AN ABSTRACT OF THE THESIS OF

Thomas Lee Nordblom for the Master of Science
(Name) (Degree)

in Agricultural Economics presented on Oct. 18, 1971
(Major) (Date)

Title: ECONOMIC FEASIBILITY OF FALL-CALVING ON OREGON HIGH DESERT COW-CALF OPERATIONS

Abstract approved: ______________________
A. Gene Nelson

The traditional practice on beef cow-calf ranches in the high desert region of Eastern Oregon has been to breed the cows to calve in the Spring months. Interest has been growing recently in the practice of Fall-calving; that is, breeding cows to calve in the months of October and November. The Squaw Butte Experiment Station at Burns, Oregon, began a Fall-calving program with part of their range beef herd several years ago. They found that climatic conditions are generally more favorable for calving in the Fall, resulting in higher weaned-calf percentages. Calves from both Spring and Fall-calving herds were weaned in late Summer, with Fall calves averaging around 500 pounds compared with 330 pounds for the Spring calves.

There was little doubt about the biological feasibility of the Fall-calving practice in that area, but its economic feasibility was somewhat in question. The purpose of this research was to analyze the

economic aspects of Fall-calving and determine what are the most important factors in deciding its economic feasibility.

A linear programming model was developed for comparing Fall and Spring-calving systems under different conditions. The model was designed to maximize net returns to labor, management and fixed resources in the beef enterprise. This model took account of range forage utilization patterns.

Solutions from the model indicated that Spring-calving systems may have slightly higher net returns than Fall-calving because of two main differences: (1) the lighter Spring-born calves bring a higher average price per cwt., and (2) the Fall-calving herd requires about 1500 pounds more Winter hay than cows in the Spring-calving herd. An algebraic relationship was found between calf price differentials and the price of meadow hay, which would equate the net return values for Spring and Fall-calving systems. With an expected differential of $2.95, between the average prices of calves sold from the Spring and Fall-calving herds, it was found that a price as low as $14.12 per ton of meadow hay would be needed to equate the net returns of a Fall-calving system with those of a Spring-calving system (with calf sales on September 1).

Labor costs were not included in the model, but the ranch operator's labor situation may well be the most important element in his decision to go with Fall rather than Spring calving. The main difference is in the times of the year that labor is needed. The Fall-calving system needs more labor in the Fall, and the Spring-calving system needs even more in the Spring.

Economic Feasibility of Fall-Calving on Oregon High Desert Cow-Calf Operations

by

Thomas Lee Nordblom

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

June 1972

APPROVED:

Assistant Professor of Agricultural Economics
in charge of major

Head of Department of Agricultural Economics

Dean of Graduate School

Date thesis is presented Oct. 18, 1971

Typed by Cheryl E. Curb for Thomas Lee Nordblom

ACKNOWLEDGEMENTS

I wish to express my appreciation to the Department of Agricultural Economics for its generous patience with regard to my rate of progress in completing this thesis.

Dr. A. Gene Nelson has earned my sincere respect and personal thanks for the help and advice he has consistently provided over the last two years as my major professor. Dr. John Trierweiler's help and criticism while I put this thesis together was very useful, and much appreciated.

The study described in this thesis would not have been possible without the friendly and generous cooperation provided by the staff of the Squaw Butte Experiment Station: Robert J. Raleigh, Forrest A. Sneva, Harley A. Turner, Larry Foster and Larry Rittenhouse. These men have my real thanks for the help they have given me.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont.)

LIST OF TABLES

LIST OF APPENDIX TABLES

LIST OF APPENDIX TABLES (Cont.)

LIST OF FIGURES

ECONOMIC FEASIBILITY OF FALL-CALVING ON OREGON HIGH DESERT COW-CALF OPERATIONS

I. INTRODUCTION

1. Problem Area and Review of Literature

Technical studies done by personnel at the Squaw Butte Experiment Station in Burns, Oregon, provide evidence that Fall-calving (calves dropped in October and November) is biologically feasible. That is, Fall-calving appears to be not only possible, but a production alternative with several physical-biological advantages over a system of Spring-calving. The practice of calving in the Spring (months of March and April) has traditionally been followed on essentially all beef cow-calf ranches in Eastern Oregon and, as well, in the high desert range areas of Washington and Nevada. It is with the economic side of the Spring vs. Fall-calving issue that this thesis is concerned. The problem dealt with in this study arises from a lack of information regarding the economic feasibility of Fall-calving systems on beef ranches in the high desert region of Eastern Oregon.

The high desert region is generally characterized by warm, dry summers and cold winters. Most of the region receives less than ten inches of annual precipitation, the greater portion of which occurs as snow from November through March. There is also a rainy season which includes most of April, May and June, with May being the wettest month. The amount and distribution of this rainfall is crucial in determining the amount of range forage that will be available for grazing [16, p. 3]. Most ranches in the area depend on native flood meadows for Winter feed, and sagebrush-bunchgrass range for Summer grazing. The vegetation on the native flood meadows consists mainly of rush and sedge, with some water-tolerant grasses and native clover. The sagebrush-bunchgrass range in the area begins growth in late April and reaches maturity by early July [1, p. 4].

The range forage in the high desert region of Oregon tends to mature early in the season, with a steady decline in nutritive value thereafter. In late Summer, the forage quality is so low that milk production of range cows, and the weight gains of their calves, are greatly reduced. In fact, after the middle of August in most years, calves on unsupplemented range forage may stop gaining, or even lose weight [12, p. 81].

The climate is typically cool and dry for Fall-calving in October and November, while for Spring-calving time, in March and April, the climate is often cold, wet and windy. Thus, Fall-born calves are presented with a more favorable environment at birth than the Spring-born calves. A study by the Squaw Butte Experiment Station showed fewer disease problems, and a three percent greater weaned calf-crop with Fall-born calves [12, p. 84].

Lactating Fall-calving cows need some supplementary feed during the Winter, and their calves need some creep fed concentrate at this time. By the time the range forage reaches its highest quality, usually in late May and June, the Fall-born calves are old enough and big enough to utilize it at this peak value. Spring-born calves, on the other hand, are still very young when the range forage is at its highest quality and cannot utilize this feed nearly as well as the Fall-calves. Range forage should be more efficiently converted to beef if consumed directly by a grazing calf rather than through milk from the grazing cow [2, p. 10].

Fall-born calves at the Squaw Butte Experiment Station averaged about 500 pounds when weaned in late July while Spring-born calves averaged only about 330 pounds when weaned in early September. Since the Spring-born calves are so much younger and lighter when the range feed runs out, many ranchers feel that they must carry these calves over the Winter to return to the range the next season. These calves are then sold as long yearlings after their second season on the range. The Fall-born calves, being much heavier at weaning, can be sold immediately as feeder cattle, after only one season on the range.

Because the Fall-calving cows and their calves would normally be wintered in pastures at ranch headquarters, systems of intensive breeding management (such as A. I.) and nutrition practices may be possible [14, p. 1]. While Spring-calving cows are also wintered on these pastures, they are not bred until summer when they are on the range. So, more bulls may be needed for breeding the Spring-calving cows on the wide open range than the Fall-calving cows in the smaller pastures.

Judging from the things mentioned above that there can be little doubt of the biological feasibility of a Fall-calving system on high desert beef ranches with characteristics similar to those at the Squaw Butte Facility. But this biological feasibility alone cannot insure the economic success of Fall-calving compared to Spring-calving.

Economic factors such as calf prices (at different weight levels), feed prices and quantities available, interest rates on livestock capital, hauling charges, grazing fees, labor costs, etc., can each be expected to have some influence on the profitability of a change in calving dates from Spring to Fall.

A study done in Montana [3, p. 18] found the economic feasibility of Fall-calving was directly assumed to be a function of the balance of stored and total feed required, and calf crop percentages. According to that study, Fall-calving is generally not economically feasible when Winter food constrains the enterprise.

A Washington study [7, p. 69] on Fall-calving concluded that lower death losses and better marketing opportunities more than offset the higher Winter feed costs compared to Spring-calving.

The problem faced by this thesis research is one of bringing the biological and economic elements of a decision between Spring and Fall-calving into realistic perspective.

2. Justification of this Research

Because this study is aimed at bringing together, organizing and making economic sense out of the available relevant information on the Fall-calving vs. Spring-calving issue, it may be justified in two ways. First, the study may be viewed as a key to the usefulness of the empirical experiment station work on the subject which has gone before. As an aid to a rancher's decision on whether to shift to Fall-calving, stay with Spring-calving, or adopt some combination of these practices, this study may allow him to more clearly anticipate the consequences of a change. Thus, better able to know what effect his decision will have, a rancher (or someone advising him) can tell how to more efficiently allocate his labor, capital and other resources.

The second way to justify this study is to examine its expected cost-benefit ratio. The relatively small added cost to society for this study will, almost certainly, bring a greater offsetting benefit to Oregon's beef industry, most of which will ultimately accrue to the consumers of beef products. This second justification depends on the first and involves the assumption that resources will be most efficiently allocated if resource managers know what to expect from different production practices.

3. Statement of Objectives

There are three main objectives which this study aspires to attain. The first is to discover and quantify the important factors involved in the economics of the Fall vs. Spring-calving question and assemble these into a linear programming model.

The second objective is to find the conditions necessary for a shift, from Spring to Fall-calving, to make economic sense; in other words, to find the important "shift-feasibility parameters".

The third objective is to examine the various possible management plans which could be used to actually shift the calving dates of a herd, if that were the action called for.

4. Possible Wording of a "Testible" Hypothesis

A study of this type is more involved in description and concept formulation than in any kind of scientific hypothesis testing. If, indeed, this study is capable of testing a hypothesis, it would need to be a fairly weak hypothesis, worded perhaps as follows: "There is no reason to expect Fall-calving to be economically feasible on any Oregon high desert cow-calf ranch where Spring-calving is already profitably being practiced."

The hypothesis stated above may seem to have a very negative tone about it. So, the reader should realize that it is the purpose of this study to try and disprove it rather than prove it.

5. Approach to the Solution

A linear programming model to maximize net returns of various cow-calf operations is developed in Chapter II. Assumptions made in the data development for the model are explained in Chapter III. Chapter IV looks at the details of the linear programming model's solution and separately analyzes various elements in the Spring vs. Fall-calving issue. Chapter V is an attempt at summarizing the important aspects of the research development in this study and deriving some conclusions therefrom.

II. A LINEAR PROGRAMMING MODEL

1. Reason for Using Linear Programming

The reason for using a linear programming model in this study was that it provided a convenient framework for handling the number of biological and economic relationships that were to be considered. The complex relations involved in balancing animal nutritional requirements with available feed sources can be readily handled in a linear program. The method also facilitates the possibility of considering a large number of alternative plans of operation simultaneously, while at the same time tracing through the impacts of, for example, a change in the price of an input such as meadow hay.

