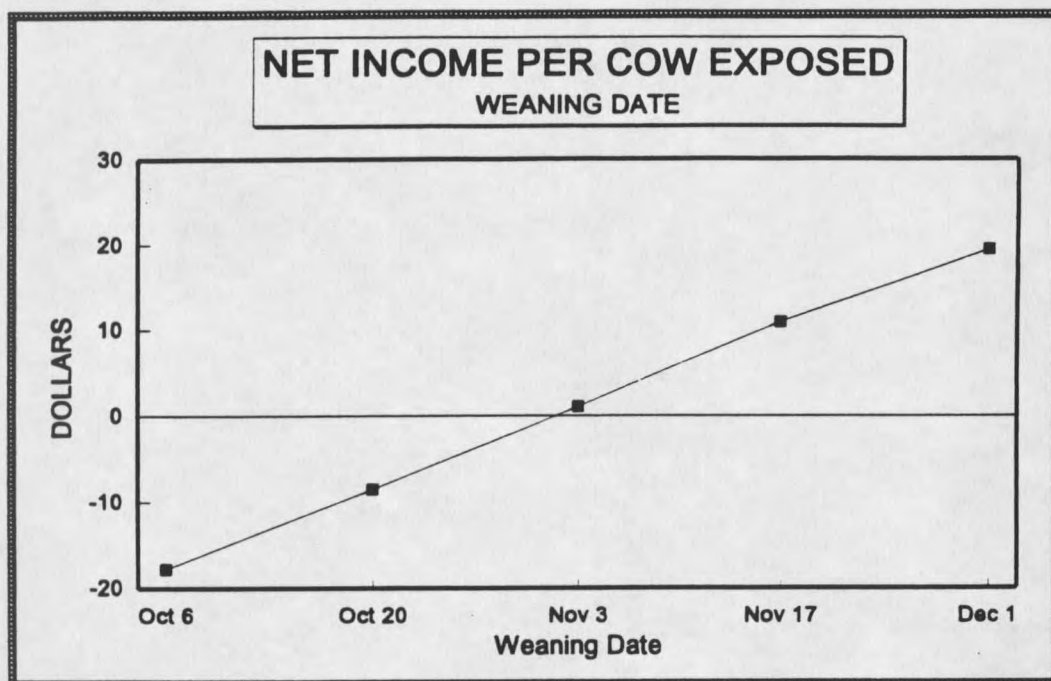


Figure 23. Net Income per Cow Exposed - Weaning date (Northern Great Plains).

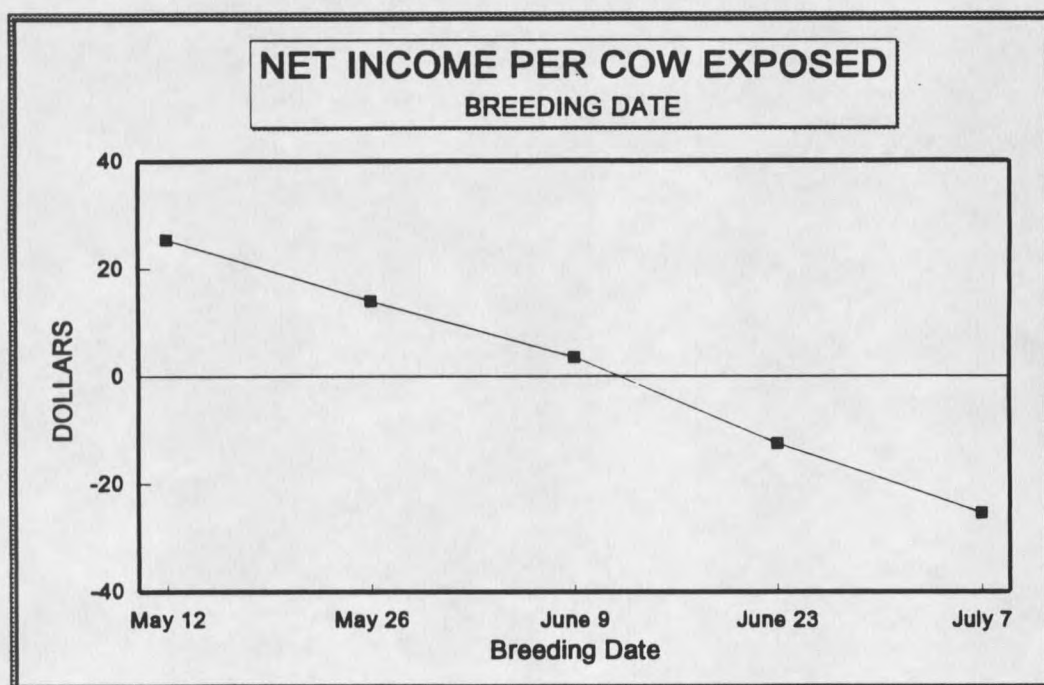


Figure 24. Net Income per Cow Exposed - Breeding date (Northern Great Plains).

Ranch Gross Margin

Ranch gross margin, for the purposes of this study, was defined as gross income less the variable livestock costs. This measure does not include ranch fixed costs.

The analysis resulted in three two-way interactions for ranch gross margin (RGM). The RGM increased with earlier BD and later WD (Figure 25). Comparisons of May 12 and July 7 BD showed in a \$24,351 increase in RGM at WD October 6 and \$20,171 when WD was December 1. Increased age of calves at weaning improved efficiency.

The RGM increased for all WD as RR moved from October 6 to December 1 (Figure 26). When RR was October 6, earliest and latest WD differed by \$17,142. Although ranch gross margin increased for both WD of October 6 and December 1 as RR was extended, by December 1 RR the difference narrowed to \$14,443. Simulated results indicated weaning on December 1 combined with RR on December 1 provide the greatest RGM. The least efficient combination was WD and RR of October 6. Extended use of range by older calves provided the lowest production costs.

When range removal moved later into the fall season, ranch gross margin improved for all BD (Figure 27). The latest BD improved \$13,957 when RR moved from October 6 to December 1, while a May 12 BD increased \$6,174 with the same change. Earliest BD estimated a \$26,673 increase in ranch gross margin over the latest BD for October 6 RR and a \$18,890 increase for December

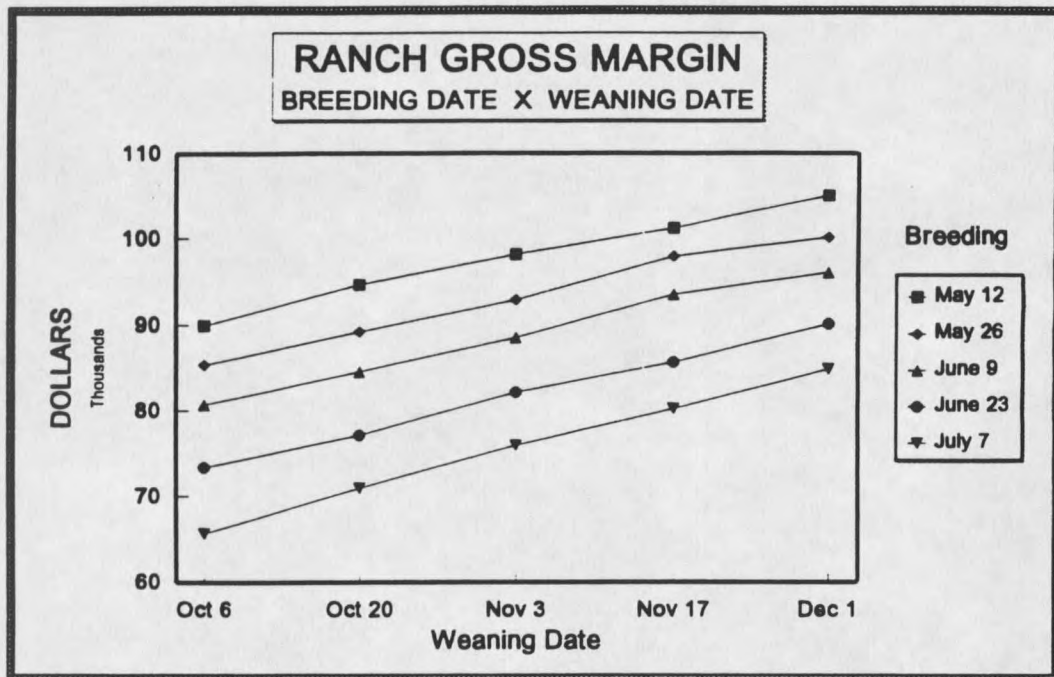


Figure 25. Ranch Gross Margin - Breeding date and weaning date interaction (Northern Great Plains).

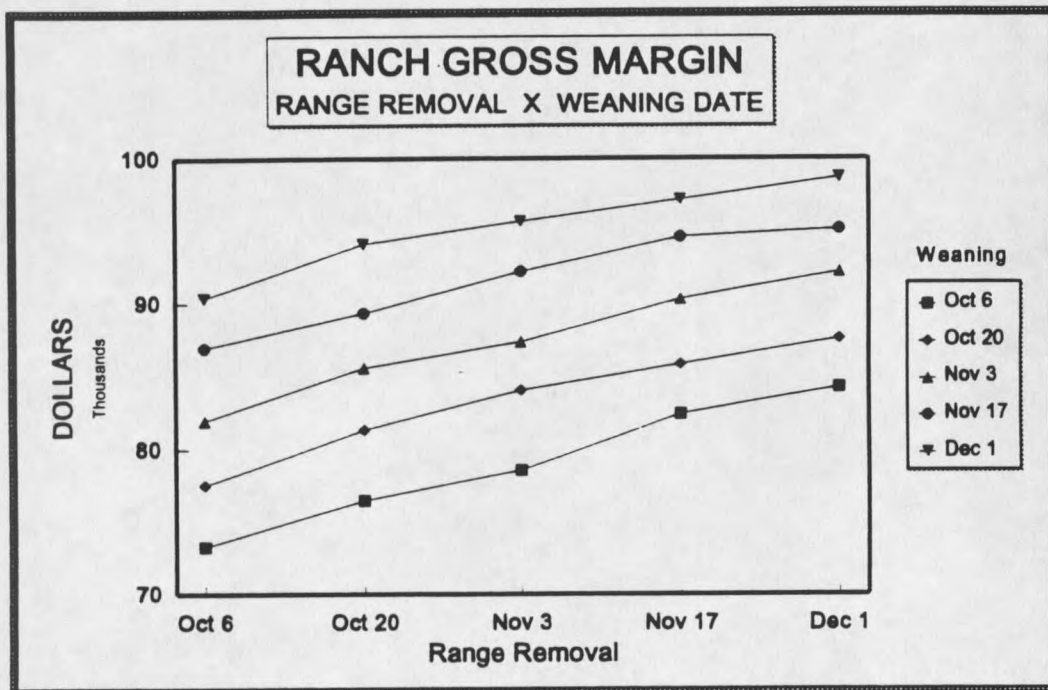


Figure 26. Ranch Gross Margin - Range removal and weaning date interaction (Northern Great Plains).

1 RR. Older calves were more dependent on grazing range than younger calves. As range use is extended the declining nutritional quality slowed older calves rate of gain to a greater extent than younger calves.

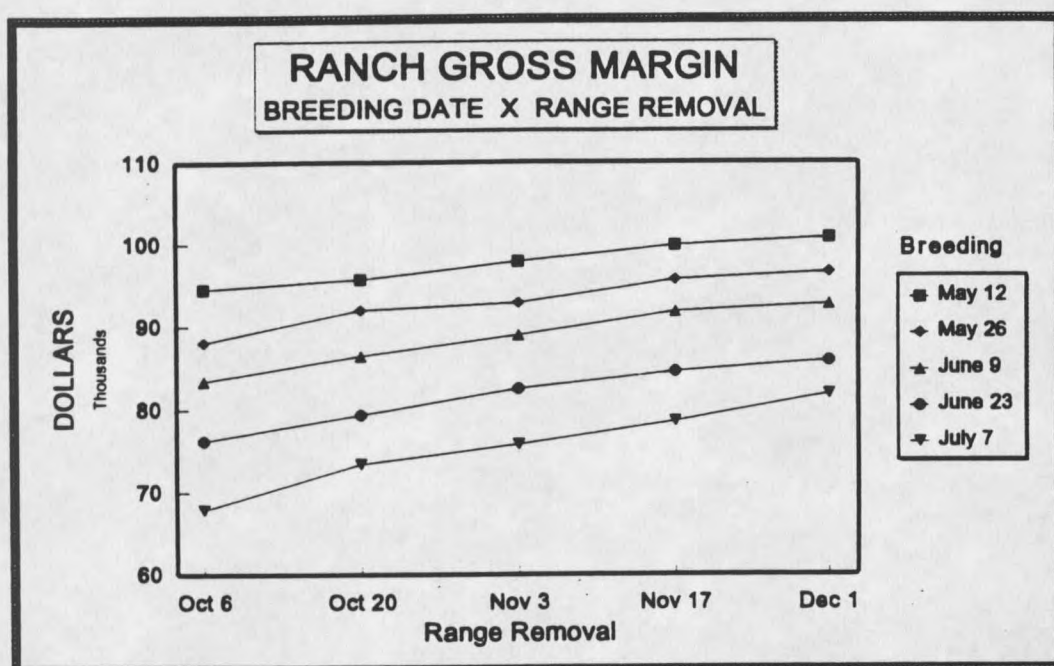


Figure 27. Ranch Gross Margin - Breeding date and range removal date interaction (Northern Great Plains).

Foothill / Mountain Region

Table 15 shows the ANOVA of the dependent variables for each class and class combination.

Average Calf Weaning Weight

Analysis of variance for average calf weaning weight (AWW) demonstrated a three-way interaction (Figure 28). The earliest

Table 15. Analysis of Variance - Foothills/Mountains

Source	df	AWW	P	WWCE	P	HS	P	BESP	P	NICEX	P	RGM	P
BD	4	103069	0.0001	65102	0.0001	39005	0.0001	1.1512	0.0001	33015	0.0001	7.327E+09	0.0001
WD	4	58813	0.0001	39927	0.0001	26359	0.0001	0.6078	0.0001	22776	0.0001	4.986E+09	0.0001
RR	4	4648	0.0001	4397	0.0001	336594	0.0001	0.0458	0.0001	2435	0.0001	4.434E+08	0.0001
BD x WD	16	6	0.0001	76	0.0001	63	0.0001	0.0067	0.0001	67.11	0.0001	2.568E+07	0.0001
BD x RR	16	43	0.0001	126	0.0001	442	0.0001	0.0016	0.0001	77.54	0.0001	5.762E+07	0.0001
WD x RR	16	887	0.0001	764	0.0001	2328	0.0001	0.0032	0.0001	107.17	0.0001	9.1540E+07	0.0001
WD x BD x RR	64	2	0.0005	32	0.0409	15	0.0281	0.0005	0.1319	30.1	0.0587	6.798E+06	0.0809
R-Square		0.999		0.975		0.997		0.971		0.954		0.953	

df - Degrees freedom; AWW - Average weaning weight; WWCE - Weaning weight per cow exposed; HS - Herd size; BESP - Break-even steer price; NICEX - Net income per cow exposed; RGM - Ranch gross margin.
P - P value

breeding date combined with the earliest range removal and latest weaning date produced the heaviest calves at 360 kg. The lightest calves (213 kg) resulted from the latest breeding date, combined with the earliest weaning date for all range removal dates. The quality of the aftermath grazing, although limited in quantity, and fed stored forages provided greater calf gains than fall range due to the declining nutritional value of native range. With more active rumens, rate of gain was greater for older calves which were more dependent on forages. Younger calves were more dependent on milk and utilized less fall range or aftermath grazing.

Weaning Weight per Cow Exposed

Results for weaning weight per cow exposed (WWCE) indicated a three-way interaction (Figure 29). All WWCE increased as weaning was extended into the fall with earlier range removal dates and earlier breeding dates. The greatest WWCE was 303 kg. The least WWCE (182 kg) resulted from a June 3 breeding date combined with September 20 weaning and range removal date. Older calves, due to extended time to weaning and/or earlier breeding dates with early range removal, when placed on aftermath grazing or stored forages provided the highest WWCE.

Herd Size

With constrained resources, herd size decreased for all weaning dates as RR and WN were extended later into the season

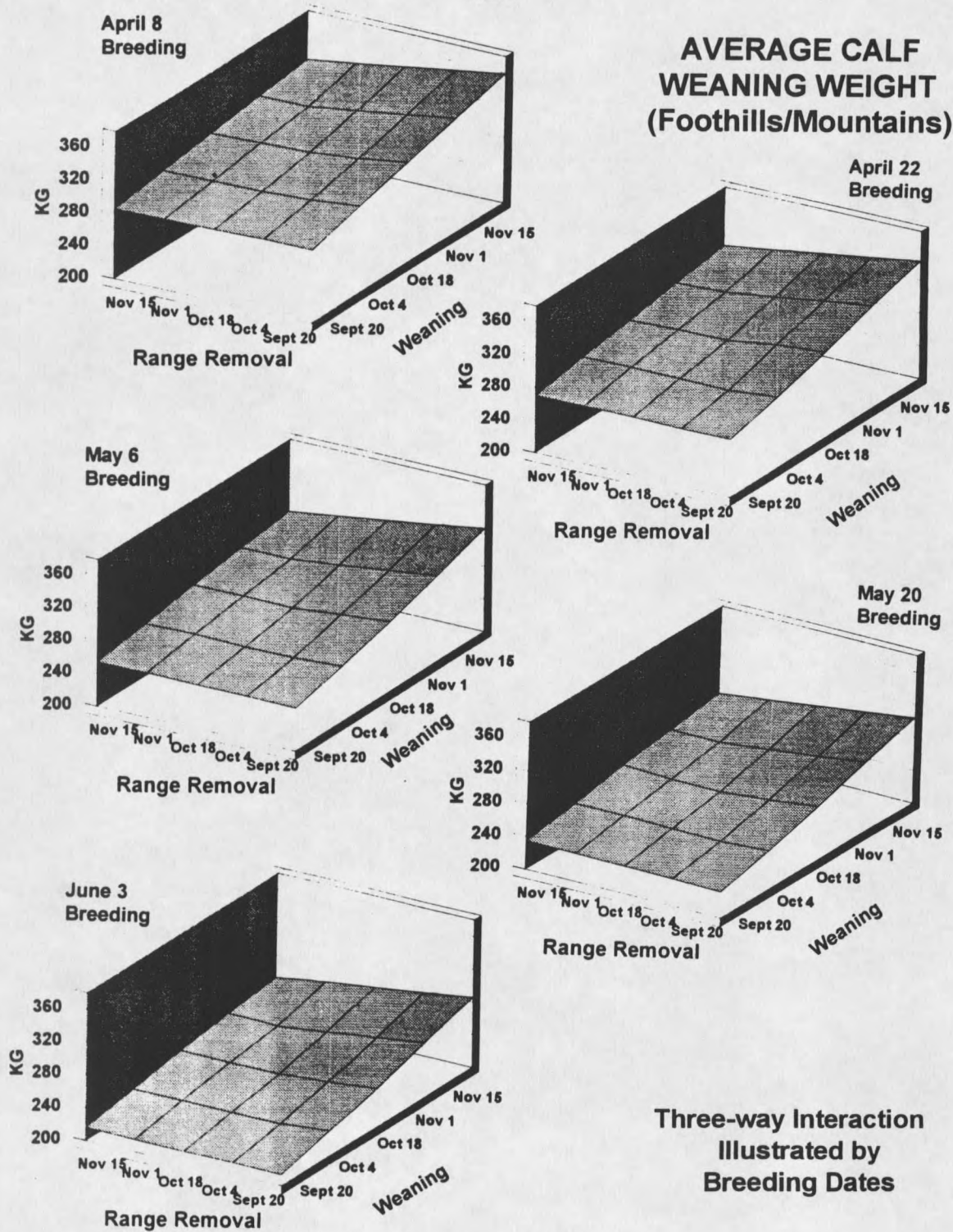


Figure 28. Average Calf Weaning Weight - Three way interaction illustrated by breeding dates (Foothills/Mountains).

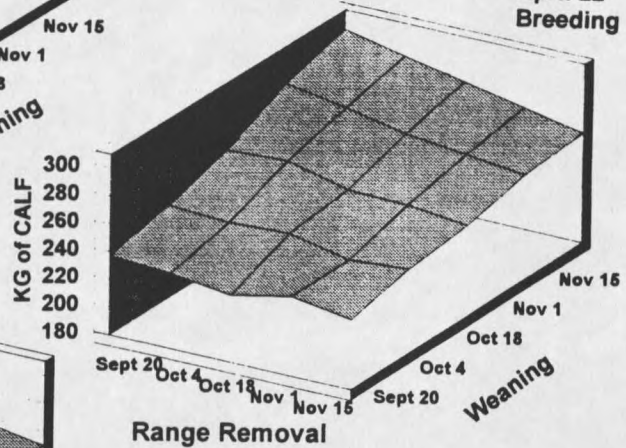
112

April 8
Breeding

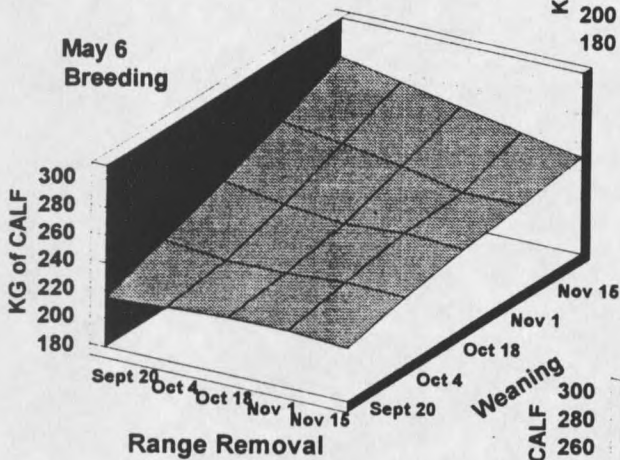


WEANING WEIGHT PER COW EXPOSED (Foothills/Mountains)

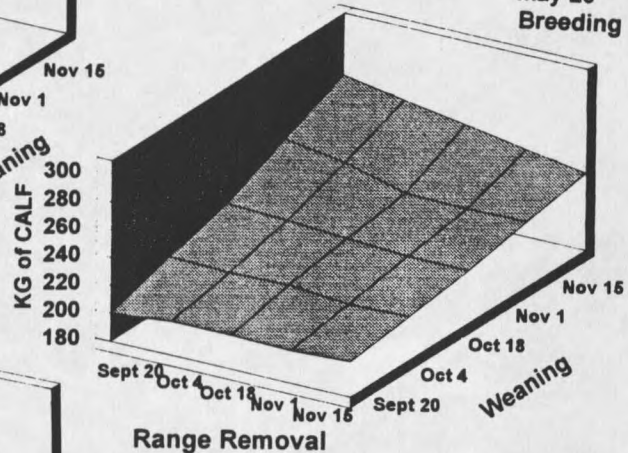
April 22
Breeding



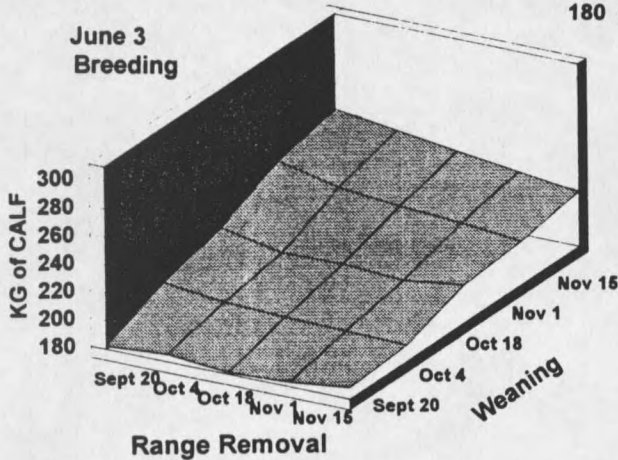
May 6
Breeding



May 20
Breeding



June 3
Breeding



Three-way Interaction
Illustrated by
Breeding Dates

Figure 29. Weaning Weight per Cow Exposed - Three way interaction illustrated by breeding dates (Foothills/Mountains).

(Figure 30). The three-way interaction estimated a herd size of 616 cow for the latest breeding date and 577 cows for the earliest breeding date when range removal and weaning occurred on September 20. Herd size decreased to 434 for the latest BD and 413 for the earliest BD when RR and were November 15. Older calves gain more rapidly than younger calves which resulted in the multiple interaction effect. Older calves also competed for the available range forage decreasing the number of cows which could be maintained on the range.

Break-even Steer Price

Break-even steer price decreased as breeding date was moved earlier into the spring and weaning was extended later into the fall (Figure 31). Larger calves at weaning, influenced by earlier calving and/or later weaning improved ranch efficiency. For all RR, Figure 32 shows that BESP decreased with earlier breeding dates. Later RR decreased BESP until October 18 which was followed by a gradual increase. Mid-season range removal of cattle placed the herd on aftermath grazing and provided the lowest BESP. Aftermath grazing was limited to 194t. Cattle removed early from range were fed expensive stored forages when aftermath grazing ended and later RR often failed to utilize all aftermath available before winter feeding commenced.