Simple enterprise budgets could have been used in place of linear programming in this study. In fact, budgets are used in Chapter IV to illustrate the results from the linear programming model. However, budgeting a large number of possible plans of operation in search of a "best" plan would be a cumbersome and inefficient process if there are many relationships to consider. Even if a large number of possible plans are evaluated through budgets and the "best" of these determined, there would likely be no assurance that this is the best of all possible plans. A linear programming model, on the other hand, considers all possible plans, given the resource input constraints, and determines the optimal (best possible) plan.

2. Objective: Maximum Net Returns

One can determine what is "best" or optimal only by reference to some criteria. The criteria used by the model in this study is "net returns" to labor, management and fixed resource investment in the beef production enterprise. Net returns are maximized by the linear programming method, subject to a number of constraints in the model. No labor costs or constraints were considered in the model since they were not thought to be critical at this stage of the study. Labor costs and considerations are discussed in the conclusions section of this thesis.

3. Structure of the Linear Programming Model

A major part of the model is made up of maximum return feed-ration submodels, with one submodel for each livestock category. Each of these submodels balances the nutrient requirements of one animal of a certain category, say a Fall-calving cow, against the nutritional quality of several feed sources, over several time periods. The feed used by these livestock activities[1] comes from feed purchasing or

---

[1] An "activity" is a unit of a production process in the linear programming model. For example, there are activities in the model for cows, replacement heifers, steer calves, steer calf sales, hay feeding, hay purchasing, barley feeding, and barley purchasing. Each activity has a column in the linear program matrix. Each constraint in the model has a row in the matrix.

range grazing activities. The purchasing activities have negative net returns. For example, one unit (ton) of the barley purchasing activity has a net return value of -$50.

Calf sales activities in the model have positive net return values, while all the livestock raising activities have negative values. There are constraints within the model to insure that the numbers of the various livestock activities come out in specific proportions. For example, one unit of a cow activity must be accompanied by exactly 0.14 replacement heifer activities.

4. Description of Livestock Raising Activities

The purpose of this section is to generally and briefly describe the livestock activities included in the linear programming model. There are livestock activities for both Fall and Spring calving operations. The description of each activity is headed by the activity's code name. The assumption concerning nutrient requirements, animal number relationships, and net returns are explained in detail in Chapter III.

FALCOW - Fall calving cows: This activity includes one Fall-calving brood cow from calving time (Nov. 1) until weaning time (July 30). For the remainder of the year it includes only 86 percent of a cow; the reason being that all cull cows are assumed to be sold at weaning time and not replaced until calving time. Included in the nutritional requirements of this cow activity are those for one cow's fraction (4 percent) of a bull's requirements.

FALGEST - Pregnant replacement heifer, for Fall-calving herd: This activity represents one pregnant heifer that will come into the Fall-calving brood herd at calving time (Nov. 1). The time span of this activity begins on February 1st and ends at calving time. The nutrient requirements involved here are those for a gestating yearling heifer which will be just two years old at calving.

FALREP - Replacement heifer, before breeding for Fall-calving: This activity carries a young replacement heifer from weaning time (July 30) until February 1st. This activity's nutritional requirements are those for a growing Fall-born heifer that will be in breeding condition around mid-January. FALREP is the source of animals for the FALGEST activity. The FALGEST activity, in turn, is the source of replacement animals for the FALCOW activity.

FALCAS - Fall-born steer: This activity represents a Fall-born steer, from birth (Nov. 1) until weaning on July 30. This calf receives food nutrients from several sources: milk, creep-fed concentrates, hay and range forage. The portion of the calf's nutritional needs that is satisfied by the milk received from his dam is not included in the nutrient requirements of this activity.

FALHEF - Fall-born heifer: This activity is essentially the same as the Fall-born steer activity (FALCAS) except that it provides for a heifer instead of a steer. The nutritional requirements and body weights are slightly different for heifers and steers. The FALCOW activity provides a source of animals for both FALCAS and FALHEF activities.

SPRCOW - Spring-calving cow: This activity represents one Spring-calving brood cow from calving (April 1) until weaning on September 1. The rest of the year it only represents 86 percent of a cow. Included in the nutritional requirements of this activity are the requirements of a suckling calf from birth to weaning. Also included is the cow's fraction of a bull's requirements.

SPRGEST - Pregnant replacement heifer, for Spring-calving herd: This activity carries a pregnant Spring-calving replacement heifer from September 1 until calving (April 1). This is a Spring-born animal which has been bred to calve as a two-year-old.

SPRREPL - Young replacement heifer, for Spring-calving herd: This activity represents a Spring-born replacement heifer for a period of one year, from weaning on September 1 until the next September. This animal is bred in mid-June and is the source of animals for the SPRGEST activity. The SPRGEST activity is the source of replacement animals for the SPRCOW activity.

SSP3303 - Spring-born growing steer in September and October: This activity is for a weaned steer gaining two pounds per day from September 1 to November 1.

HSP3302 - Spring-born growing heifer in September and October: This activity is for a weaned heifer gaining 1-1/2 pounds per day from September 1 to November 1. The SPRCOW activity is the source of animals for the HSP3302 as well as the SSP3303 activities.

5. Description of Calf-Sales Activities

This section names and briefly describes the six calf sales activities in the model. The net return values for these activities are explained in Chapter III since they involve a number of assumptions on calf weights, transportation charges, prices, etc. The description of each activity is headed by the activity's code name.

SELLSTR - Fall-born steer sales on August 1: This activity sells one steer provided by the FALCAS activity at weaning time.

SELLHEF - Fall-born heifer sales on August 1: This activity sells a heifer which comes from the FALHEF activity at weaning.

SSSP330 - Spring-born steer sales on September 1:

SHSP330 - Spring-born heifer sales on September 1:

These two activities sell Spring-born calves at weaning. The source of animals for these activities is the SPRCOW activity.

SSNV450 - Spring-born steer sales on November 1: This activity sells steers provided by the SSP3303 activity.

SHNV420 - Spring-born heifer sales on November 1: Heifers provided by the HSP3302 activity are sold by this activity.

6. Description of Feed Purchasing Activities

Five kinds of purchased feeds are considered in the model. The feed purchasing activities described below are the sources of feed for the livestock feeding activities. The description of each of these purchasing activities is preceded by the activity's code name.

MEADOW - Meadow hay purchasing activity: One unit of this activity represents the purchase of a ton of meadow hay. This hay may be grown on the ranch where it is consumed or it may actually be purchased. The hay may be cut and bunched on the ground for the cattle to pick up or it may be cut and stacked for use over the winter months. It is assumed to have the same nutrient values and net return values in either case.

ALFALFA - Alfalfa hay purchasing activity: A unit of this activity stands for a ton of alfalfa hay, either purchased or home grown, supplied to alfalfa feeding activities.

PELALF - Pelleted alfalfa purchasing activity: The pelleted alfalfa from this activity is used in a creep-feed ration for Fall-born calves only. One unit of this activity represents a ton of purchased alfalfa pellets.

COTSEED - Cottonseed meal purchasing activity: One unit of this activity is a ton of cottonseed meal. Along with pelleted alfalfa, it is used only in creep-feed for Fall-born calves. Pelleted alfalfa and cottonseed meal are required directly by the Fall-born calf activities rather than indirectly through feeding activities.

BARLEY - Barley purchasing activity: A unit of this activity is the source of a ton of barley which can be used by the various barley feeding activities.

7. Livestock Feeding Activities

One type of feed, such as meadow hay, may be used by each of the livestock activities. Each of the livestock activities has a meadow hay feeding activity which is a source of meadow hay for that specific livestock category only. This multiplicity of feeding activities is necessary to avoid the absurd situation where one animal category utilizes the energy and another type of animal uses the protein out of the same pound of feed.

The description of each of the feeding activities is headed by the activity's code name. The blanks in the code names indicate the position of time period codes in the names. The time period codes are made up of two letters and the meaning of each of these codes is as follows: JA = January, FB = February, MA = March 1 through April 15, AM = April 16 through May 31, JN = June, JL = July, AG = August, SP = September, OT = October, NV = November, and DC = December. There may be a number of feeding activities for the same feed and the same animal, the only difference being the time periods in which they are available. These feeding activities are all in 100 pound units.

FCMHY_ _Meadow hay feed for Fall-calving cows in the time periods: OT, NV, DC, JA, FB and MA. These six activities provide available nutrients for the FALCOW activity.

FGMHY_ _Meadow hay feed for Fall-calving gestation[2] heifers in the time periods: OT, FB and MA. These three activities make meadow hay nutrients available to the FALGEST activity.

FRMHY_ _Meadow hay feed for replacement heifers in the Fall-calving herd in the time periods: AG, SP, OT, NV, DC, and JA. These six activities provide nutrients for the FALREP activity.

FXMHY_ _Meadow hay feed for Fall-born calves in the time periods: NV, DC, JA, FB, and MA. These five activities make nutrients available to the FALCAS and FALHEF activities.

SCMHY_ _Meadow hay feed for Spring-calving cows in the time periods: NV, DC, JA, FB and MA. These five activities provide nutrients for the SPRCOW activity.

SGMHY_ _Meadow hay feed for Spring-calving gestation heifers in the time periods: OT, NV, DC, JA, FB and MA. These six activities provide nutrients for the SPRGEST activity.

SRMHY_ _Meadow hay feed for replacement heifers in the Spring-calving herd in the time periods: SP, OT, NV, DC, JA, FB and MA.

---

[2] "Gestation" heifers are pregnant replacement heifers.

These seven activities provide nutrients for the SPRREPL activity.

SSMHY_ _Meadow hay feed for Spring-born steer calves in the SP and OT time periods. These two activities provide nutrients for the SSP3303 activity.

SHMHY_ _Meadow hay feed for Spring-born heifer calves in the SP and OT time periods. These activities provide nutrients for the HSP3302 activity.

FCALF_ _Alfalfa hay feed for Fall-calving cow (FALCOW) in the time periods: OT, NV, DC, JA, FB and MA.

FGALF_ _Alfalfa hay feed for Fall-calving gestation heifer (FALGEST) in the time periods: FB, MA and OT.

FRALF_ _Alfalfa hay feed for replacement heifers (FALREP) in the Fall-calving herd in the time periods: AG, SP, OT, NV, DC and JA.

FXALF_ _Alfalfa hay feed for Fall-born calves (FALCAS and FALHFF) in the time periods: NV and DC.

SGALF_ _Alfalfa hay feed for Spring-calving gestation heifers (SPRGEST) in the time periods: SP, OT, NV, DC, JA, FB and MA.

SRALF_ _Alfalfa hay feed for replacement heifers (SPRREPL) in the Spring-calving herd in the time periods: SP, OT, NV, DC, JA, FB and MA.

SSALF_ _Alfalfa hay feed for Spring-born steer calves in the time periods: SP and OT. These two activities provide nutrients for the SSP3303 activity.

SHALF__ Alfalfa hay feed for Spring-born heifer calves in the time periods: SP and OT. These activities provide nutrients for the HSP3302 activity.

FCBAR__ Barley feed for Call-calving cows (FALCOW) in the time periods: OT, NV, DC, JA, FB and MA.

FGBAR__ Barley feed for Fall-calving gestation heifers (FAL-GEST) in the time periods: FB, MA and OT.

FRBAR__ Barley feed for replacement heifers (FALREP) in the Fall-calving herd in the time periods: AG, SP, OT, NV, DC and JA.

SSBAR__ Barley feed for Spring-born steer calves (SSP3303) in the time periods: SP and OT.

SHBAR__ Barley feed for Spring-born heifer calves (HSP3302) in the time periods: SP and OT.

8. Range Forage Activities

Range forage is the only source of feed for several months of the year for both the Spring and Fall calving herds in the model. The grazing season lasts from April 16 until November 1 for Spring-calving cows, and until October 1 for Fall-calving cows. In the course of a grazing season the forage quantity and quality available to livestock varies in a seasonal pattern. The grazing season, for the purpose of this study, was divided into six time periods, whose code names are:

AM, JN, JL, AG, SP and OT (which represent the period of April 16 to May 31, and the months from June through October). In each period the quantity of dry matter "grazeable" from an acre of range is different. The proportions of energy and digestible protein in this forage dry matter change significantly as the season progresses.

The model has six range forage activities, one for each time period in the season. These activities may be thought of as livestock feeding activities which make so many pounds of dry matter available to the various livestock activities in the prescribed time periods. In Chapter III an explanation is given for the method of determining how many pounds of range forage dry matter are required for the different livestock activities in the different time periods. Also, the other assumptions involved in finding the coefficients for the range forage activities are given there. These range forage activities are named here and their code names given.

AMRANGE - Range forage available in the period, April 16 - May 31. This activity provides both old-growth forage and new-growth forage for the various livestock activities (on a per acre basis).

JNRANGE - Range forage available in June.

JLRANGE - Range forage available in July.

AGRANGE - Range forage available in August.

SPRANGE - Range forage available in September.

OTRANGE - Range forage available in October.

The range forage activities from June through October are assumed to provide only new-growth forage. This will be explained in some detail in Chapter III.

One unit of any of the above range forage activities requires one acre of rangeland, and the model is constrained to allow only 10,000 acres of rangeland use.

9. Model Summary

This chapter has named and briefly described each activity in the linear programming model. It has given some explanation of the various relationships between the activities, but no attention has been given to the assumptions behind the quantification of these relationships. That is what Chapter III is about.

A copy of the computer input data for the entire model is given in Appendix A. It shows every activity, constraint and coefficient in the model in a fairly simple format.

III. DATA DEVELOPMENT ASSUMPTIONS

1. Introduction

The purpose of this chapter is to lay out the assumptions made in this study in a manner which makes them easy to understand. The first assumptions discussed are those regarding the type of livestock production inspected in this study. This will give the reader an idea of the limitations on the scope of the study's applicability.

Next, livestock performance and nutrient requirement assumptions are explained. Then follows three sections discussing feed sources. The first of these concerns the decisions on what types and qualities of feeds to consider in the study. The following two sections involve range forage quantity-quality assumptions and range utilization assumptions.

Finally, there is a section on the variable cost assumptions and calculations of the net return values for each activity in the linear programming model.

The reason for explaining all the assumptions of the study in detail is to prevent, or try to prevent, the results of the study from being extrapolated beyond their limits of applicability.

2. Plans of Cattle Production Inspected by This Study

Each cattle ranching operation in the Oregon high desert region has some characteristics unique to itself; no two ranches being quite the same. Different cattle operations have the use of different types of range land under different ownership conditions. Some use only deeded (owned) range land, while others depend on B. L. M. or Forest Service land. The nutritive quality and carrying capacities of these range lands can vary considerably from one location to another. Also, different ranches have different types and qualities of Winter pasture available.

For all the differences in these cattle ranches, the cow calf operations generally have some similar characteristics. Generally, these operations utilize some kind of public range lands for about a six-month grazing season. At the end of the grazing season each year, the cattle are moved to owned Winter pasture where they receive meadow hay which is sometimes supplemented with alfalfa hay or some grain. In the Spring, as soon as the range land can be used (and this varies with the elevation of the range) the cattle are moved back onto this natural food source.

For the purpose of this study it was assumed that the amount of range land available, to a hypothetical ranch operation, is the restricting resource which limits the size of the cow herd. The model was set up to look at two possible cow-calf systems, Fall-calving and Spring-calving. These two systems were designed to operate on the type of rangeland and Winter pasture resources used by the Squaw Butte Experiment Station.

The assumptions used in charging the livestock activities for the feeds they consume are explained later in this chapter. However, it might serve to avoid some confusion to mention here that B. L. M. grazing fee rates have been used to charge the cattle grazing, and that the "purchased" feeds were priced at their expected opportunity costs.

Under both the Spring- and Fall-calving systems it was assumed that the cattle go out on the range on April 15. Calves are assumed to be born on April 1 and weaned on September 1 in the Spring-calving system. These calves may be sold at weaning, or fed for two months and sold on November 1. No allowance was made in the model for considering the alternative of carrying these calves through the Winter for sale in the Spring, or of going back on the range to be sold as long yearlings in the following Fall.

With the Fall-calving system, calves are assumed to be born on November 1 and sold at weaning on August 1. The possibility of carrying these calves to some later selling date was not considered in the model. The Fall-calving cows and "gestation" heifers stay out on the range until the end of September, while Spring-calving cows are assumed to stay out until the end of October. The replacement heifers for the Spring-calving herd are brought in from the range at the end of August. The differences in dates for coming off the range land are due to the differences in animal nutrient requirements in relation to the deteriorating nutritional quality of the range forage as the season advances.

In the model, the quantity of meadow hay from the Winter pasture, or purchaseable from other sources, is assumed to be unlimited. The amount of meadow hay used depends only on its price and nutritional quality with respect to the prices and qualities of the other feeds available.

It has been assumed for the model that the range land is located about 40 miles from the Winter pasture, so that it is necessary to haul the cattle from one place to the other. Calves that are sold at weaning are hauled directly from the range to a market 100 miles away.

3. Livestock Performance Assumptions

The Squaw Butte Experiment Station's figures for calf-crop percentages, death rates, calf weight gains, etc., were used in developing the model. There is little doubt that the experiment station's cow herds have been managed more carefully than the ordinary livestock operation in the area. How, then, can the use of the experiment station's cattle performance figures be justified? First, they are the only published figures available for that geographical area. There is also some expectation that the persons most interested in this study will be the more progressive cattlemen in the area and that they could expect to come up with similar performance figures in their own cattle.

The model assumes no differences in death rates between the Spring and Fall-calving herds, except for birth-to-weaning death losses in the calves. An annual death rate of 1.5 percent is assumed for cows in both herds. The death loss in young replacement heifers is assumed to be rather low, at 0.5 percent, while that for pregnant replacement heifers is slightly higher, at 0.6 percent.

Over a five year period, at the Squaw Butte Experiment Station, both Spring and Fall-calving herds had about 90 percent conception rates, with 60 day breeding seasons[11, p. 11]. However, because fewer disease problems were encountered by the Fall-born calves, the Fall-calving herd had an 85 percent weaned calf crop, compared to 82 percent from the Spring-calving herd. This means a survival rate of 94.4 percent for Fall-born calves and 91.1 percent for Spring-born calves, from birth to weaning. It is assumed in the model that most of the birth-to-weaning death loss in Fall-born calves occurs in the five and a half months before they are put out on the range with their dams.

If the average cow is assumed to produce eight calves in her lifetime it would mean that 12.5 percent of the brood cow herd would need to be replaced each year. Add to this the 1.5 percent death loss assumed for cows and the result is a 14 percent annual replacement rate for brood cows.

The cows in the Spring-calving herd are assumed to gain weight, from April 15 to September 1, at a rate of more than a half pound a day, and to lose weight, from September 1 to April 15, at less than a half pound a day. The Fall-calving cows are assumed to follow a similar weight change pattern, except with lower rates of gain and loss, since they are kept at a relatively more even plane of nutrition throughout the year. Spring-calving cows are producing their most milk just after they are put out on the range on April 15. On this same date a Fall-calving cow would already have been lactating for five and a half months and her milk production would be down to about 15 percent of her peak level back in November.

Spring-born calves are assumed to weigh 330 pounds at weaning on September 1, for an average daily gain of about 1.7 pounds while on the range. Fall-born calves in the model are assumed to perform like the calves at the Squaw Butte Experiment Station, gaining an average of 1.36 pounds per day from birth to the time they go out on range, April 15. On that date, these calves are assumed to average 300 pounds in weight. During the time on range feed, the Fall-born steers gain faster than the heifers, reaching an average of 520 pounds by weaning, compared to 480 pounds with the heifers [13, p. 8].

Replacement heifers for both Spring and Fall-calving herds in the model are assumed to be bred at about 14 months of age, at the same time as the cows are bred. In actual practice, though, heifers would be bred a little earlier than the cows so that more attention could be given to them at calving time. Replacement heifers in both herds are assumed to weigh 950 pounds at calving, compared to about 1100 pounds with the cows.

4. Livestock Nutrient Requirements

The nutritional requirements of an animal are closely related to the animal's performance (i.e., body weight maintenance, stage of pregnancy, level of lactation, rate of gain, etc.). For a given level of performance, in a given type of beef animal, the animal's nutrient needs can be estimated.

Several reference sources were used in this study to estimate the requirements of each class of livestock under the performance levels described above. However, the suggested nutrient requirements from these sources were not strictly adhered to in making the estimates. Instead, they were considered as basic starting points and adjusted to match, as closely as possible, the experience of the personnel at the Squaw Butte Experiment Station.

The nutritional parameters used in this study are in terms of dry matter (D. M.), total digestible nutrients (T. D. N.) and digestible protein (D. P.). The minimum T. D. N. and D. P. amounts, and maximum dry matter consumption, for cattle at the various performance levels were estimated. For each livestock activity in the model there is a table of assumed nutrient requirements in Appendix B. These Appendix tables are in terms of pounds of nutrients per head, per day, in the various time periods of the year.

The livestock nutrient requirements, as they are expressed in the linear program input data, are on a "per time period" and "per activity unit" basis. For example, the requirements listed for the Spring-calving cow activity (SPRCOW) in August are on quite a different basis than the requirements in September. In August, the activity's requirements include those of a lactating cow plus allowances for a 300 pound calf and 4 percent of a bull. In September, the SPRCOW activity has the requirements of only 86 percent of a dry cow, plus the bull allowance.