For all RR and WD, BESP decreased as WD was extended into the fall (Figure 33). For all RR, BESP decreased until October

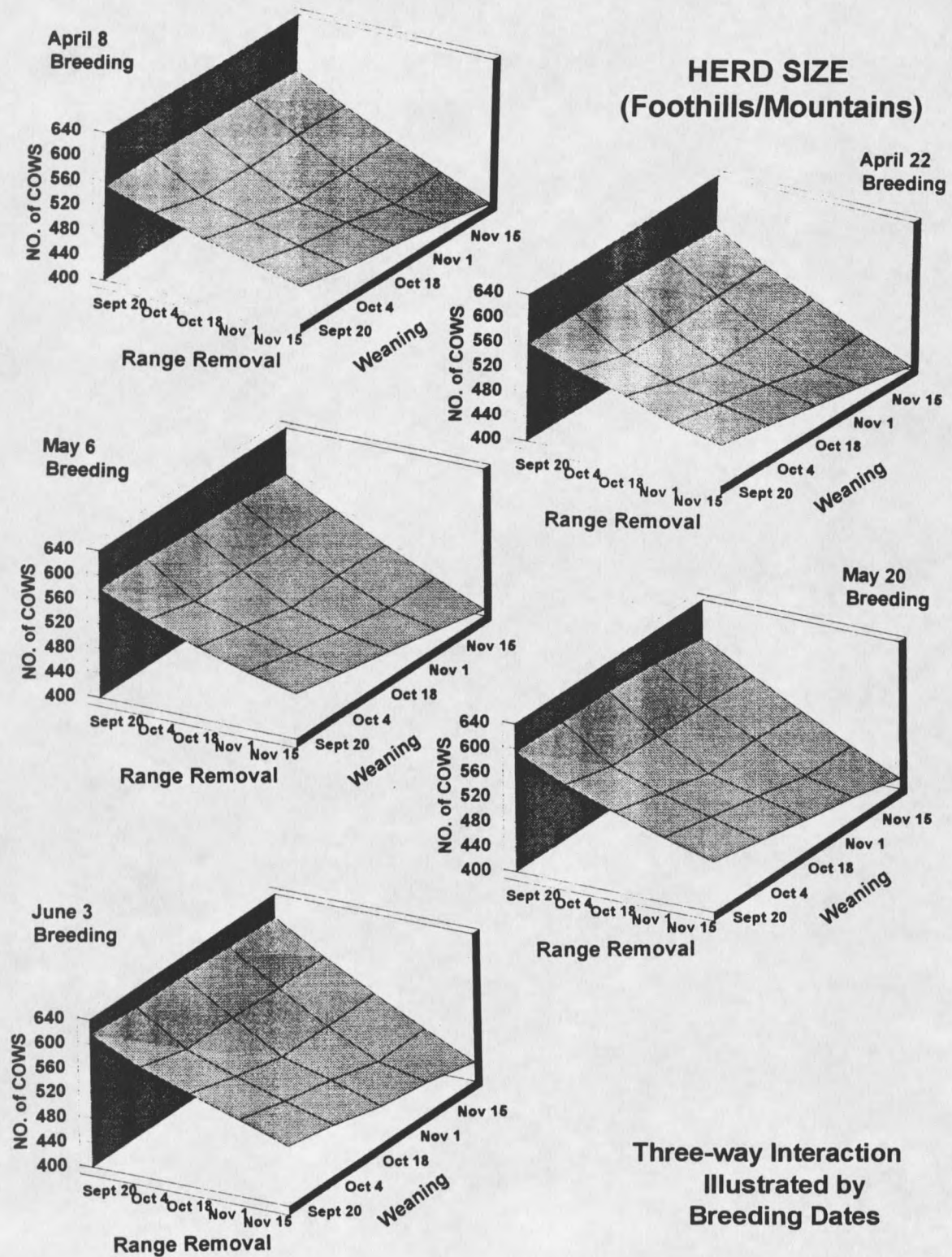


Figure 30. Herd Size - Three way interaction illustrated by breeding date (Foothills/Mountains).

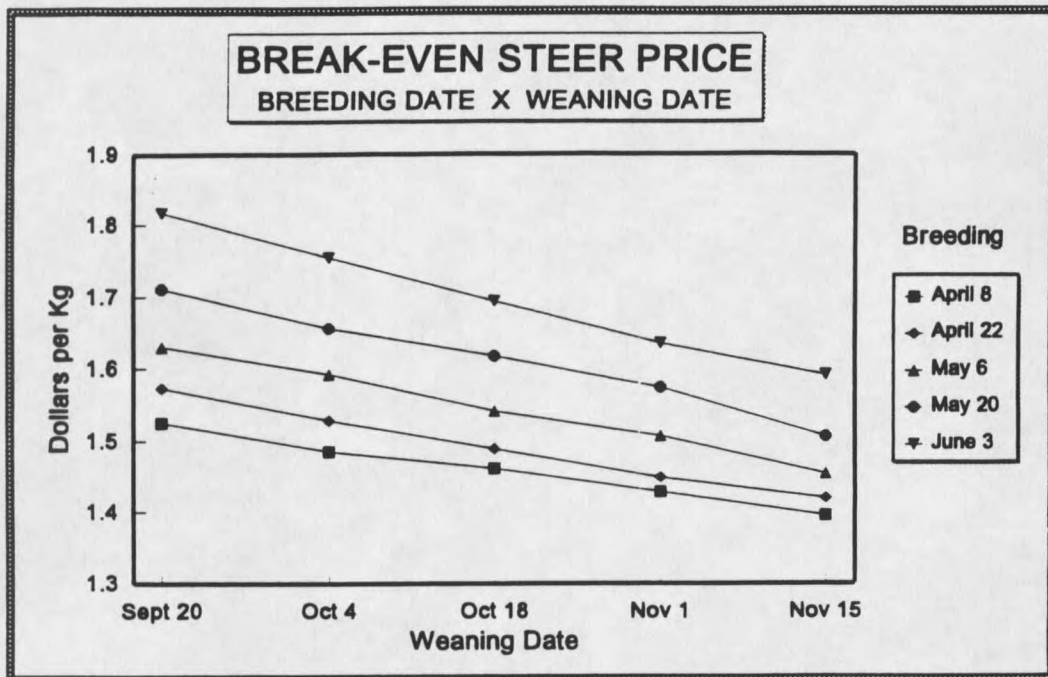


Figure 31. Break-even Steer Price - Breeding date and weaning date interaction (Foothills/Mountains).

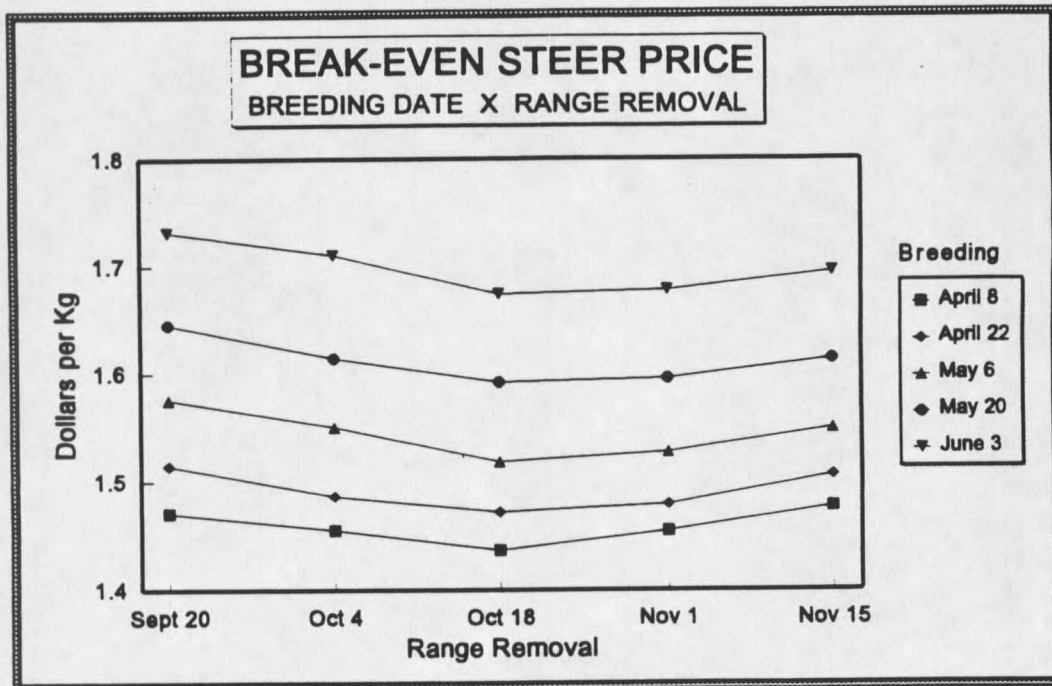


Figure 32. Break-even Steer Price - Breeding date and range removal date interaction (Foothills/Mountains).

18 and then increased slightly until November 15. This pattern was under similar influences as the BD and RR interaction. Mid-season RR provided the optimum efficiency of range, aftermath, and stored forages.

Net Income per Cow Exposed

The interaction between BD and WD showed that net income per cow exposed (NICEX) increased as breeding dates were moved earlier into the spring and weaning dates were extended later into the fall (Figure 34). Earlier breeding and/or later weaning increased calf size and resulted in improved efficiency for NICEX. For all range removal dates, earlier breeding dates provided the greatest NICEX (Figure 35). Range removal increased NICEX when moved from September 20 to October 18, but decreased when moved further into the fall. The greatest estimated NICEX resulted from earliest breeding and mid-season range removal.

Figure 36 illustrates the RR x WD interaction. For all WD, NICEX increased as weaning was extended further into the fall season. Mid-season range removal provided the greatest NICEX. Several factors effected the decline in NICEX as range removal moved to the latest possible dates. Later range removal left some available aftermath forage unused prior to more expensive feeding of stored forage and decreased NICEX. Earlier weaning provided calves with inexpensive and more nutritional aftermath grazing which resulted in increased rate of gains over

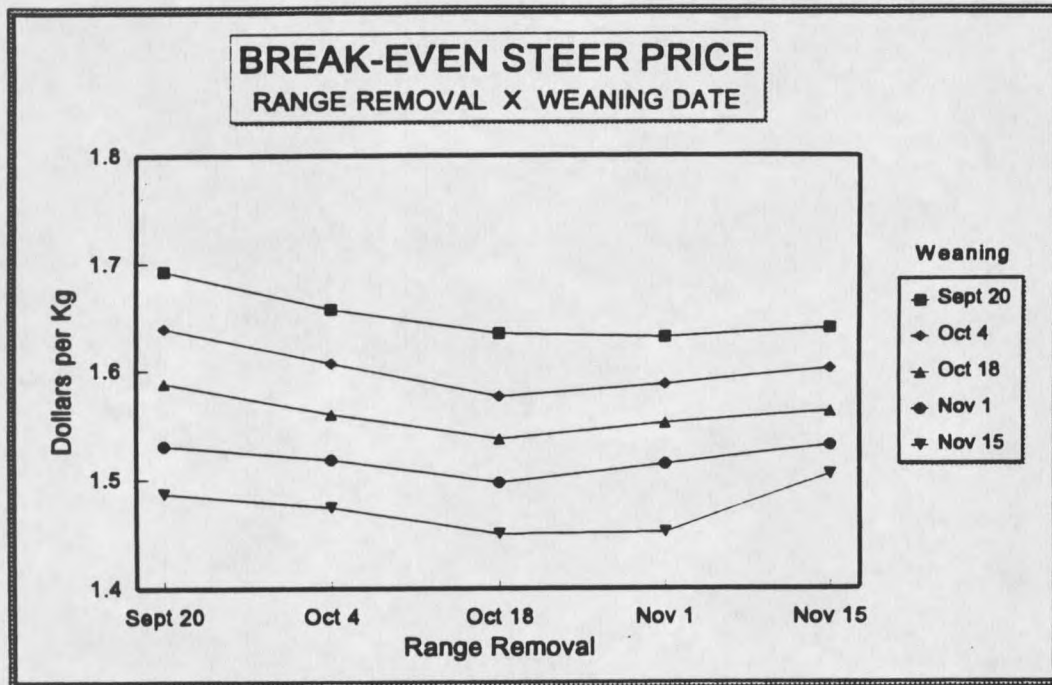


Figure 33. Break-even Steer Price - Range removal date and weaning date interaction (Foothills/Mountains).

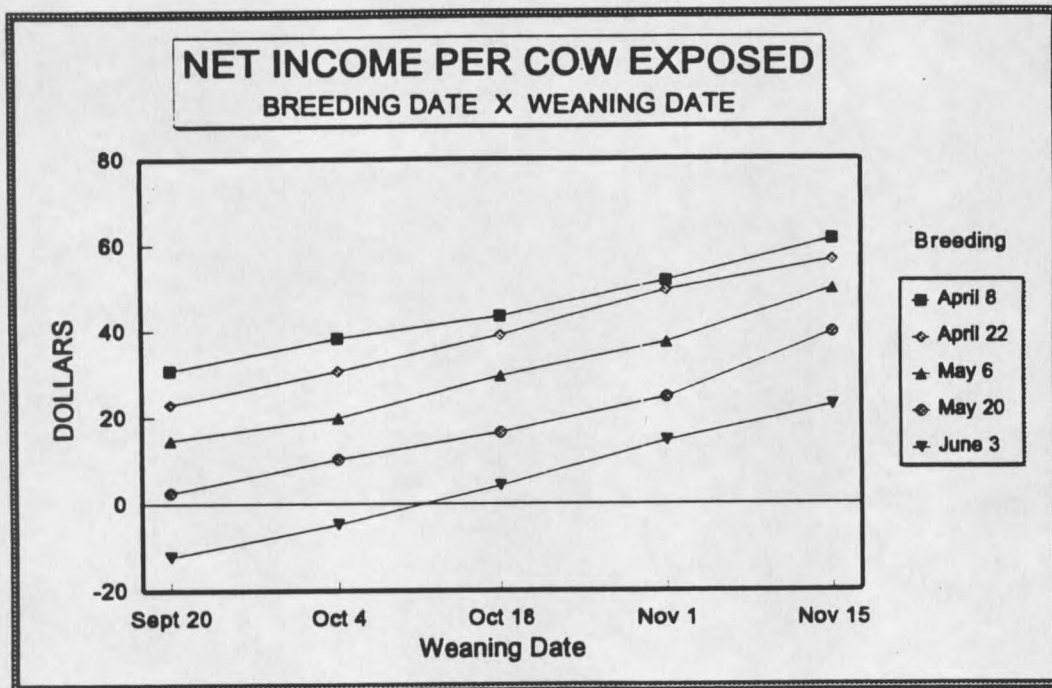


Figure 34. Net Income per Cow Exposed - Breeding date and weaning date interaction (Foothills/Mountains).

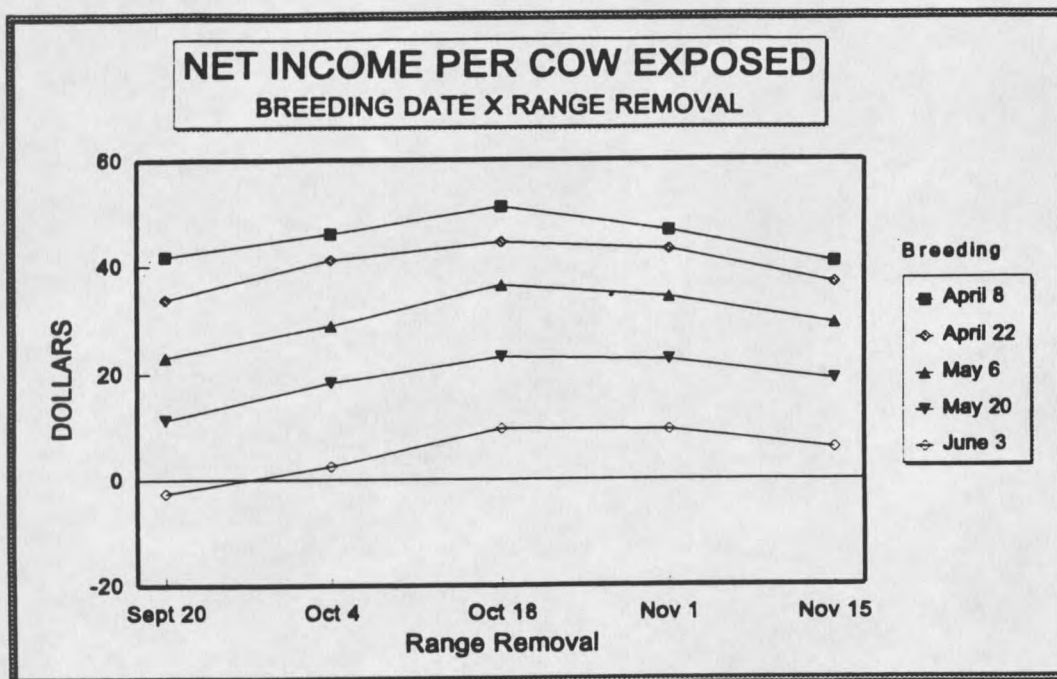


Figure 35. Net Income per Cow Exposed - Breeding date and range removal interaction (Foothills/Mountains).

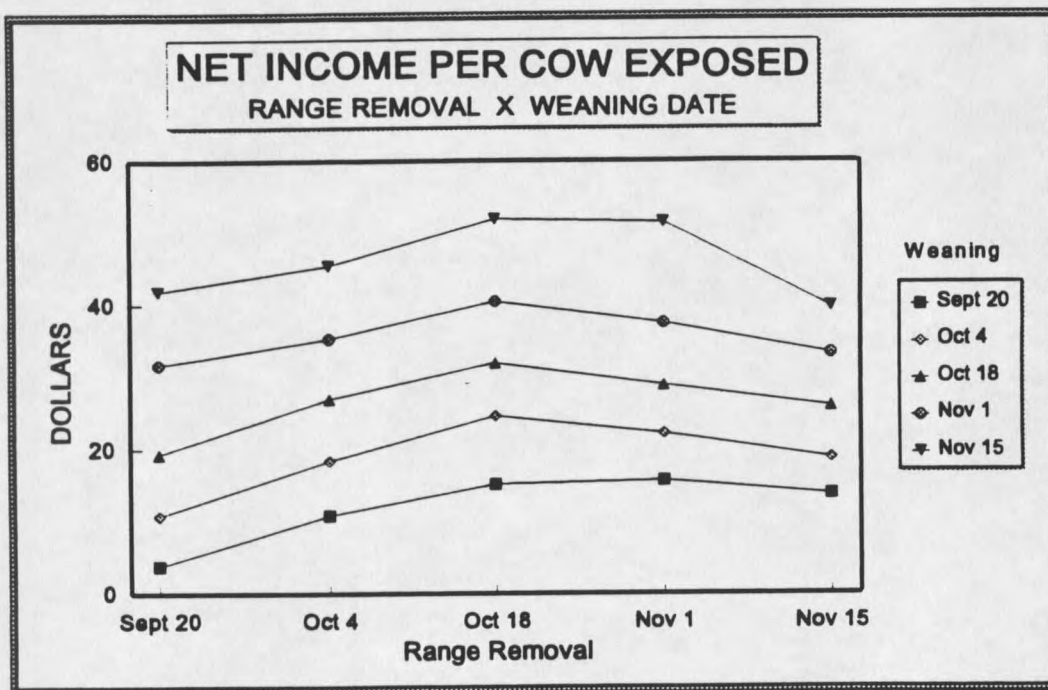


Figure 36. Net Income per Cow Exposed - Range removal date and weaning date interaction (Foothills/Mountains).

calves removed from range later in the fall. Calving interval (CI) of cows was affected declining by range quality and decreased body condition which resulted when weaning calves and range removal were at later dates. Simulated output indicated that older cows remaining on the range with calves until November 15 increased mean CI by 17 days. NICEX decreased as older cows failed to rebreed and were sold.

Ranch Gross Margin

Analyses of RGM resulted in three two-way interactions. Figure 37 indicated that RGM increased as BD was earlier in the spring and WD was moved further into the fall. Older and therefore heavier calves increased RGM. Results indicated that RGM increased (Figure 38) as breeding dates were moved earlier into the spring for all range removal dates. Later breeding dates increased RGM slightly while earlier BD remained fairly constant until the October 18 RR. As RR was extended to November 15 all BD decreased the RGM. Herd size was reduced, CI increased, and aftermath grazing left unused with the latest range removal creating a number of inefficiently used resources. Figure 39 shows the RR and WD interaction for RGM. Ranch Gross Margin increased as WD was moved later into the fall season for all RR. However, later range removal dates followed a similar pattern as the BD x RR interaction as range removal moved later into the fall. Calves weaned later are older, heavier, and when

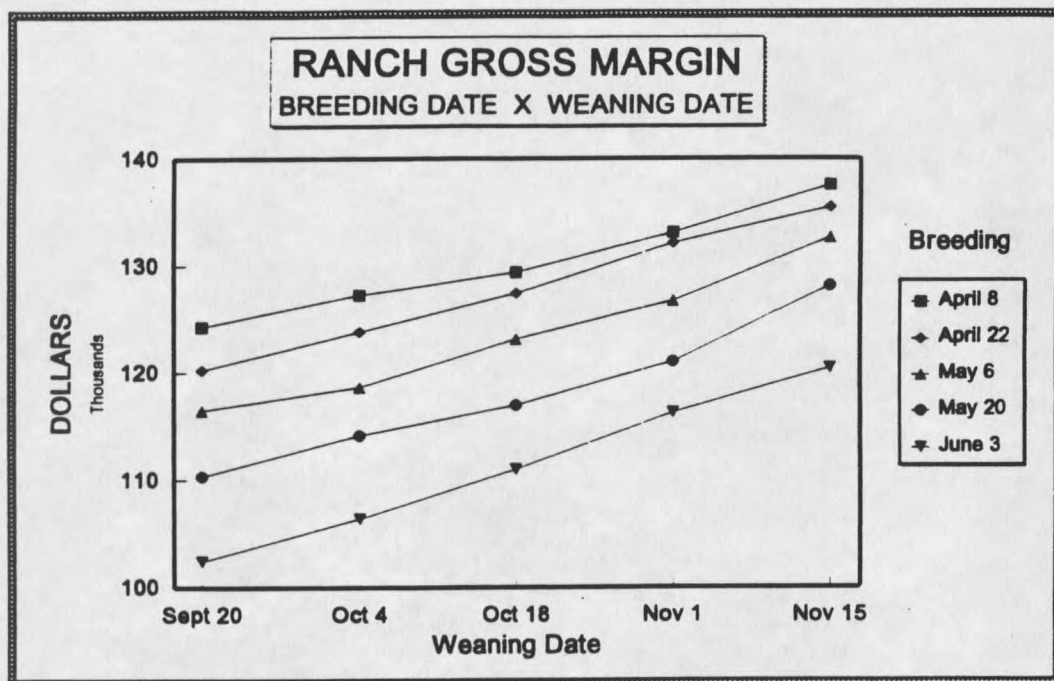


Figure 37. Ranch Gross Margin - Breeding date and weaning date interaction (Foothills/Mountains).

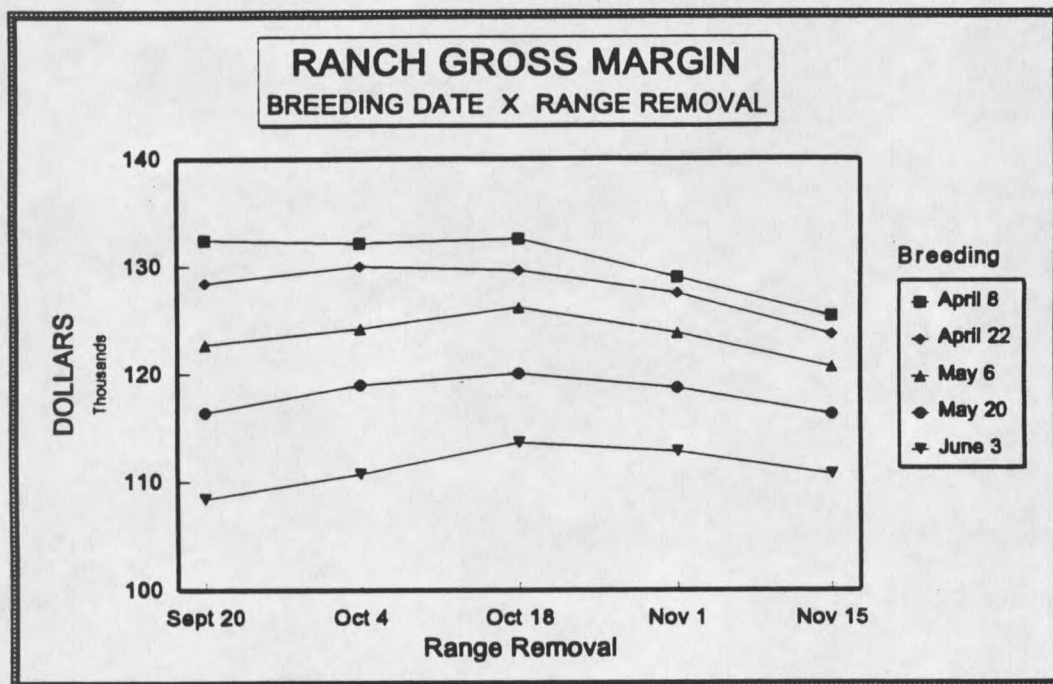


Figure 38. Ranch Gross Margin - Breeding date and range removal interaction (Foothills/Mountains).

removed from range early and placed on aftermath grazing and/or stored forages had increased rate of gain over calves which remained on range. Cows removed from range early onto aftermath grazing with their calves weaned earlier had no problems rebreeding the following mating season, however extending either or both of these options resulted in decreased pregnancy and higher culling rates and decreased RGM.