There is another difference between the nutrient requirement tables in Appendix B and the requirements shown in the linear programming input (in Appendix A). It is that for the periods of the year when an animal is on the range, its requirements are in terms of pounds of range forage dry matter per month rather than in terms of pounds of D. M., T. D. N. and D. P. per day. Except in the earliest months of the range season, most of the livestock in the model have to consume range forage up to their maximum dry matter limits in order to get the nutrients they need for their assumed performance. The range forage dry matter requirements of the livestock activities were calculated by finding the pounds of range forage of a given quality (see Section 6 of this chapter) that would be needed to meet the T. D. N. and D. P. requirements of a given animal in a given time period.

The Fall-born calves in the model are assumed to be creep fed from the first of January until they are turned out on the range. Over this period each calf consumes 100 pounds of a creep ration which consists of 40 pounds of pelleted alfalfa, 40 pounds of rolled barley and 20 pounds of cottonseed meal. Work at the Squaw Butte Experiment Station has shown this to be a satisfactory ration [13, p. 7].

5. Available Feeds

Aside from range forage, the model allows the use of five other feeds; these are: meadow hay, alfalfa hay, barley grain, pelleted alfalfa and cottonseed meal. This is by no means a complete list of the feeds available in the region but it is a group of fairly representative and common feeds.

It was mentioned earlier that the quantity of meadow hay assumed to be available is unlimited and that its price and nutrient quality are the only factors determining how much will be used. A price of $20 per ton was assumed, so the meadow activity has a net return value of -\$20. This price could be considered a reasonable price for purchased meadow hay in the area, or the opportunity cost of a ton of meadow hay grown on the ranch and saleable. Meadow hay in the model was assumed to consist of 90.2 percent dry matter, 48 percent T.D.N. and 4.1 percent digestible protein. Meadow hay is the basic Winter feed for cattle in this model.

Alfalfa hay has been given a net return value of -\$30 per unit (\$30 per ton) which could be considered as a purchase price for hay or its opportunity cost. Alfalfa hay in the model consists of 90.5 percent dry matter, 50.7 percent T.D.N. and 10.9 percent digestible protein. Alfalfa hay is a good source of protein.

Barley, used as an energy supplement feed, was given a cost of \$50 per ton for the purpose of the model. It is assumed to consist of 89.9 percent dry matter, 78.8 percent T.D.N. and 6.9 percent digestible protein.

Pelleted alfalfa, at an assumed cost of \$40 per ton, is used only in the creep ration fed to Fall-born calves. The other feed used only in the creep ration is cottonseed meal, with a price of \$95 per ton. There are no pelleted alfalfa or cottonseed meal feeding activities in the model. Because only the Fall-born calves use these two feeds, the calf activities (FALCAS and FALHEF) are set up to require them in the amounts and proportions necessary for an adequate creep ration.

The pelleted alfalfa is assumed to be of higher nutritional quality than alfalfa hay. For calculation purposes it was assumed to consist of 90.6 percent dry matter, 53.5 percent T.D.N. and 12.5 percent digestible protein.

6. Range Forage Quantity and Quality Assumptions

The model assumes one type of rangeland that allows one pattern of forage quantity and quality variation through a season. It is good quality sagebrush-bunchgrass native range in an average year. In the Oregon High Desert Region, however, there is considerable variation in the quality and characteristics of range lands between different locations. The time of year that range forage matures is closely related to the elevation of the range. The lower elevation ranges mature earlier, generally, than do the higher elevation ranges. In the higher elevations, forage quality may remain good several months after the lower ranges have lost most of their protein value. Yet, the lower ranges are able to support livestock several months sooner than the highest ranges. The range land in this model is assumed to be at the same elevation (about 4,500 feet) as the Squaw Butte Experiment Station's range.

Besides the variation in range forage quantity and quality due to location and elevation, there can be a great deal of variation in forage quantity, on the same range land, from year to year because of differences in rainfall.

Table 1 shows the assumed figures for dry matter availability, T.D.N. and D.P. content, in each time period, for the range forage in the model. These assumed figures were arrived at by reference to a forage quality study [15; p.3] and the practical judgment of the Squaw Butte Experiment Station personnel. The available dry matter figures represent estimates of the pounds per acre of range forage dry matter, consumable by cattle, at about a 50 percent utilization level. That is, only about 50 percent of the forage which could be consumed is assumed to be available to the cattle in the model.

Table 1. Assumed available dry matter, T.D.N. and digestible protein per acre of range forage if consumed in specified time periods.

Time Period	Pounds of Available Dry Matter[1]	T.D.N. as % of D.M.[2]	Digestible Protein as % of D.M.
April 16-May 31			
New Growth	53	68	12
Old Growth	100	40	0
June	120.5	55	7
July	145.5	50	5
August	149.0	48	3
September	147.5	43	2
October	146.0	40	1

[1] This dry matter is on an "air-dry" basis.

[2] T.D.N. percentages here are estimates of "T.D.N. equivalents" to digestible energy.

For the April 16-May 31 time period it was assumed that old growth forage makes up the majority of the available feed on the range with higher quality new growth being present in a smaller amount. Old growth is defined here as range forage left over on the range from the previous year's growing season. Some of this old growth may be regrowth forage from early grazing in the previous year but most of it is out of the 50 percent of the previous year's new growth which wasn't consumed then. This forage is of low nutritional quality but provides an important source of energy for the livestock while the new growth forage is coming up. The reason for considering old and new growth forage separately in this model is that different livestock activities are expected to consume these feeds in different proportions.

7. Range Forage Utilization Assumptions

All the cows in the model are assumed to consume old and new growth forage (in the April 16-May 31 period) in the same proportions that they occur on the range: 100 pounds of old to 53 pounds of new growth dry matter. Fall-calving gestation heifers and Spring-herd replacement heifers are assumed to use these feeds in the ratio of 55 percent old, to 45 percent new. Fall-born calves are assumed to consume equal quantities of old and new growth, while Spring-born calves are too young to eat much of any kind of forage in the first period of the grazing season.

The amount of nutrients taken from the 10,000 acres of range land in the model is assumed to be a function of the time periods in which it is grazed. In other words, if an acre of range is used in one month it would yield different quantities of T.D.N. and digestible protein than if it were used in the next month. For example, an acre used in June gives about 66 pounds of T.D.N. and 8.4 pounds of digestible protein while, if that same acre were used in October instead of June, it would yield only about 58.4 pounds of T.D.N. and 1.5 pounds of digestible protein. The way the model is designed, the entire 10,000 acres of range land could be used up in the month of June alone if there were a profitable livestock that only used range forage in June. However, no such activity is included in the model since cows are assumed to be on the range throughout the season, and if there are no cows there can be no other livestock activities. The Spring-calving herd in the model requires range forage from April 16 through the end of October, and the Fall-calving herd needs range land up to the first of October.

8. Variable Cost Assumptions for Net Return Values of Livestock Activities

Variable costs and incomes are those which occur in direct proportion to the number of units of inputs or outputs. The net return value of an activity is a variable cost (or income). This is in contrast to fixed costs (such as taxes on cattle sheds, or interest on investments in cattle equipment) which are encountered (in the short run) regardless of the number of livestock produced.

The method of determining the net return values for the livestock and livestock sales activities is explained in this section. The costs are broken down into several categories: (a) opportunity cost of capital investment in livestock, (b) salt and minerals, (c) hauling costs, (d) equipment costs for inspection and feeding, (e) property taxes on livestock, (f) veterinary and medicine expenses, (g) grazing fees, (h) selling commission charges, and (i) cattle price assumptions. Each of these categories is explained below and, at the end of this section, the net return calculations are summarized in Tables 3, 4, and 5.

Opportunity Cost of Investment in Livestock

An annual interest rate of 8 percent was applied to the average estimated value of each animal activity during its given time period. For example, a Fall-born steer assumed to be worth $50 at birth and $150 at weaning is worth an average of $100 over the nine-month period. The opportunity cost of his average capital value is calculated as follows: (9/12)(.08)($100) = $6.00.

The 8 percent rate was chosen under the assumption that the hypothetical ranch owner could find an alternative use for the capital tied up in his livestock which would return 8 percent on his investment. This assumption is certainly not valid for all cow-calf operations in the area, and was made to allow a basis for comparison. The effects of changes in this rate are inspected in Chapter IV.

For the purpose of calculating opportunity costs of capital it was assumed that a Spring-calving cow (plus her calf until weaning) is worth $250 on the average, while a Fall-calving cow alone is worth $200. Fall-born calves were valued at $100 and $85.50 per head for steers and heifers, respectively, over a nine-month period. Gestation heifers in both Spring and Fall-calving herds were valued at $200 per head. Young replacement heifers in the Spring-calving herd were valued at $155 and those in the Fall-calving herd at $144. The bulls, whose variable costs have been put in with the net returns of the cows, were valued at an average of $650 each.

Salt and Mineral Costs

Charges were made on a basis of $0.25 for salt and $2.00 for minerals per cow per year. Adjustments in these basic charges were made for younger, lighter animals.

Hauling Costs

Charges for hauling livestock to and from the range (assumed to be about 40 miles from the Winter pasture) were made at a rate of $.21

per cwt. Hauling charges for the calf sales activities were at the rate of $.33 per cwt (assuming a hauling distance of 100 miles to market). This rate was also used for the hauling charge in the sale of cull cows.

Equipment Charges for Inspection and Feeding

A basic charge of $1.50 per head, per year, for a Spring cow-calf pair was adjusted subjectively to estimate equipment charges for the inspection and feeding of the other livestock activities.

Property Taxes on Livestock

Harney County tax rates on livestock were used. These rates were charged against the cattle at their ages and classifications as of January 1. The per head rates were: $1.00 for calves under six months of age; $2.00 for heifers six months to one year of age; $2.89 for heifers one to two years old; $3.44 for cows two years of age and older; and $6.44 for bulls one year of age and older.

Veterinary and Medicine Expenses

Charges of $2.00 per cow-calf unit were made for veterinary and medicine expenses and adjusted subjectively to estimate charges for the other livestock activities.

Grazing Fees

Grazing fees were assumed to be at the B. L. M. rate of $. 64 per animal unit month (A. U. M.). Although the B. L. M. fees were used, the B. L. M. restrictions on cattle numbers on a given area of land were not used. If calves over six months of age are charged for a full A. U. M. and the number of A. U. M. 's is limited on a given range to a maximum number, then the number of Fall-cow-calf pairs that could be carried on that range (under present B. L. M. rules) would be much less than the number of Spring-cow-calf pairs. Since this institutional restriction on numbers does not make much sense in the context of this study it was ignored in the model and only the fees were used. In other words, Fall-born calves were charged $. 64 per month on the range after reaching six months of age, but there was no restriction of cattle numbers because of an A. U. M. limitation. This study is concerned more with rangeland productivity than with the present rules governing range use.[4, p. 205] .

Selling Commission Charges

The selling commission charges assumed in the model were $3. 00 per head for animals weighing more than 450 pounds, and $2. 75 per head for lighter animals.

Cattle Price Assumptions

The prices assumed for the calf sales activities are of critical importance in the comparison of Spring and Fall-calving systems. Price differentials due to animal weight, animal sex and selling dates were considered in arriving at the prices used in the model.

Eleven year (1960-1970) averages of monthly price quotations for calves at the Ontario, Oregon, livestock auction were used as the basis for calculating expected prices for the different calf selling activities. Eugene Panasuk [9] calculated the expected prices for calves at the Ontario market for every month of the year and for weights ranging from 300 to 800 pounds, using as the key price $31.00 for 400 pound steers in September. Using these figures, expected prices were found for the calves in this model. Table 2 lists the prices assumed for the calf sales activities. There is nothing sacred about these assumed prices for they are only to serve as historically based points of reference for calculations and further discussions. In Chapter IV, some attention is given to the effects of changes in the price level of calves. Price differentials, reflecting differences in calf weight, sex and sales date classifications, are subject to change; but usually not to the degree experienced with the general cattle price level from year to year.

Table 2. Calf sales price assumptions.

Activity Code	Name of Calf Type	Calf Weight (lbs)	Sales Date	Price/ cwt. ($)
SELLSTR	Fall-born steer sales	520	Aug. 1	29.83
SELLHEF	Fall-born heifer sales	480	Aug. 1	26.18
SSSP330	Spring-born steer sales at weaning	330	Sept. 1	33.08
SHSP330	Spring-born heifer sales at weaning	330	Sept. 1	28.74
SSNH450	Spring-born steer sales on Nov. 1	450	Nov. 1	30.73
SHNV420	Spring-born heifer sales on Nov. 1	420	Nov. 1	26.67

Portland, Oregon, prices for utility cows were used in choosing prices for the sale of cull cows in the model. Cull cows from the Fall-calving herd were assumed to be sold on August 1, at $16.05 per cwt, while those from the Spring calving herd were sold on September 1, at $15.82 per cwt. For each cow in a herd at calving time, 12.5 percent of a cull cow is sold at weaning time.

Bulls in the model were assumed to be purchased for $1,000, used for four years, and sold for $300.

Variable Cost Summary and Net Return Calculations for Livestock Raising and Selling Activities

In Table 3 the net return calculations for Spring and Fall-calving cows are shown along with the variable costs assumed for a bull. For the purpose of the model it was assumed that the 25 to 1 ratio of cows

Table 3. Net return calculations for Fall and Spring calving cow activities

Variable Cost Item	Fall-calving cow (FALCOW)	Spring-calving cow (SPRCOW)	Costs for One Bull
+ Cull cow sales income	+ $22.00	+ $20.76	-0-
- Opportunity cost of Investment (8%)	- 15.44	- 18.40	- $52.00
- Salt and minerals	- 2.25	- 2.25	- 2.25
- Hauling charges	- 4.26	- 4.15	- 7.56
- Equipment for inspection and feeding	- 2.45	- 1.38	- 1.50
- Property taxes on animal	- 3.44	- 2.96	- 6.44
- Vet and medicine	- 2.00	- 2.00	- 2.00
- Grazing fee	- 3.52	- 4.16	- 4.25
- Selling commission for cull cows	- .81	- .81	-0-
- Depreciation	-0-	-0-	-175.00
- Bull charge[1]	- 10.04	- 10.04	
Total Variable Cost			-$251.00
Net Returns	-$22.21	-$25.39	

[1] The bull charge against each cow was found by dividing a bull's total variable costs between 25 cows: $251/25 = $10.04 per cow.

Table 4. Net return calculations for Fall and Spring herd calf and replacement heifer activities.

Variable Cost Item	Activity Code Name[1]							
	FALGEST	SPRGEST	FALREP	SPRREPL	FALCAS	FALHEF	SSP3303	HSP3302
Opportunity cost of investment (8%)	-$12.36	-$ 9.33	-$ 5.75	-$12.40	-$ 6.00	-$ 5.13	-$1.63	-$1.37
Salt and minerals	- 1.69	- 1.32	- 1.12	- 2.25	- .75	- .75	- .40	- .40
Hauling charges	- 3.47	-0-	- 1.00	- 2.72	- .63	- 1.30	- .69	- .69
Equipment for inspection and feeding	- 1.13	- .88	- .75	- 1.50	0	0	- .25	- .25
Property taxes on animal	0	- 1.68	- 2.89	- 2.89	- 1.00	- 1.00	0	0
Vet and medicine	- 1.50	- .28	- 2.00	- 2.00	0	0	- .24	- .24
Grazing fee	- 2.24	0	0	- 2.88	- 1.92	- 1.92	0	0
Net returns	-$22.39	-$13.49	-$13.51	-$26.64	-$10.30	-$10.10	-$3.21	-$2.95

[1] Where: FALGEST and FALREP are pregnant and young replacement heifers in the Fall herd; and FALCAS and FALHEF are steer and heifer calves in the Fall herd; and SPRGEST and SPRREPL are the replacement heifers in the Spring herd; and SSP3303 and HSP3302 are Spring-born steers and heifers in September and October.

to bulls holds for both Spring and Fall herds. This was done in spite of the expectation that the Fall herd could get by with slightly fewer bulls.

Table 4 lays out the variable costs assumed, and the net return calculations, for all calves and replacement heifer activities in the model.

Table 5 shows the calculations used for the net return values for all the calf sales activities in the model. These calculations simply involve subtracting the hauling charge and selling commission from the sales value of each animal. The sales values were calculated from the figures given in Table 2, multiplying calf weight by the given price level.

Table 5. Net return calculations for all calf sales activities.

Activity Code Name	Sales Value	-	Hauling Charge	-	Selling Commission	=	Net Return
SELLSTR	$155.12	-	$1.72	-	$3.00	=	$150.40
SELLHEF	125.66	-	1.58	-	3.00	=	121.08
SSSP330	109.16	-	1.09	-	2.75	=	105.32
SHSP330	94.84	-	1.09	-	2.75	=	91.00
SSNV450	138.29	-	1.49	-	3.00	=	133.80
SHNV420	112.01	-	1.39	-	2.75	=	107.87

9. A Note on Assumptions

This chapter has presented most of the assumptions behind the data developed and used in this study. Some of the detailed assumptions on nutrient requirements for the various livestock categories have been left out of the text of the chapter and included in Appendix B.

Using the explanations in this chapter, and referring to Appendix B, the reader should hopefully be able to understand how the coefficients in the linear programming model were determined.

IV. ANALYSIS AND RESULTS

1. Computer Analysis

The linear programming model was solved a number of times before it reached the form shown in Appendix Table A-6. Earlier forms and coefficients had to be changed to reconcile the model with the range utilization characteristics of the actual cow herds at the Squaw Butte Experiment Station. For example, only after several solutions of earlier versions of the model was it realized that range forage old growth should have been included as a source of available feed in the first six weeks of the grazing season.

The results of the first solutions of the model, when only Fall-calving was allowed, were baffling in that all activities were called for at the zero level. In other words, the results of the linear programming analysis indicated that the highest net returns could be gotten by producing no cattle at all. At that time, the model was not constrained to use any certain amount of rangeland, and the only possible use of it had a negative resultant net return value so the optimal solution was to produce nothing, and use no rangeland. This problem was circumvented by changing the range forage use rows and the GRZRST (grazing restriction) row in the model from inequalities to equalities; thus requiring the model to use up all 10,000 acres of rangeland. The optimal (maximum net return) solution for the model, under this new condition, was a negative value.

2. Income Statement Budgets for Three Systems

In the model's final form, Fall-calving and Spring-calving systems were both allowed, with two possible calf sales dates for the Spring-born calves. In a final series of solutions, the Spring-calving system with calf sales on November 1 turned out to be optimal. For the next solution the November 1 calf sales activities were not allowed and the Spring-calving system with calf sales on September 1 was optimal, even though it had a negative net return. In the last solution, no Spring-born calf sales activities were allowed so a Fall-calving system was called for, with its negative net returns. An income statement budget for each of the three optimal (under different conditions) solutions is given here. Table 6 shows the numbers of cattle produced, and the optimum combination of feeds for them, when only a Fall-calving system was allowed in the linear program solution. A net return value of -\$6.42 per cow was calculated to be the highest possible, under the given assumptions, for a Fall-calving system.

Tables 7 and 8 show cattle numbers and optimal feed combinations for Spring-calving systems with the two calf sales dates. With Spring-calving, and calf sales on September 1, a net return value of -\$1.82 per cow was the maximum attainable. With calf sales on November 1 in the Spring-calving system the net return value per cow was positive, at \$5.03.

Table 6. Income statement for a Fall-calving operation which uses 10,000 acres of rangeland.

Units[1]	Net Return per Unit	(A) per 10,000 Acres of range	(B) per Cow (A)/253.8
Income:			
Sell 107.8 Steers (Aug. 1)	$150.40	$16,213	
Sell 72.0 Heifers (Aug. 1)	121.08	8,718	
Total Calf Sales		$24,931	$ 98.23
Expenses:			
Variable costs for:			
253.8 Cows	22.21	$ 5,637	
35.8 "Gestation" Heifers	22.39	802	
35.9 Young Replacement Heifers	13.51	485	
114.2 Steer Calves	10.30	1,176	
114.2 Heifer Calves	10.10	1,153	
Total Variable Costs		$ 9,253	$ 36.46
Feed costs for:			
645.9 Tons Meadow Hay	20.00	$12,918	
60.9 Tons Alfalfa Hay	30.00	1,827	
43.2 Tons Barley	50.00	2,160	
2.3 Tons Cottonseed Meal	95.00	218	
4.6 Tons Pelleted Alfalfa	40.00	184	
Total Feed Costs		$17,307	$ 68.19
Total Expenses		$26,560	$104.65
Net Return Total (Income-Expenses)		-$ 1,629	-$ 6.42

[1] These are the numbers of units of activities which came into the computer solution of the L.P. model when only Fall-calving was allowed and the model was constrained to use up all 10,000 acres of range forage.

Table 7. Income statement for a Spring-calving operation limited to 10,000 acres of rangeland and with calf sales at weaning, September 1.