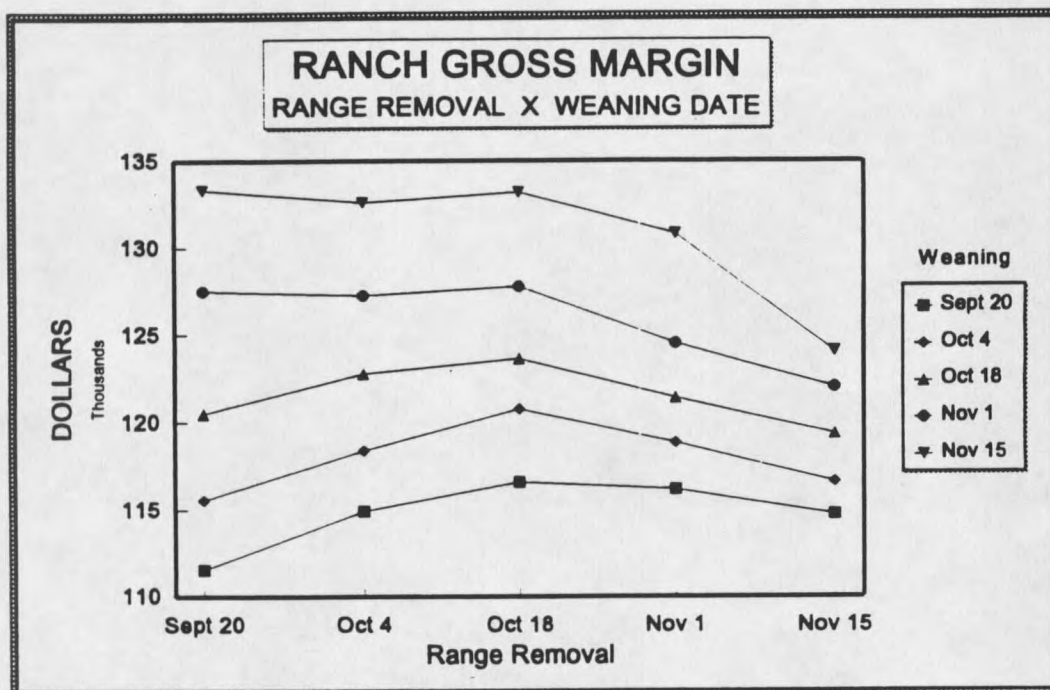


Figure 39. Ranch Gross Margin - Range removal date and weaning date interaction (Foothills/Mountains).

CHAPTER 8

DISCUSSION

Fitzgerald (1989) reported feed costs account for 46% of the production costs of United States beef cow herds. There is considerable potential to increase the efficiency and stability of many Montana ranches by reducing hay costs. However, to develop sustainable fall-winter grazing practices, current practices must be identified before areas of improved efficiency or reduced costs can be considered (Olsen, 1991).

This study and the resulting view of current and potential management decisions, through the use of computer simulation modeling, was designed to aid in ranch sustainability for the foothill/mountain and Northern Great Plains areas of Montana. When a resource such as available grazing land is restricted, potential for improving profits for beef cow/calf production may have to come from changing currently used management practices.

The environment and type of cattle used in the different areas played an important role in the study results. Average precipitation and temperatures for both the foothill/mountain (F/M) and Northern Great Plains (NGP) areas are similar. The

greatest differences are in the topography of the land and the timing of moisture accumulation.

The NGP area is dominated by mixed grass, rolling plains with pine covered breaks to the east leading into the Black Hills region, varying but 300 m in elevation. Moisture falls primarily in the spring rather than the winter months and is accompanied by windy conditions most of the year. This leaves winter range open for grazing where water is available and accounts for its reputation as a 'cake and range' winter grazing area (Olsen, 1991). Accumulations of snow mass are minimal and water for crop irrigation is marginal resulting in a large proportion of dryland farming and range rather than pasture grazing.

The F/M region is primarily broad valleys surrounded by grassy foothills which ascend to pine mountain forest lands. Elevations vary dramatically and repeatedly throughout the area. Major moisture accumulation is during the fall to spring months and winds do not readily blow areas free of snow for winter grazing. Snow trapped in the mountainous areas provide more consistent annual water flow and crop irrigation is prevalent. Stored forages provide most of late fall to mid-spring feed.

Ranch surveys indicate the NGP area ranches produce primarily Hereford and Angus crossbred cows and calves. These British breeds are noted for their hardiness in this

environment. Smaller than exotic European breeds, they produce slower growing calves and cows remain productive while raising calves under more extreme conditions due to lower milk production and smaller frame size. They are a good match for Great Plains grazing where forage quality is seasonal and hay from dryland fields is limited in production (Kress et al., 1986).

Cattle in the F/M area are primarily Black Angus crossed with European exotics. Ranch surveys indicate that Hereford bloodlines are being replaced with Continental breeds such as Simmental and Charolais. This type of crossbred has higher milk production and larger body size than British breeds, producing a growthier, larger framed calf. Mountain and foothill grazing provides these animals with a more consistent quality of nutrition from range which matures at different times during the season as it increases in elevation (Kress et al., 1986). When range grazing concludes in the fall, the higher quality of nutrition provided by aftermath grazing and stored forages allows larger framed calves to continue with high gains and cows to maintain their weight on larger frames.

The majority of costs for a cow/calf herd are incurred in the annual maintenance of the dam. She provides but one calf per year and should be managed to provide the greatest net returns per cow exposed without sacrificing her reproductive capability. Results from both areas indicate older calves

(whether from earlier births and/or later weaning) improve ranch gross margin and the break-even steer price.

Herd size for both areas was reduced with improved ranch efficiency. Older calves compete with their dams for available range forage which decreased the number of cows on range. Results indicate that fewer cows raising heavier calves was more profitable.

Management of the herd during fall grazing differs dramatically between the two regions. For NGP area with smaller, hardier cows ranch gross margin was improved by extending range grazing later into the fall. The fall and winter weather patterns in this area make this a feasible management decision. The foothills/mountain area, however improved steer break-even prices by removing the herd from range mid-season (October 18). Weather patterns in this area often do not allow late fall range grazing due to snow accumulations.

CHAPTER 9

CONCLUSIONS

Results from the Northern Great Plains Region suggest that steer break-even price and ranch gross margin are improved by increasing calf weaning age and extending the range grazing season, even if herd size must be reduced.

Foothill/Mountain Region results estimate that the greatest ranch gross margin and the least break-even steer price result when calves are older and range removal occurs mid-season (October 18).

The model does not include additional costs which may be incurred (i.e., facilities, labor, and veterinary) with early calving in these areas. Decisions to move calving seasons to earlier dates should consider potential health problems, labor needs, and area weather patterns.

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APPENDICES

APPENDIX A
Julian Date Calendar

Day	January	February	March	April	May	June	July	August	September	October	November	December
1	1	32	60	91	121	152	182	213	244	274	305	335
2	2	33	61	92	122	153	183	214	245	275	306	336
3	3	34	62	93	123	154	184	215	246	276	307	337
4	4	35	63	94	124	155	185	216	247	277	308	338
5	5	36	64	95	125	156	186	217	248	278	309	339
6	6	37	65	96	126	157	187	218	249	279	310	340
7	7	38	66	97	127	158	188	219	250	280	311	341
8	8	39	67	98	128	159	189	220	251	281	312	342
9	9	40	68	99	129	160	190	221	252	282	313	343
10	10	41	69	100	130	161	191	222	253	283	314	344
11	11	42	70	101	131	162	192	223	254	284	315	345
12	12	43	71	102	132	163	193	224	255	285	316	346
13	13	44	72	103	133	164	194	225	256	286	317	347
14	14	45	73	104	134	165	195	226	257	287	318	348
15	15	46	74	105	135	166	196	227	258	288	319	349
16	16	47	75	106	136	167	197	228	259	289	320	350
17	17	48	76	107	137	168	198	229	260	290	321	351
18	18	49	77	108	138	169	199	230	261	291	322	352
19	19	50	78	109	139	170	200	231	262	292	323	353
20	20	51	79	110	140	171	201	232	263	293	324	354
21	21	52	80	111	141	172	202	233	264	294	325	355
22	22	53	81	112	142	173	203	234	265	295	326	356
23	23	54	82	113	143	174	204	235	266	296	327	357
24	24	55	83	114	144	175	205	236	267	297	328	358
25	25	56	84	115	145	176	206	237	268	298	329	359
26	26	57	85	116	146	177	207	238	269	299	330	360
27	27	58	86	117	147	178	208	239	270	300	331	361
28	28	59	87	118	148	179	209	240	271	301	332	362
29	29		88	119	149	180	210	241	272	302	333	363
30	30		89	120	150	181	211	242	273	303	334	364
31	31		90		151		212	243		304		365

APPENDIX B

Mean Sample Input For Simulation Run
Northern Great Plains Region

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'Test run for Debbie -MODIFIED TO READ EXTERNAL INITIAL FILE'
' 60 heifers started at weaning
  1,1,12 'NUMGEN,MATSYS,NOPRINT(1=OFF)
-----DATA IS MATERNAL PARAMETERS-----
60,111 'NUM, GENOTY
0, 220.,263...108 'YRAGE, AGE, WT, FATPCT (may be blank if NP
11.5,42.,373...65 'PKMILK, PKDAY, PUBAGE, PREG
-----DATA IS THE NONMATERNAL PARAMETERS-----
1 'NUMBRD
111,36.,1.,420.,527...36,2.1,1.0,1.0, 'GENOT,BWT,BWTADJ,YWT,AWT,AFAT,EFAT,ZFRAC
-----
78.75,72.03,63.71,48.98,43.00,.040,.022, 'STPRC,HFPRC,YR1PRC,YR2PRC,COWPRC,SLIDE
.05,.05,.035,.035,.035 'SHRNK(1-5)
.0176,.0193,.0100,.0100,.0100 'COMMSN(1-5)
1.35,.0112,6.91,15.0,63.,65.,70.,10. 'CHKOFF, TRUCK,HIRED,DYSCST,MIX$,GRS$,A
5.22,8.06,35.21,51.30,51.87,539.39,.10, 'YRCOST(1-6) INTRST
100000., 3060.,214000.,352000.,178000.,1.15 'FIXED,FXAUM,FXMIX,FXGRS,FXALF,SELA
.25, 50, 13, .80, 1.0, 3.0, 'BMILK,PPI,MAXAGE,REPPCT,CAPADJ,MEIMAX
26.,0.0., 0, .04,.1 'CBULL,REPRO,DAYGES,LACT,PDEATH,DYSTAD
307, 365, 14, 0, 0 'IFLAG,JFLAG,SFLAG,KFLAG,PFLAG
1,2,3,4,4,4,4,4,4,4,4,4,4,4,4,4,4 'MCODE(I)
4 'LSTMG
160, 227, 307, 307, 1, 1, 0 'JOIN,BSTOP,WEAN,SELL,NFOR,NSUP,CRPCODE
4, 307, 6.10, 2.10, .4600 , .170, .750, .08574 'ALFALFA HAY
307, 1.60, 3.104, .1983 , .141, .750, .17637 'CUBES 14%
160, 227, 307, 307, 3, 3, 0 'JOIN,BSTOP,WEAN,SELL,NFOR,NSUP,CRPCODE
4, 1, 7.75, 2.10, .4600 , .170, .750, .08574 'ALFALFA HAY
1, 120, 99.0, 1.00, .1000 , .100, .100, .10000 'RANGE
4, 307, 8.17, 2.10, .4600 , .170, .750, .08574 'ALFALFA HAY
1, 1.55, 3.104, .1983 , .141, .750, .17637 'CUBES 14%
120, .00, 3.104, .1983 , .141, .750, .17637 'CUBES 14% OFF
307, 1.70, 3.104, .1983 , .141, .750, .17637 'CUBES 14%
160, 227, 307, 307, 4, 3, 0 'JOIN,BSTOP,WEAN,SELL,NFOR,NSUP,CRPCODE
4, 1, 13.3, 2.10, .4600 , .170, .750, .08574 'ALFALFA HAY
1, 120, 99.0, 1.00, .1000 , .100, .100, .10000 'RANGE
3, 307, 13.6, 2.075, .5433 , .140, .703, .07961 'ALF/GRASS HAY
2, 357, 13.6, 2.037, .5563 , .133, .696, .07709 'ALF/GRASS/STRAW MIX
1, 1.15, 3.104, .1983 , .141, .750, .17637 'CUBES 14%
104, .00, 3.104, .1983 , .141, .750, .17637 'CUBES 14% OFF
345, 1.15, 3.104, .1983 , .141, .750, .17637 'CUBES 14%
160, 227, 307, 307, 5, 3, 0 'JOIN,BSTOP,WEAN,SELL,NFOR,NSUP,CRPCODE
2, 1, 13.6, 2.037, .5563 , .133, .696, .07709 'ALF/GRASS/STRAW MIX
3, 68, 13.6, 2.075, .5433 , .140, .703, .07961 'ALF/GRASS HAY
1, 120, 99.0, 1.000, .1000 , .100, .100, .10000 'RANGE
3, 307, 13.6, 2.075, .5433 , .140, .703, .07961 'ALF/GRASS HAY
2, 357, 13.6, 2.037, .5563 , .133, .696, .07709 'ALF/GRASS/STRAW MIX
1, 1.15, 3.104, .1983 , .141, .750, .17637 'CUBES 14%
104, .00, 3.104, .1983 , .141, .750, .17637 'CUBES 14% OFF
345, 1.15, 3.104, .1983 , .141, .750, .17637 'CUBES 14%
-----
'ENDEND'

```

CODE 333 (0, 0, 0) BREED 160 - 227, WEAN 307, OFF RANGE 307

APPENDIX C

Mean Sample Output From Simulation Run
Northern Great Plains Region

EXECUTION BEGAN 08-13-1997 00:33:28:40
 Input File = runtest4.333
 SAS Output File = c:\output2.333
 Treatment Code = 333
 Rep Number = 4

MSU RANCH SIMULATION PROGRAM
 written by Mike Tess & Brad Kolstad

Title: Test run for Debbie -MODIFIED TO READ EXTERNAL INITIAL FILE

Note: 60 heifers started at weaning

 Parameters Input by User

MATING SYSTEM = PUREBRED/COMPOSITE

INITIAL COWS READ FROM EXTERNAL FILE: TRIAL.IN

Maternal Genotypes = 1

NUM	GENO	YRAGE	AGE	WEIGHT	FATPCT	PKMILK	PKDAY	PUBAGE	PREG
1	111	0	228.	274.5	.177	11.5	42.	373.	.65
2	111	0	228.	274.2	.177	11.5	42.	373.	.65
3	111	0	227.	273.0	.176	11.5	42.	373.	.65
4	111	0	227.	271.5	.175	11.5	42.	373.	.65
5	111	0	227.	271.3	.174	11.5	42.	373.	.65
6	111	0	226.	271.1	.175	11.5	42.	373.	.65
7	111	0	228.	271.0	.174	11.5	42.	373.	.65
8	111	0	225.	270.9	.176	11.5	42.	373.	.65
9	111	0	226.	270.8	.175	11.5	42.	373.	.65
10	111	0	225.	270.5	.175	11.5	42.	373.	.65
11	111	0	224.	270.0	.176	11.5	42.	373.	.65
12	111	0	225.	270.0	.174	11.5	42.	373.	.65
13	111	0	224.	269.7	.176	11.5	42.	373.	.65
14	111	0	225.	269.5	.173	11.5	42.	373.	.65
15	111	0	224.	269.3	.175	11.5	42.	373.	.65
16	111	0	224.	269.0	.174	11.5	42.	373.	.65
17	111	0	224.	268.8	.174	11.5	42.	373.	.65
18	111	0	225.	268.6	.173	11.5	42.	373.	.65
19	111	0	224.	268.1	.172	11.5	42.	373.	.65
20	111	0	226.	268.0	.172	11.5	42.	373.	.65
21	111	0	223.	268.0	.174	11.5	42.	373.	.65
22	111	0	224.	267.9	.173	11.5	42.	373.	.65
23	111	0	223.	267.7	.173	11.5	42.	373.	.65
24	111	0	223.	267.7	.173	11.5	42.	373.	.65
25	111	0	223.	267.7	.173	11.5	42.	373.	.65
26	111	0	224.	267.4	.172	11.5	42.	373.	.65
27	111	0	222.	266.6	.173	11.5	42.	373.	.65
28	111	0	225.	266.5	.169	11.5	42.	373.	.65
29	111	0	225.	266.2	.169	11.5	42.	373.	.65
30	111	0	223.	266.0	.171	11.5	42.	373.	.65
31	111	0	221.	264.6	.171	11.5	42.	373.	.65
32	111	0	224.	264.6	.168	11.5	42.	373.	.65
33	111	0	220.	264.5	.173	11.5	42.	373.	.65
34	111	0	220.	264.4	.172	11.5	42.	373.	.65
35	111	0	223.	264.2	.169	11.5	42.	373.	.65
36	111	0	223.	264.0	.170	11.5	42.	373.	.65
37	111	0	223.	263.9	.169	11.5	42.	373.	.65

38	111	0	221.	263.8	.170	11.5	42.	373.	.65
39	111	0	219.	263.2	.172	11.5	42.	373.	.65
40	111	0	219.	263.2	.172	11.5	42.	373.	.65
41	111	0	222.	262.9	.169	11.5	42.	373.	.65
42	111	0	219.	262.8	.171	11.5	42.	373.	.65
43	111	0	219.	262.7	.171	11.5	42.	373.	.65
44	111	0	222.	262.7	.168	11.5	42.	373.	.65
45	111	0	219.	262.1	.170	11.5	42.	373.	.65
46	111	0	221.	262.0	.169	11.5	42.	373.	.65
47	111	0	217.	261.6	.173	11.5	42.	373.	.65
48	111	0	217.	260.8	.171	11.5	42.	373.	.65
49	111	0	217.	260.4	.170	11.5	42.	373.	.65
50	111	0	216.	259.7	.171	11.5	42.	373.	.65
51	111	0	220.	259.5	.165	11.5	42.	373.	.65
52	111	0	225.	259.1	.160	11.5	42.	373.	.65
53	111	0	216.	259.1	.169	11.5	42.	373.	.65
54	111	0	219.	258.7	.165	11.5	42.	373.	.65
55	111	0	216.	258.3	.168	11.5	42.	373.	.65
56	111	0	218.	257.8	.165	11.5	42.	373.	.65
57	111	0	216.	257.8	.168	11.5	42.	373.	.65
58	111	0	216.	257.7	.168	11.5	42.	373.	.65
59	111	0	218.	257.5	.166	11.5	42.	373.	.65
60	111	0	215.	257.0	.168	11.5	42.	373.	.65

Replacement Heifers Input

NUM	AGE	WT	FAT%
60.	222.	265.4	.171

Non-maternal Genotypes = 1

GENO	BWT	BWTADJ	YWT	AWT	AFAT	EFAT	ZFRACT	MEMADJ
111	36.0	1.00	420.0	527.0	.36	2.10	1.000	1.000

PRICE1	PRICE2	PRICE3	PRICE4	PRICE5	SLIDE1	SLIDE2	
78.75	72.03	63.71	48.98	43.00	0.0400	0.0220	
SHRINK1	SHRINK2	SHRINK3	SHRINK4	SHRINK5			
0.050	0.050	0.035	0.035	0.035			
COMMSN1	COMMSN2	COMMSN3	COMMSN4	COMMSN5			
0.018	0.019	0.010	0.010	0.010			
CHKOFF	TRUCK	HIRED	DYSCST	MIX\$	GRS\$	ALF\$	AUM\$
1.35	0.01120	6.91	15.00	63.00	65.00	70.00	10.00
YRCOST1	YRCOST2	YRCOST3	YRCOST4	YRCOST5	YRCOST6	INTRST	
5.22	8.06	35.21	51.30	51.87	539.39	0.10	
FIXED	FXAUM	FXMIX	FXGRS	FXALF	SELADJ		
100000.	3060.	214000.	352000.	178000.	1.150		
REPPCT	BMILK	PPI	MAXAGE	CBULL	REPRO	DYSTAD	
0.80	.2500	50	13	26.	0	0.100	
DAYGES	LACT	PDEATH	CAPADJ	MEIMAX			
0.	0	0.0400	1.00	3.00			
IFLAG	JFLAG	SFLAG	KFLAG	FFLAG			
307	365	14	0	0			

CALVES WEANED									
AGE	STR	AVGWT	RPL	TOT-HF	AVGWT	TOT-CV	AVGWT	AVERAGE	CWT
0	0	0.0	0	0	0.0	0	0.0	0.0	0.0
1	0	0.0	0	0	0.0	0	0.0	0.0	0.0
2	25	233.7	0	27	219.9	52	226.6	208.6	11782.2
3	21	237.0	0	22	224.8	43	230.8	207.3	9924.1
4	20	252.7	0	19	245.6	39	249.2	212.7	9720.0
5	14	263.9	0	21	248.8	35	254.8	211.5	8919.3
6	20	263.1	0	14	260.5	34	262.1	212.3	8910.0
7	15	263.7	0	13	244.5	28	254.8	206.4	7133.8
8	12	262.1	0	12	251.0	24	256.5	207.9	6156.8
9	10	254.1	0	11	247.5	21	250.6	203.3	5263.3
10	11	266.8	0	7	255.6	18	262.4	212.8	4723.5
11	5	278.3	0	11	255.2	16	262.4	216.0	4198.4
12	5	259.5	0	9	250.3	14	253.6	210.1	3549.8
13	9	263.5	60	4	260.0	13	262.4	213.9	3411.5

YR	AGE	#COWS	DEAD	SOLD	#DYST	BR-WT	BR-FAT	WN-WT	WN-FAT
2	1	55	0	5	0	471.8	0.182	534.0	0.199
3	2	46	0	14	12	597.4	0.277	583.2	0.256
4	3	41	1	18	2	583.4	0.266	565.7	0.236
5	4	37	1	22	0	559.8	0.245	536.5	0.217
6	5	35	1	24	0	547.7	0.225	517.0	0.202
7	6	31	2	27	0	539.9	0.206	508.7	0.186
8	7	25	2	33	1	544.9	0.208	512.0	0.191
9	8	22	2	36	0	539.6	0.201	504.8	0.183
10	9	20	2	38	0	543.9	0.205	504.0	0.187
11	10	17	3	40	0	539.1	0.197	513.8	0.180
12	11	15	3	42	0	540.0	0.200	518.1	0.184
13	12	13	3	44	0	543.5	0.207	512.9	0.186
14	13	0	3	57	1	542.3	0.205	515.9	0.186

CLVS BORN		CLVS WEANED	M1	M2	T1	M4	T2
354		337	337	0	0	0	0
CEXP	TCEXP	WT-WN/CEXP	C-WN/CEXP	STRWT	HEFWT	CWT	