Units[1]	Net Return per Unit	(A) per 10,000 Acres of range	(B) per Cow (A)/245.9
Income:			
Sell 100.8 Steers (Sept. 1)	$105.32	$10,616	
Sell 65.9 Heifers (Sept. 1)	91.00	5,997	
Total Calf Sales		$16,613	$67.56
Expenses:			
Variable costs for:			
245.9 Cows	25.39	$ 6,243	
34.6 "Gestation" Heifers	13.49	467	
34.8 Young Replacement Heifers	26.64	927	
Total Variable Costs		$ 7,637	$31.06
Feed costs for:			
444.8 Tons Meadow Hay	20.00	$ 8,896	
17.6 Tons Alfalfa Hay	30.00	528	
Total Feed Costs		$ 9,424	$38.32
Total Expenses		$17,061	$69.38
Net Return Total (Income-Expenses)		-$ 448	-$ 1.82

[1] These are the numbers of activity units which came into the computer solution when the November selling date for Spring-born calves was not allowed and when the model was constrained to use up all 10,000 acres of range forage.

Table 8. Income statement for a Spring-calving operation limited to 10,000 acres of rangeland, with calf sales two months after weaning, November 1.

Units[1]	Net Return per Unit	(A) per 10,000 Acres of range	(B) per Cow (A)/245.9
Income:			
Sell 100.5 Steers (Nov. 1)	$133.80	$13,447	
Sell 65.7 Heifers (Nov. 1)	107.87	7,087	
Total Calf Sales		$20,534	$83.51
Expenses:			
Variable costs for:			
245.9 Cows	25.39	$ 6,243	
34.6 "Gestation" Heifers	13.49	467	
34.8 Young Replacement Heifers	26.64	927	
100.8 Steer Calves (for two months)	3.21	324	
65.9 Heifer Calves (for two months)	2.95	194	
Total Variable Costs		$ 8,155	$33.16
Feed costs for:			
478.2 Tons Meadow Hay	20.00	9,564	
31.6 Tons Alfalfa Hay	30.00	948	
12.6 Tons Barley	50.00	630	
Total Feed Costs		$11,142	$45.31
Total Expenses		$19,297	$78.47
Net Return Total (Income-Expenses)		$ 1,237	$ 5.03

[1] These are the numbers of activity units called for in the computer solution when constrained (unnecessarily in this case) only to use up all 10,000 acres of range forage.

Comparing Tables 6, 7 and 8, one finds considerable differences in the total calf sales figures and in the quantities of meadow hay called for in the different systems. These differences and other considerations are discussed in the remaining sections of this chapter with emphasis on their impacts on the relative merits of Fall-calving.

3. Feed Consumption Patterns

The Fall-calving herd in the model required more meadow hay and other winter feeds than the Spring-calving herd. There were two reasons for this. First, the Fall herd was assumed to spend one month less time on the range and, therefore, rely on winter feed a month longer than the Spring herd. Secondly, Fall-calving cows are lactating over most of the Winter and need to be kept at a higher plane of nutrition and at higher consumption levels than the dry Spring-calving cows.

While on the range the Fall and Spring-calving herds use up the available forage at different rates. Table 9 shows that the Fall-calving herd, on a per cow basis, requires more acres of range forage than the Spring herd in every time period except for the month of August (and, of course, October, when they are not on the range at all).

The subject of carrying capacity of the range under a Spring-calving system, compared to that with a Fall-calving system, is rather confusing. In terms of A.U.M.'s, the carrying capacity of the range

Table 9. Patterns of range land use for Spring and Fall-calving herds[1].

Range Forage Activity	Time Period	Acres used per Day		Acres used per Cow per Day[2]	
		Spring Herd	Fall Herd	Spring Cow	Fall Cow
AMRANGE	April 16-May 31	53.58	67.78	0.218	0.267
JNRANGE	June	63.40	71.53	0.258	0.282
JLRANGE	July	52.97	66.27	0.215	0.261
AGRANGE	August	52.20	46.57	0.212	0.183
SPRANGE	September	42.13	47.3	0.171	0.186
OTRANGE	October	42.27	0[3]	0.172	0[3]

[1] Based on herd sizes that would use up 10,000 acres of range within the appropriate grazing seasons.

[2] These "per cow" figures were calculated by dividing the acres used by the herd per day by the number of cows in the herd (245.9 Spring-cows and 253.8 Fall-cows).

[3] The Fall-calving herd was assumed to be taken off the range at the end of September.

is higher with the Fall-calving herd. This is because calves over six months of age are counted as full "animal units." By this system, the Fall-calving herd in the model would get something over 2,200 A.U.M.'s from the 10,000 acres of range, compared to something under 1,800 A.U.M.'s taken by the Spring-calving herd from the same amount of range but over a longer period.

On the other hand, if one looks at range land productivity in terms of the number of "saleable pounds of calf gains from the range", the Fall and Spring-calving systems appear to get nearly identical results. Table 10 shows the pounds of saleable calf gains expected from 10,000 acres of langland for Fall and Spring-calving systems. About 36,670 pounds of gain are expected from both.

Table 10. Pounds of saleable calf gains from range forage for Fall and Spring calving systems operating on 10,000 acres of range.

Number of calves sold	Pounds of gain per head on range	Total pounds gained on range
	With Fall-calving herd:	
107.8 steers	220	23,716
72.0 heifers	180	12,960
Pounds saleable calf gains total =		36,676
	With Spring-calving herd:	
100.8 steers	220	22,176
65.9 heifers	220	14,498
Pounds saleable calf gains total =		36,674

There is yet another way of comparing rangeland productivity under Spring and Fall-calving systems. Spring-calving cows can utilize very poor quality range forage later in the grazing season than can the Fall-calving cows. According to the assumptions in the model, even though the Fall-calving herd comes off the range a month earlier, only about three percent more cows can be carried on the 10,000 acres than with a Spring-calving system. Of course, these figures can be expected to change as the assumptions on cow performance, range nutrient requirements and length of the grazing season are varied.

The patterns of winter feed consumption of cows under both calving systems are displayed in Table 11. Spring-calving cows required about four pounds per day less meadow hay than the Fall cows, and no supplementary alfalfa hay or barley at all. If different prices for feeds were used in the model, some different combination of feeds could be expected to come into the solution for Fall-calving cows. For example, if cottonseed meal were available for cows in the model and the price of meadow hay were dropped from $20 to $10 per ton, the cottonseed meal might be expected to come into the Fall-cow's diet as a protein source substituting for alfalfa hay.

In the linear programming model solutions the Fall-calving herd required nearly 1500 pounds more meadow hay per cow than did the Spring-calving herd (with calf sales on September 1). With this great a difference in consumption of meadow hay between the two systems the price level assumed for meadow hay is a very important item in deciding which one has the highest net returns.

Table 11. Winter feed consumption patterns for Fall and Spring-calving cow[1] activities in linear programming model solutions.

Time Period	Pounds per Day per Fall-Cow[2]			Pounds per Day per Spring-Cow[2]
	Meadow Hay	Alfalfa Hay	Barley	Meadow Hay
October	18.7	0	0	0
November	23.2	2.1	1.9	19.3
December	22.8	2.0	1.9	18.9
January	22.7	2.1	1.9	18.7
February	22.4	2.1	1.9	18.3
March 1-April 15	22.5	2.0	1.8	21.8

[1] These feed quantities include an allowance for the cow's fraction of a bull's requirement and are the averages for the given period.

[2] To the nearest tenth of a pound.

4. Effects of Changes in the Prices of Meadow Hay and Calves

In examining the effects of calf price changes, the main emphasis here is on the price differential, per hundredweight, between Fall-born calves and Spring-born calves which are sold directly off the range at weaning. This means that the least profitable of the two Spring-herd calf sales dates (September 1) is the one for the Spring-system that is to be compared with the Fall-calving system in the model. The reasoning here is that if a low-net return Spring-calving system is considered feasible, (and if the net return value of a system were the only basis for evaluating it) then a Fall-calving system, with an equal or higher net return, might also be considered feasible.

The prices used for finding a differential were weighted averages in both herds. The price used for Fall-born calves is the average price per hundredweight of steers and heifers weighted by the total pounds sold of each. Since more steers than heifers are sold, the average price of calves sold is closer to the steer prices than to the heifer prices. This same method was followed for finding an average price for Spring-born calves. The average prices calculated from the prices assumed in the model are as follows:

$28.43 = Avg. price per cwt. for Fall-born calves sold August 1

$31.36 = Avg. price per cwt. for Spring-born calves sold September 1

The Spring-born calf prices here are nearly $3.00 per hundredweight higher than for Fall-calves. The difference is mainly due to the difference in calf weights and the market's willingness to pay more per pound for lighter animals.

Two net return equations, one each for Spring and Fall-calving systems, were derived with data from the income statement budgets in Tables 6 and 7, and using the average calf prices given above. They are as follows:

Net Returns (Fall-calving) = $P_{bf}(906.16) - P_m(645.9) - \$14,473$

Net Returns (Spring-calving)[1] = $P_{bs}(550.1) - P_m(444.8) - \$8,803$

where:

P_{bf} = Avg. price per cwt. for Fall-born calves sold August 1

P_{bs} = Avg. price per cwt. for Spring-born calves sold September 1.

P_m = Price per ton of meadow hay

Setting the two equations above equal to each other, and using the average Spring calf price as a basis, one may derive the following "net return indifference" equation:

$$D_{bp}(906.16) + P_m(201.1) = \$5,496$$

where:

$$D_{bp} = P_{bs} - P_{bf} = \$31.36 - P_{bf}$$

This equation defines the combinations of calf price differentials and meadow hay prices which would give the Spring and Fall-calving systems equal net returns. A graph of this indifference equation is shown in Figure 1. In the area below the figure 1 curve (lower meadow hay price or lower price differentials), a Fall-calving system has higher net returns while above the curve, Spring-calving has the higher net returns.