401	414	208.71	0.840	254.3	242.5	248.3	
NREP	REPAGE	REPWT	REFAT				
60.	223.	265.3	.170				
PFEED		ONFEED	LABOR	FOR\$		ADJFOR\$	
12641.54		35962.97	3003.78	82801.13		269.34	

TOTDM	TOTME	TOTCP	TOTMLK
1776795.0	4264874.5	242846.7	487345.0

Biological Inputs

Output	DM	ME	CP
Calf Weight	26.2155	62.9255	3.5831
Yr. Heifer Wei	665.0599	1596.3557	90.8983
2 Yr. Weight	330.4910	793.2837	45.1705
3+ Yr. Weight	76.1487	182.7811	10.4078
Total Cow Weig	56.6199	135.9059	7.7386
Total weight	17.9189	43.0111	2.4491
Steer wt. equi	22.4446	53.8743	3.0677

	FEED	NONFEED	CASH	
	95442.66	38966.75	134409.41	
	MIXED HAY	GRASS HAY	ALFALFA HAY	RANGE
kg	210542.91	346729.66	173896.06	1077083.50
AUM	584.84	963.14	483.04	2991.90

Cash Inputs, \$

Output	FEED	NONFEED	CASH	\$/lb
Calf Weight	1.4082	0.5749	1.9831	
Yr. Heifer Wei	35.7245	14.5854	50.3099	
2 Yr. Weight	17.7527	7.2480	25.0007	
3+ Yr. Weight	4.0904	1.6700	5.7604	
Total Cow Weig	3.0414	1.2417	4.2831	
Total weight	0.9625	0.3930	1.3555	
Steer wt. equi	1.2056	0.4922	1.6979	0.7718

	STEER	HEIFER	YRLNG	2-YR	3&>-YR	TOTAL
PRICE	1.71	1.59	1.40	1.08	0.95	
WEIGHT	42468.52	25308.01	2671.63	5376.23	23333.23	99157.61
DOLLARS	67849.99	37404.74	3584.90	5546.11	21131.76	135517.52

NET INCOME = 1108.11
NET INCOME/EXP = 2.76
NET INCOME/TEXP = 2.68

ADJUST = 1.0228

Adjusted Cash Inputs

Output	FEED	NONFEED	CASH
Steer wt. equi	0.1630	0.4543	0.6173
HAY PURCHASED	kg		\$
MIXED HAY	1335.27		92.73
GRASS HAY	2621.91		187.86
ALFALFA HAY	-145.72		-11.24

ADJUSTED NET INCOME = 1133.33
RANCH GROSS MARGIN = 88621.97
RANCH NET INCOME = -11378.03

AGE IN YEARS = 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
 MGT GROUP = 1 2 3 4 4 4 4 4 4 4 4 4 4 4 4

MGT GROUP	START BRDNG	STOP BRDNG	WEAN DATE	SELL DATE	NO. FOR.	NO. SUP.	CREEP CODE
1	160	227	307	307	1	1	0
2	160	227	307	307	3	3	0
3	160	227	307	307	4	3	0
4	160	227	307	307	5	3	0

MANAGEMENT GROUP NO. 1

FORAGES

CODE	BEGIN	LIMIT	ME/DM	NDF/DM	CP/DM	RDP/CP	\$/DM	CONSUMED
4	307	6.1	2.10	.4600	.1700	.7500	0.09	21593.23

SUPPLEMENTS

1	307	1.6	3.10	.1983	.1410	.7500	0.18	5664.20
---	-----	-----	------	-------	-------	-------	------	---------

MANAGEMENT GROUP NO. 2

FORAGES

CODE	BEGIN	LIMIT	ME/DM	NDF/DM	CP/DM	RDP/CP	\$/DM	CONSUMED
4	1	7.8	2.10	.4600	.1700	.7500	0.09	55328.95
1	120	99.0	1.00	.1000	.1000	.1000	0.10	100846.02
4	307	8.2	2.10	.4600	.1700	.7500	0.09	26511.42

SUPPLEMENTS

1	1	1.5	3.10	.1983	.1410	.7500	0.18	11066.21
2	120	0.0	3.10	.1983	.1410	.7500	0.18	0.00
3	307	1.7	3.10	.1983	.1410	.7500	0.18	5516.58

MANAGEMENT GROUP NO. 3

FORAGES

CODE	BEGIN	LIMIT	ME/DM	NDF/DM	CP/DM	RDP/CP	\$/DM	CONSUMED
4	1	13.3	2.10	.4600	.1700	.7500	0.09	70462.45
1	120	99.0	1.00	.1000	.1000	.1000	0.10	133997.00
3	307	13.6	2.08	.5433	.1400	.7030	0.08	21548.76
2	357	13.6	2.04	.5563	.1330	.6960	0.08	3607.27

SUPPLEMENTS

1	1	1.1	3.10	.1983	.1410	.7500	0.18	6514.40
2	104	0.0	3.10	.1983	.1410	.7500	0.18	0.00
3	345	1.1	3.10	.1983	.1410	.7500	0.18	1110.91

MANAGEMENT GROUP NO. 4

FORAGES

CODE	BEGIN	LIMIT	ME/DM	NDF/DM	CP/DM	RDP/CP	\$/DM	CONSUMED
2	1	13.6	2.04	.5563	.1330	.6960	0.08	185330.47
3	68	13.6	2.08	.5433	.1400	.7030	0.08	154071.64
1	120	99.0	1.00	.1000	.1000	.1000	0.10	782051.19
3	307	13.6	2.08	.5433	.1400	.7030	0.08	128116.93
2	357	13.6	2.04	.5563	.1330	.6960	0.08	21605.18

SUPPLEMENTS

1	1	1.1	3.10	.1983	.1410	.7500	0.18	35637.64
2	104	0.0	3.10	.1983	.1410	.7500	0.18	0.00
3	345	1.1	3.10	.1983	.1410	.7500	0.18	6166.32

 EXECUTION ENDED 08-13-1997 00:38:15:94

APPENDIX D

Mean Sample Input For Simulation Run
Foothill / Mountain Region

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'Test run for Debbie -MODIFIED TO READ EXTERNAL INITIAL FILE'
' 66 heifers started at weaning
  1,1,12 'NUMGEN,MATSYS,NOPRINT(1=OFF)
-----DATA IS MATERNAL PARAMETERS-----
66,111 'NUM, GENOTY
0, 232.,285.,.108 'YRAGE, AGE, WT, FATPCT (may be blank if NP
12.6,42.,373.,.70 'PKMILK, PKDAY, PUBAGE, PREG
-----DATA IS THE NONMATERNAL PARAMENTERS-----
1 'NUMBRD
111,36.,1.,435.,567.,.36,2.1,1.0,1.0, 'GENOT,BWT,BWTADJ,YWT,AWT,AFAT,EFAT,ZPRAC
-----
78.56,71.74,63.56,48.86,42.89,.042,.029, 'STPRC,HFPRC,YR1PRC,YR2PRC,COWPRC,SLIDE
.05,.05,.035,.035,.035 'SHRNK(1-5)
.0225,.0225,.0225,.0225,.0225 'COMMSN(1-5)
1.35,.0099,12.31,15.0,61.,65.,70.,10. 'CHKOFF, TRUCK,HIRED,DYSCST,MIX$,GRSS$,
6.03,8.12,33.06,48.47,49.04,554.38,.10, 'YRCOST(1-6) INTRST
000000., 3640.,291000.,385000.,242000.,1.15 'FIXED,FXAUM,FXMIX,FXGRS,FXALF,SELA
.25, 50, 13, .87, 1.0, 3.0, 'BMILK,PPI,MAXAGE,REPPCT,CAPADJ,MEIMAX
25.,0.0., 0 ,.03,.1 'CBULL,REPRO,DYGES,LACT,PDEATH,DYSTAD
291, 365, 14, 0, 0 'IFLAG,JFLAG,SFLAG,KFLAG,FFLAG
1,2,3,4,4,4,4,4,4,4,4,4,4,4,4,4 'MCODE(I)
4 'LSTMGT
126, 181, 291, 291, 1, 1, 0 'JOIN,BSTOP,WEAN,SELL,NFOR,NSUP,CRPCODE
4, 291, 7.00, 2.17, .4000 , .180, .750, .08574 'ALFALFA HAY
291, 0.80, 3.104, .1983 , .141, .750, .17637 'CUBES 14%
126, 181, 291, 291, 3, 3, 0 'JOIN,BSTOP,WEAN,SELL,NFOR,NSUP,CRPCODE
4, 1, 9.00, 2.17, .4000 , .180, .750, .08574 'ALFALFA HAY
1, 122, 99.0, 1.00, .1000 , .100, .100, .10000 'RANGE
4, 291, 10.5, 2.17, .4000 , .180, .750, .08574 'ALFALFA HAY
1, .80, 3.104, .1983 , .141, .750, .17637 'CUBES 14%
122, .00, 3.104, .1983 , .141, .750, .17637 'CUBES 14% OFF
319, .62, 3.104, .1983 , .141, .750, .17637 'CUBES 14%
136, 196, 291, 291, 4, 3, 0 'JOIN,BSTOP,WEAN,SELL,NFOR,NSUP,CRPCODE
4, 1, 12.0, 2.17, .4000 , .180, .750, .08574 'ALFALFA HAY
1, 122, 99.0, 1.00, .1000 , .100, .100, .10000 'RANGE
5, 291, 99.0, 2.000, .5200 , .120, .727, .02778 'AFTERMATH GRAZING
2, 339, 12.2, 2.100, .5112 , .151, .727, .07498 'ALF/GRASS/STRAW MIX
1, .00, 3.104, .1983 , .141, .750, .17637 'CUBES 14% OFF
42, .52, 3.104, .1983 , .141, .750, .17637 'CUBES 14% ON
131, .00, 3.104, .1983 , .141, .750, .17637 'CUBES 14% OFF
136, 196, 291, 291, 5, 3, 0 'JOIN,BSTOP,WEAN,SELL,NFOR,NSUP,CRPCODE
2, 1, 12.5, 2.100, .5112 , .151, .727, .07498 'ALF/GRASS/STRAW MIX
3, 46, 13.2, 2.166, .5050 , .160, .743, .07961 'ALF/GRASS HAY
1, 122, 99.0, 1.000, .1000 , .100, .100, .10000 'RANGE
5, 291, 99.0, 2.000, .5200 , .120, .727, .02778 'AFTERMATH GRAZING
2, 339, 12.5, 2.100, .5112 , .151, .727, .07498 'ALF/GRASS/STRAW MIX
1, .00, 3.104, .1983 , .141, .750, .17637 'CUBES 14% OFF
42, .52, 3.104, .1983 , .141, .750, .17637 'CUBES 14% ON
131, .00, 3.104, .1983 , .141, .750, .17637 'CUBES 14% OFF
-----
'ENDEND'

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CODE 333 H-BREED 126 - 181, WEAN 291, OFF RANGE 291 PETRO/FERG
C-BREED 136 - 196

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APPENDIX E

Mean Sample Output From Simulation Run
Foothill / Mountain Region

EXECUTION BEGAN 08-10-1997 01:05:07:50
 Input File = runtesta.333
 SAS Output File = c:\output2.333
 Treatment Code = 333
 Rep Number = 4

MSU RANCH SIMULATION PROGRAM
 written by Mike Tess & Brad Kolstad

Title: Test run for Debbie -MODIFIED TO READ EXTERNAL INITIAL FILE

Note: 66 heifers started at weaning

 Parameters Input by User

MATING SYSTEM = PUREBRED/COMPOSITE

INITIAL COWS READ FROM EXTERNAL FILE: TRIAL.IN

Maternal Genotypes = 1									
NUM	GENO	YRAGE	AGE	WEIGHT	FATPCT	PKMILK	PKDAY	PUBAGE	PREG
1	111	0	236.	293.3	.171	12.6	42.	373.	.70
2	111	0	236.	293.2	.171	12.6	42.	373.	.70
3	111	0	236.	293.0	.171	12.6	42.	373.	.70
4	111	0	236.	292.5	.170	12.6	42.	373.	.70
5	111	0	236.	292.5	.170	12.6	42.	373.	.70
6	111	0	235.	291.9	.171	12.6	42.	373.	.70
7	111	0	236.	291.8	.170	12.6	42.	373.	.70
8	111	0	234.	290.8	.170	12.6	42.	373.	.70
9	111	0	234.	290.6	.170	12.6	42.	373.	.70
10	111	0	234.	290.3	.170	12.6	42.	373.	.70
11	111	0	235.	290.2	.169	12.6	42.	373.	.70
12	111	0	236.	290.0	.169	12.6	42.	373.	.70
13	111	0	233.	289.7	.170	12.6	42.	373.	.70
14	111	0	245.	289.2	.160	12.6	42.	373.	.70
15	111	0	244.	288.4	.161	12.6	42.	373.	.70
16	111	0	232.	288.4	.169	12.6	42.	373.	.70
17	111	0	244.	288.2	.160	12.6	42.	373.	.70
18	111	0	232.	288.1	.169	12.6	42.	373.	.70
19	111	0	232.	287.8	.169	12.6	42.	373.	.70
20	111	0	233.	287.6	.167	12.6	42.	373.	.70
21	111	0	243.	286.5	.159	12.6	42.	373.	.70
22	111	0	233.	286.4	.166	12.6	42.	373.	.70
23	111	0	243.	286.3	.159	12.6	42.	373.	.70
24	111	0	232.	286.3	.167	12.6	42.	373.	.70
25	111	0	231.	286.1	.167	12.6	42.	373.	.70
26	111	0	242.	285.8	.160	12.6	42.	373.	.70
27	111	0	231.	285.6	.167	12.6	42.	373.	.70
28	111	0	232.	285.3	.166	12.6	42.	373.	.70
29	111	0	232.	285.0	.165	12.6	42.	373.	.70
30	111	0	230.	284.4	.166	12.6	42.	373.	.70
31	111	0	241.	283.9	.158	12.6	42.	373.	.70
32	111	0	235.	283.7	.162	12.6	42.	373.	.70
33	111	0	229.	283.6	.166	12.6	42.	373.	.70
34	111	0	228.	282.9	.167	12.6	42.	373.	.70
35	111	0	228.	282.7	.166	12.6	42.	373.	.70
36	111	0	240.	282.7	.157	12.6	42.	373.	.70
37	111	0	228.	282.7	.166	12.6	42.	373.	.70
38	111	0	231.	282.7	.163	12.6	42.	373.	.70

39	111	0	229.	282.6	.164	12.6	42.	373.	.70
40	111	0	230.	282.5	.164	12.6	42.	373.	.70
41	111	0	230.	282.3	.164	12.6	42.	373.	.70
42	111	0	240.	282.3	.157	12.6	42.	373.	.70
43	111	0	239.	281.1	.156	12.6	42.	373.	.70
44	111	0	239.	281.0	.156	12.6	42.	373.	.70
45	111	0	233.	280.8	.161	12.6	42.	373.	.70
46	111	0	227.	280.1	.164	12.6	42.	373.	.70
47	111	0	229.	279.7	.161	12.6	42.	373.	.70
48	111	0	232.	279.7	.160	12.6	42.	373.	.70
49	111	0	232.	279.2	.159	12.6	42.	373.	.70
50	111	0	227.	279.1	.162	12.6	42.	373.	.70
51	111	0	225.	278.8	.164	12.6	42.	373.	.70
52	111	0	226.	278.4	.163	12.6	42.	373.	.70
53	111	0	226.	278.4	.162	12.6	42.	373.	.70
54	111	0	225.	278.2	.163	12.6	42.	373.	.70
55	111	0	224.	277.9	.164	12.6	42.	373.	.70
56	111	0	237.	277.9	.153	12.6	42.	373.	.70
57	111	0	236.	277.6	.156	12.6	42.	373.	.70
58	111	0	227.	277.5	.160	12.6	42.	373.	.70
59	111	0	236.	277.3	.155	12.6	42.	373.	.70
60	111	0	236.	277.2	.155	12.6	42.	373.	.70
61	111	0	224.	277.1	.163	12.6	42.	373.	.70
62	111	0	226.	277.1	.163	12.6	42.	373.	.70
63	111	0	236.	276.9	.153	12.6	42.	373.	.70
64	111	0	225.	276.8	.162	12.6	42.	373.	.70
65	111	0	230.	276.8	.158	12.6	42.	373.	.70
66	111	0	235.	276.4	.155	12.6	42.	373.	.70

Replacement Heifers Input

NUM	AGE	WT	FAT%
66.	233.	284.0	.164

Non-maternal Genotypes = 1

GENO	BWT	BWTADJ	YWT	AWT	AFAT	EFAT	ZFRACT	MEMADJ
111	36.0	1.00	435.0	567.0	.36	2.10	1.000	1.000

PRICE1	PRICE2	PRICE3	PRICE4	PRICE5	SLIDE1	SLIDE2
78.56	71.74	63.56	48.86	42.89	0.0420	0.0290

SHRINK1	SHRINK2	SHRINK3	SHRINK4	SHRINK5
0.050	0.050	0.035	0.035	0.035

COMMSN1	COMMSN2	COMMSN3	COMMSN4	COMMSN5
0.023	0.023	0.023	0.023	0.023

CHKOFF	TRUCK	HIRED	DYSCST	MIX\$	GRS\$	ALF\$	AUM\$
1.35	0.00990	12.31	15.00	61.00	65.00	70.00	10.00

YRCOST1	YRCOST2	YRCOST3	YRCOST4	YRCOST5	YRCOST6	INTRST
6.03	8.12	33.06	48.47	49.04	554.38	0.10

FIXED	FXAUM	FXMIX	FXGRS	FXALF	SELADJ
0.	3640.	291000.	385000.	242000.	1.150

REPPCT	BMILK	PPI	MAXAGE	CBULL	REPRO	DYSTAD
0.87	.2500	50	13	25.	0	0.100

DAYGES	LACT	PDEATH	CAPADJ	MEIMAX
0.	0	0.0300	1.00	3.00

IFLAG	JFLAG	SFLAG	KFLAG	FFLAG
291	365	14	0	0

CALVES WEANED									
AGE	STR	AVGWT	RPL	TOT-HF	AVGWT	TOT-CV	AVGWT	AVERAGE	CWT
0	0	0.0	0	0	0.0	0	0.0	0.0	0.0
1	0	0.0	0	0	0.0	0	0.0	0.0	0.0
2	37	285.0	0	23	269.4	60	279.0	230.8	16741.9
3	29	270.7	0	23	252.8	52	262.8	219.3	13664.9
4	25	276.8	0	19	265.1	44	271.8	220.7	11957.7
5	20	279.3	0	20	270.2	40	274.8	219.5	10990.8
6	19	296.5	0	16	264.3	35	281.8	221.7	9861.8
7	16	287.9	0	14	273.9	30	281.4	221.4	8440.7
8	18	291.2	0	11	272.4	29	284.1	222.2	8238.9
9	13	289.5	0	15	270.1	28	279.1	220.0	7816.0
10	17	292.1	0	9	264.7	26	282.6	221.5	7348.4
11	15	287.9	0	9	268.1	24	280.5	220.5	6732.0
12	7	282.5	0	9	267.5	16	274.1	219.2	4385.0
13	9	281.2	66	5	267.1	14	276.2	218.6	3866.4

YR	AGE	#COWS	DEAD	SOLD	#DYST	BR-WT	BR-FAT	WN-WT	WN-FAT
2	1	63	1	2	0	462.0	0.147	548.1	0.172
3	2	55	1	10	4	599.7	0.221	596.6	0.211
4	3	48	1	17	5	609.4	0.230	598.3	0.212
5	4	40	1	25	1	595.5	0.223	586.8	0.193
6	5	38	1	27	0	577.6	0.202	569.1	0.164
7	6	30	2	34	0	570.6	0.188	565.5	0.157
8	7	29	2	35	0	565.8	0.180	559.8	0.148
9	8	29	2	35	0	562.2	0.174	556.8	0.142
10	9	26	2	38	0	564.8	0.175	559.6	0.147
11	10	25	2	39	0	564.6	0.171	557.9	0.144
12	11	16	2	48	0	567.6	0.175	560.9	0.150
13	12	14	2	50	0	570.1	0.180	562.6	0.153
14	13	0	2	64	1	572.1	0.183	564.0	0.155

CLVS BORN	CLVS WEANED	M1	M2	T1	M4	T2
412	398	398	0	0	0	0

CEXP	TCEXP	WT-WN/CEXP	C-WN/CEXP	STRWT	HEFWT	CWT
464	478	237.16	0.858	284.2	266.5	276.5

NREP	REPAGE	REPWT	REFAT
66.	232.	282.5	.163

PFEED	ONFEED	LABOR	FOR\$	ADJFOR\$
6333.29	40803.12	6178.39	102596.07	296.13

TOTDM	TOTME	TOTCP	TOTMLK
2332266.5	5454609.0	14964295.0	678726.1

Biological Inputs

Output	DM	ME	CP
Calf Weight	25.5165	59.6769	163.7189
Yr. Heifer Wei	2120.0010	4958.1709	13602.3555
2 Yr. Weight	483.1900	1130.0649	3100.2454
3+ Yr. Weight	74.2091	173.5573	476.1408
Total Cow Weig	62.4348	146.0199	400.5943
Total weight	18.1136	42.3634	116.2207
Steer wt. equi	22.5129	52.6522	144.4472

FEED	NONFEED	CASH
108929.36	46981.51	155910.86

	MIXED HAY	GRASS HAY	ALFALFA HAY	RANGE
kg	286796.47	381928.41	252979.84	1311358.50
AUM	796.66	1060.91	702.72	3642.66

Cash Inputs, \$

Output	FEED	NONFEED	CASH	\$/lb
Calf Weight	1.1918	0.5140	1.7058	
Yr. Heifer Wei	99.0154	42.7056	141.7210	
2 Yr. Weight	22.5676	9.7334	32.3010	
3+ Yr. Weight	3.4660	1.4949	4.9608	
Total Cow Weig	2.9160	1.2577	4.1737	
Total weight	0.8460	0.3649	1.2109	
Steer wt. equi	1.0515	0.4535	1.5050	0.6841

	STEER	HEIFER	YRLNG	2-YR	3&>-YR	TOTAL
PRICE	1.68	1.56	1.40	1.08	0.95	
WEIGHT	63941.41	27460.96	1100.13	4826.81	31428.30	128757.61
DOLLARS	99683.12	39845.20	1454.12	4904.42	28031.79	173918.66

NET INCOME = 18007.80
NET INCOME/EXP = 38.81
NET INCOME/TEXP = 37.67

ADJUST = 0.9993

Adjusted Cash Inputs

Output	FEED	NONFEED	CASH
Steer wt. equi	0.0640	0.3939	0.4579

HAY PURCHASED	kg	\$
MIXED HAY	-4413.16	-296.74
GRASS HAY	-3350.75	-240.08
ALFALFA HAY	10794.94	832.95

ADJUSTED NET INCOME = 17994.63
RANCH GROSS MARGIN = 126393.46
RANCH NET INCOME = 126393.46

AGE IN YEARS = 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
 MGT GROUP = 1 2 3 4 4 4 4 4 4 4 4 4 4 4 4 4

MGT GROUP	START BRDNG	STOP BRDNG	WEAN DATE	SELL DATE	NO. FOR.	NO. SUP.	CREEP CODE
1	126	181	291	291	1	1	0
2	126	181	291	291	3	3	0
3	136	196	291	291	4	3	0
4	136	196	291	291	5	3	0

MANAGEMENT GROUP NO. 1

FORAGES

CODE	BEGIN	LIMIT	ME/DM	NDF/DM	CP/DM	RDP/CP	\$/DM	CONSUMED
4	291	7.0	2.17	.4000	.1800	.7500	0.09	34650.00

SUPPLEMENTS

1	291	0.8	3.10	.1983	.1410	.7500	0.18	3960.17
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MANAGEMENT GROUP NO. 2

FORAGES

CODE	BEGIN	LIMIT	ME/DM	NDF/DM	CP/DM	RDP/CP	\$/DM	CONSUMED
4	1	9.0	2.17	.4000	.1800	.7500	0.09	71874.00
1	122	99.0	1.00	.1000	.1000	.1000	0.10	110384.29
4	291	10.5	2.17	.4000	.1800	.7500	0.09	49612.50

SUPPLEMENTS

1	1	0.8	3.10	.1983	.1410	.7500	0.18	6388.42
2	122	0.0	3.10	.1983	.1410	.7500	0.18	0.00
3	319	0.6	3.10	.1983	.1410	.7500	0.18	1835.81

MANAGEMENT GROUP NO. 3

FORAGES

CODE	BEGIN	LIMIT	ME/DM	NDF/DM	CP/DM	RDP/CP	\$/DM	CONSUMED
4	1	12.0	2.17	.4000	.1800	.7500	0.09	96843.34
1	122	99.0	1.00	.1000	.1000	.1000	0.10	171597.20
5	291	99.0	2.00	.5200	.1200	.7270	0.03	29565.83
2	339	12.2	2.10	.5112	.1510	.7270	0.07	16621.82

SUPPLEMENTS

1	1	0.0	3.10	.1983	.1410	.7500	0.18	0.00
2	42	0.5	3.10	.1983	.1410	.7500	0.18	2915.73
3	131	0.0	3.10	.1983	.1410	.7500	0.18	0.00

MANAGEMENT GROUP NO. 4

FORAGES

CODE	BEGIN	LIMIT	ME/DM	NDF/DM	CP/DM	RDP/CP	\$/DM	CONSUMED
2	1	12.5	2.10	.5112	.1510	.7270	0.07	178321.05
3	46	13.2	2.17	.5050	.1600	.7430	0.08	330304.41
1	122	99.0	1.00	.1000	.1000	.1000	0.10	957103.38
5	291	99.0	2.00	.5200	.1200	.7270	0.03	161704.89
2	339	12.5	2.10	.5112	.1510	.7270	0.07	91853.59

SUPPLEMENTS

1	1	0.0	3.10	.1983	.1410	.7500	0.18	0.00
2	42	0.5	3.10	.1983	.1410	.7500	0.18	16152.06
3	131	0.0	3.10	.1983	.1410	.7500	0.18	0.00

EXECUTION ENDED 08-10-1997 01:10:11:35

APPENDIX F

Range Nutrition Simulation Equations

Range Nutrition Simulation Equations

Northern Great Plains Region (Adapted from Adams and Short, 1988).

X = Real Day (Julian Date)

$$CP = 9.6698236 + (.041910675 * X) - [(2.8818876 / 10^{**8}) * (X^{**3})] - (1.2240317 * X^{**1.5})$$

$$ME = 403.2312 + (1.7595961 * X) - (.02866877 * X^{**1.5}) - (40.098856 * X^{**1.5}) - (1480.29 / X^{**1.5})$$

$$NDF = -68.746478 - (.21339908 * X) + (.000094407402 * X^{**2}) + (6.3283031 * X^{**1.5}) + (265.09778 / X^{**1.5})$$

Foothills/Mountains Region (Adapted from Cook and Harris, 1968; Peischell, 1980; Ansotegui, 1986; Holechek, et al., 1987; Adams and Short, 1988.).

X = Real Day (Julian Date)

$$CP = -11.813404 + (7925.2187 / X) - [620431.45 / (X^{**2})]$$

$$ME = -26.479885 + (.080723161 * X) + [-8.5276415 * (X^{**2}) / (100000)] + (4333.996 / X) + [-230099.26 / (X^{**2})]$$

$$NDF = .40688307 + .00078397464 * X$$

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