---

1 With calf sales on September 1

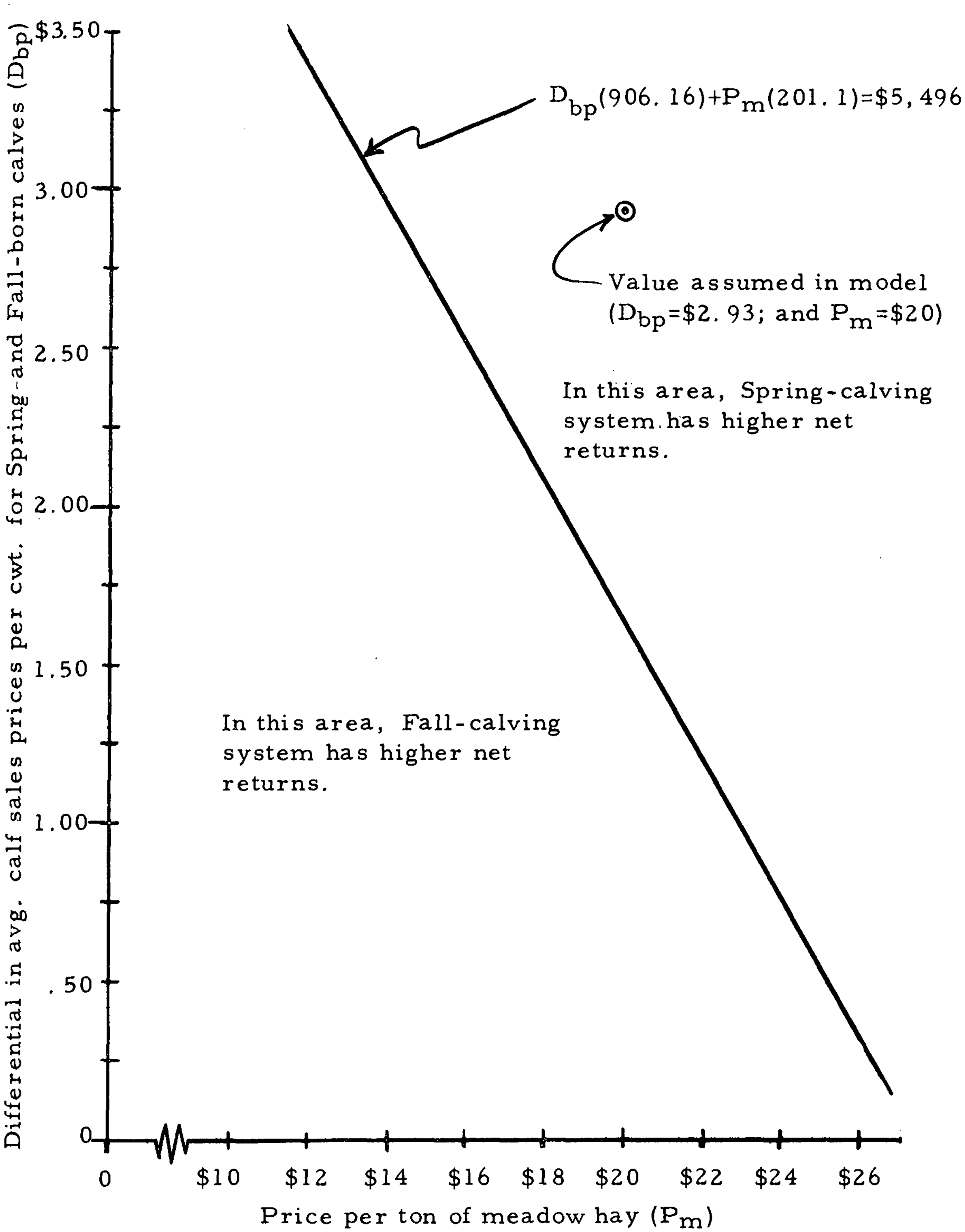

Figure 1. A net return indifference chart for Spring and Fall-calving systems.

5. Opportunity Cost of Capital Investment in Livestock

The difference in the amount of capital investment in livestock between Spring and Fall-calving systems is negligible. At an eight percent interest rate, the opportunity costs of livestock capital investment assumed in the model were calculated to be as follows (on a "herd interest charge per cow" basis):

$25.08 per Fall-calving cow

$23.55 per Spring-calving cow (with calf sales on September 1)

$24.58 per Spring-calving cow (with calf sales on November 1)

If a lower interest rate had been used, these charges would have been simply scaled down proportionately. For example, if a six percent rate were used in place of the eight percent rate, the charges given above would be reduced by 25 percent.

If an interest rate of about 5.9 percent had been used in the model initially, the Fall-calving system would have shown positive net returns, with the Spring-calving-sales date systems showing still higher net returns. But, in a choice between systems, the scale of net returns is not nearly as important as the relative difference in net returns between the systems. Only in the long run decision on whether to produce cattle at all, should the scale of net returns be important.

6. Labor Costs and Considerations

Although the labor factor may be the most important element in a range operator's decision between Fall and Spring-calving systems it was not included in the model analysis. Often much of the labor used on beef ranches in the area is provided by the ranch owner, his family and perhaps some hired help. Even if the sum of labor hours over a year's time were the same for each system their distributions at various times are expected to be different. The differences in labor requirements for Spring and Fall-calving systems at certain times of the year may be very important to some ranchers.

The Fall-calving system will require more labor in the months of October and November (calving time). Also, with Fall-calving, the calves and cows come off the range earlier (by one month, in the model). For some ranchers these differences alone may be quite critical. The need to stay on the ranch at calving time in November and foregoing the pleasures of elk hunting could, for some ranches at least, represent an unbearable psychic cost. For other ranchers, the earlier dates for coming off the range may cause conflicts with farming enterprises.

A Fall-calving system is expected to require more labor over the winter months for the extra feeding and care needed by these animals. However, the labor requirements in March and April for calving with the Spring system are expected to be greater than those for Fall-calving in October and November. The reason is that poorer weather conditions in the Spring cause more disease problems in the newborn calves.

The labor cost factor in the decision on whether to go with a Fall-calving system rather than Spring-calving is something the individual rancher needs to evaluate for himself, for only he knows his own preferences and the labor needs of other enterprises he might have.

V. SUMMARY AND CONCLUSIONS

1. Summary of Analytical Development

The purpose of this study was to analyze the economic aspects of Fall-calving on high desert beef ranches in Eastern Oregon. The Squaw Butte Experiment Station at Burns, Oregon, had switched half of their cow herd to a Fall-calving system and left the other half on a Spring-calving system. Several years of observations by the Squaw Butte Experiment Station personnel provided the basic cattle performance data for constructing a linear programming model containing activities for both Spring and Fall-calving herds.

The linear programming model was set up with the number of acres of range forage as the only external limitation on the size of a cow herd. Data on range forage quality and quantities per acre, in different time periods of the grazing season, were developed from the past experimental work and practical judgement of the Squaw Butte Experiment Station personnel. Livestock activities in the model were limited to the use of 10,000 acres of range forage which had the quality characteristics of good native sagebrush-bunchgrass range.

Nutrient requirements were estimated for all livestock activities in the model by using several standard references sources, plus some guidance by the Squaw Butte Experiment Station personnel. Feeds commonly used in winter feeding cattle in the high desert area were also included in the model. The main feeds were meadow hay, alfalfa hay and barley grain.

The model was set up to maximize net returns to labor, management, and fixed resources in the beef production enterprise. Variable costs were calculated for each livestock activity, and included charges for interest on the capital value of the animals, property taxes on animals, hauling charges, veterinary and medicine, grazing fees, etc. For the calf sales activities, calf prices were estimated on the basis of 11 year (1960-1970) averages at the Ontario, Oregon auction. Feeds used in the model were priced at their assumed opportunity cost (i.e., market price).

The model, in its final form, was solved several times under changed constraints to find the net return ranking of a Fall-calving system with Spring-calving systems with different sales dates (September 1 and November 1). These solutions indicated that net returns would be greater with either Spring-calving system, than with Fall-calving. It was found that there were considerable differences between the Fall and Spring-calving optimal solutions with respect to feed consumption and calf sales incomes.

A net return equation was derived for the optimal Fall-calving solution, and one for the optimal Spring-calving solution with calf sales on September 1. There were two variables in each of these equations: average price per cwt. of calves sold, and price per ton of meadow hay. From these equations, a "net return indifference" equation was derived. The two variables in this equation are, perhaps, the most important economic factors bearing on the choice between Fall and Spring-calving systems: the price (opportunity cost) of a ton of meadow hay, and the difference between the average prices per cwt. of calves sold in the two systems.

The effects of changes in the interest rate, used to calculate the opportunity cost of livestock investments, were discussed. Since the livestock investment levels for Fall and Spring-calving systems were not much different, changing the interest rate simply shifts the net returns of both systems by about the same amounts, with slight effect on their relative net returns.

Labor costs were also discussed, but only in the context of labor requirement distributions over a year's time for Spring and Fall-calving systems. Labor, as an input factor, was ignored in the model, since it often represents an internal cost (borne by the ranch operator and his family) which cannot be given a dollar value as easily and generally as, for example, meadow hay.

2. General Conclusions and Implications

Under the assumptions made for this study, a Fall-calving system appears to be slightly less profitable than a Spring-calving system which sells its calves at weaning. However, if the price of meadow hay were dropped by about 30 percent, from the $20 per ton assumed, these two calving systems would produce about equal net returns.

A Fall-calving system uses considerably more winter feed (i.e., 1,500 pounds more meadow hay per cow) than the Spring-calving system with calf sales at weaning; the reason being, that Fall-calving cows are lactating throughout the winter months while the Spring-calving cows are dry.

Calf price differences, between Fall-born calves and the lighter (by almost 200 pounds) Spring-born calves, work against the relative profitability of a Fall-calving system compared to a Spring-calving system. Since a Fall-calving herd produces more total pounds of saleable calves than the Spring-calving herd, as the gap between the average sales prices for calves in the two systems narrows, the Fall herd's net returns increase relative to those for the Spring-herd, and will exceed them if the gap is closed sufficiently.

The biological advantages of Fall-calving (such as fewer disease problems, higher percent weaned calf crops, and higher weaning weights) may not be enough to outweigh the economic disadvantages of extra winter feed costs and lower calf sales prices, compared to those of a Spring-calving system. An individual ranch which has an abundance of inexpensive winter feed, such as some combination of grain stubble, or aftermath grazing (which can only be utilized through grazing, and would be wasted otherwise) and meadow hay, may be the best suited for a Fall-calving system. Ranch operators who see that a Spring-calving system's labor requirement pattern conflicts with some better alternative use of their time, may find the labor needs of a Fall-calving system much easier to handle.

A limitation on the number of A.U.M.'s allowed on a given piece of public grazing land, in a given season, may act as an absolute barrier to the practical economic feasibility of Fall calving, if calves over six months old are counted as full animal units. This would cut back, seriously, the number of Fall-calving cows that could be put on the range.

Under the assumptions employed in this study, it would appear that on ranches where Spring-calving is already profitably being practiced, a Fall-calving system would not likely be a more profitable alternative. However, on ranches with plentiful sources of winter feeds (with low opportunity costs) Fall-calving could be the optimal alternative. At the feed and calf prices assumed in the linear programming model, there was a difference in net returns of less than $11.45 per cow between the best Spring-calving solution (with calf sales on November 1) and the Fall-calving solution. Considering the fact that no labor costs were used in calculating these net return values and that probably less labor would be used with the Fall system, one sees that there is really not much difference between the systems on the basis of net returns. The critical factors to note are that the Fall-calving system will require more winter feed and its major labor requirements will come at different times of the year.

The possibility of other calf selling dates for Fall and Spring-calving systems has not been mentioned yet. Research work by Eugene Panasuk [9] indicates that an optimal Spring-calving system would be one which carries the calves through the winter, at 1.5 to 2 pounds daily gain, to be sold near calving time. Furthermore, these latter selling dates for Spring calves seem to produce considerably higher net returns than the selling dates used in this study. The implication here is that a Fall-calving system, with calf sales at weaning, may never be able to surpass the net returns of a Spring-calving system which feeds calves through the winter.

3. Changing a Herd from Spring to Fall-Calving

If a decision were made by a rancher to switch from Spring-calving to Fall-calving, there would be a number of ways to make the change. To make the changeover in one year would mean foregoing the income from calf sales for an entire year (unless the change was made from a Spring-calving operation which carries yearling calves through two entire grazing season. In this case there would be no gap in calf sales). The change would be made by simply delaying breeding from June and July to January and February so the cows would calve in October and November.

Another way of changing to Fall calving would be to breed all replacement heifers to calve in the Fall instead of in the Spring. Or, some fraction (say, one-fifth) of the cows could have their breeding delayed so they would calve in the Fall, and after so many years (five in this case), the entire herd would be calving in the Fall.

Yet another system, which has not been mentioned so far, is a combination of Spring and Fall-calving systems. It involves a herd with equal numbers of cows calving in the Spring and Fall. Characteristics of this system are: (1) replacement heifers for the Fall-calving groups of cows are Spring-born and calve at two and a half years of age, while the Spring-calving replacements are Fall-born and also calve at two and a half years; (2) there would be two calving seasons instead of one; (3) more livestock handling facilities might be needed for keeping the two parts of the herd apart at certain times; (4) more hauling and handling dates may be required; (5) fewer bulls may be required since the same ones can be used on the Spring-calving and Fall-calving groups of cows.

4. Areas for Future Analysis and Consideration

It may be beneficial, from the standpoint of completing the research on the economic feasibility of Fall calving, to look into the effects of selling the calves at other times besides weaning. One possibility is that of weaning Fall-born calves early, when the cows are put out on the range and the calves are about five and a half months old, weighing about 300 pounds. This would increase substantially the number of cows that could be put on a given quantity of rangeland, since they would not have calves eating by their sides and they would not be lactating.

Other possible Fall-calf sales dates, after weaning, could be examined. However, it is not expected that their net return levels could compete with those of Spring-born calves, fed through the Winter and sold in early Spring.

One of the frustrating aspects of this study was the attempt to treat range forage in the linear programming model as any other feed; with so many pounds of dry matter digestible protein and T. D. N. per acre in each of several time periods in a grazing season on a "typical range". Of course, there is no such thing as a "typical range", so good quality sagebrush-bunchgrass range was chosen as a basis for estimates on forage quantity consumable per acre, and on forage quality, as the grazing season progresses. It may be useful for future research on the economics of various range cattle systems, to have some better estimates of consumable range forage quantities per acre at different times of the grazing season, than those developed for this study.

Finally, there is the issue again of restrictions on the number of A. U. M. 's that can be used on a given amount of public grazing land.

The indications from this study are that if calves over six months of age are counted as full animal units, then the total A. U. M. 's counted are not in accurate proportion with actual range usage. That is, the Fall-calving system in the model used exactly the same quantity of range land, yet would have had about 25 percent more A. U. M. 's charged against it than the Spring-calving system.

5. A Final Note

When a rancher comes to the point of trying to decide whether to switch from Spring to Fall-calving, he will have to analyze his own feed and labor resource situation. He will also have to formulate his own expectations about cattle performance on his kind of range land, about calf sales prices and other things. He must then make his decision, based on everything he knows about the situation, and based on his own preferences and subjective judgement. Hopefully, some of the information developed in this thesis can find its way to such ranchers, and help temper their judgements on both the possible advantages and disadvantages of Fall-calving.

BIBLIOGRAPHY

1. Castle, E. N., Joe D. Wallace and Ralph Bogart. Optimum feeding rates for wintering weaner calves. Corvallis, 1961. 19 p. (Oregon. Agricultural Experiment Station. Technical Bulletin 56)

2. Cook, Wayne C. Energy budget of the range and range livestock. Fort Collins, 1970. 28 p. (Colorado State University Experiment Station. Bulletin TB109)

3. Davis, G. A. and R. O. Wheeler. Fall calving in Montana. Bozeman, 1970. 18 p. (Montana. Agricultural Experiment Station. Bulletin 649)

4. Heady, Earl O. and Wilfred Candler. Linear programming methods. Ames, Iowa State University Press, 1970. 597 p.

5. Lofgreen, G. P. and W. N. Garret. Net energy tables for use in feeding beef cattle. Davis, 1968. 25 p. (University of California, Department of Animal Science)

6. Morrison, Frank B. Feeds and feeding. 22nd ed., Clinton, Iowa, the Morrison Publishing Company, 1959. 1165 p.

7. Mueller, Robert G. and Grant A. Harris. Economics of selected alternative calving dates. Journal of Range Management 20:67-69. March, 1967.

8. National Research Council. Nutrient requirements of beef cattle. 4th rev. ed., Washington, D.C., 1970. 55 p. (National Academy of Sciences)

9. Panasuk, Eugene D. Research Assistant, Oregon State University, Dept. of Agricultural Economics. Personal communication. Corvallis, Oregon. May 1971.

10. Preston, R. L. Protein requirements of growing-finishing cattle and lambs. Journal of Nutrition 90:157-160, 1966.

11. Raleigh, R. J., Larry Foster, and H. A. Turner. 1971 Progress Report...Research in beef cattle nutrition and management. Corvallis, 1971. 21 p. (Oregon. Agricultural Experiment Station. Special Report 322)

12. Raleigh, R. J., H. A. Turner and R. L. Phillips. Production of fall-born vs. spring-born calves. Proceedings, Western Section, American Society of Animal Science 21:81-85. 1970.

13. Raleigh, R. J. and H. A. Turner. 1967 Progress Report... Research in beef cattle nutrition and management. Corvallis, 1967. 12 p. (Oregon. Agricultural Experiment Station. Special Report 232)

14. ______________ 1969 Progress Report...Research in beef cattle nutrition and management. Corvallis, 1969. 13 p. (Oregon. Agricultural Experiment Station. Special Report 270)

15. Raleigh, R. J., and Joe D. Wallace. 1965 Progress Report... Research in beef cattle nutrition and management. Corvallis, 1965. 14 p. (Oregon. Agricultural Experiment Station. Special Report 189)

16. Wheeler, R. O. Optimum cattle inventory systems under conditions of certainty and uncertainty...Southeastern Oregon, Ph.D. Thesis, Corvallis, Oregon, Oregon State University, 1963.

APPENDICES

APPENDIX A

This Appendix names every activity and constraint in the linear programming model set up for the study. It also contains a copy of the linear program model coefficients in the computer input format that was used.

The computer input is called Table A-6 and follows Tables A-1 to A-5, which name the activities and constraints in the model. The first part of Table A-6 lists all the constraints in the model as irregularities or equalities. The remainder of the table is a listing of matrix coefficients by activity and row heading. Each line in this part of Table A-6 is begun with an activity name followed by a row name and a number and perhaps several row names and numbers. Each of these numbers is a matrix coefficient in the row named before it and in the activity column named at the beginning of the line.

Appendix Table A-1. Names of calf-selling activities in the linear programming model.

Activity Code Name	Name
SELLSTR	Fall-born steer sales at weaning, August 1
SELLHEF	Fall-born heifer sales at weaning, August 1
SSSP330	Spring-born steer sales at weaning, September 1
SHSP330	Spring-born heifer sales at weaning, September 1
SSNV450	Spring-born steer sales on November 1
SHNV420	Spring-born heifer sales on November 1

Appendix Table A-2. Names of activities for livestock raising, feed purchasing, and range forages in the linear programming model.

Activity Type/Code Name	Unit	Activity Name
Livestock in Fall-calving herd:		
FALCOW	head	Fall-calving cow
FALGEST	head	"Gestation" heifer (pregnant replacement heifer)
FALREP	head	Replacement heifer, from weaning to breeding
FALCAS	head	Steer calf, from birth to weaning
FALHEF	head	Heifer calf, from birth to weaning
Livestock in Spring-calving herd:		
SPRCOW	head	Spring-calving cow
SPRGEST	head	"Gestation" heifer (pregnant replacement heifer)
SPRREPL	head	Replacement heifer, from weaning until a year later
SSP3303	head	Steer calf growing from Sept. 1 until Nov. 1
HSP3302	head	Heifer calf growing from Sept. 1 until Nov. 1
Feed purchasing activities:		
MEADOW	Ton	Meadow hay source for feeding activities
ALFALFA	Ton	Alfalfa hay source for feeding activities
BARLEY	Ton	Barley grain source for feeding and Fall-calf activities
PELALF	Ton	Pelleted alfalfa source for Fall-calf activities
COTSEED	Ton	Cottonseed meal source for Fall-calf activities
Range forage activities:		
AMRANGE	Acre	Range forage source from April 16 to May 31
JNRANGE	Acre	Range forage source in June
JLRANGE	Acre	Range forage source in July
AGRANGE	Acre	Range forage source in August
SPRANGE	Acre	Range forage source in September
OTRANGE	Acre	Range forage source in October

Appendix Table A-3. Generalized names of livestock feeding activities in the linear programming model.

Feeding Activity Code Name[1]	Activity Name
	Feeding activities for Fall-calving herd:
FCMHY_ _	Meadow hay feed for Fall-calving cows (FALCOW)
FGMHY_ _	Meadow hay feed for "gestation" heifers (FALGEST)
FRMHY_ _	Meadow hay feed for young replacement heifers (FALREP)
FXMHY_ _	Meadow hay feed for Fall-born calves (FALCAS and FALHEF)
FCALF_ _	Alfalfa hay feed for Fall-calving cows (FALCOW)
FGALF_ _	Alfalfa hay feed for "gestation" heifers (FALGEST)
FRALF_ _	Alfalfa hay feed for young replacement heifers (FALREP)
FXALF_ _	Alfalfa hay feed for Fall-born calves (FALCAS and FALHEF)
FCBAR_ _	Barley grain feed for Fall-calving cows (FALCOW)
FGBAR_ _	Barley grain feed for "gestation" heifers (FALGEST)
FRBAR_ _	Barley grain feed for young replacement heifers (FALREP)
	Feed activities for Spring-calving herd:
SCMHY_ _	Meadow hay feed for Spring-calving cows (SPRCOW)
SGMHY_ _	Meadow hay feed for "gestation" heifers (SPRGEST)
SRMHY_ _	Meadow hay feed for young replacement heifers (SPRREPL)
SCMHY_ _	Meadow hay feed for steer calves (SSP3303)
SHMHY_ _	Meadow hay feed for heifer calves (HSP3302)
SGALF_ _	Alfalfa hay feed for "gestation" heifers (SPRGEST)
SRALF_ _	Alfalfa hay feed for young replacement heifers (SPRREPL)
SSALF_ _	Alfalfa hay feed for steer calves (SSP3303)
SHALF_ _	Alfalfa hay feed for heifer calves (HSP3302)
SSBAR_ _	Barley grain feed for steer calves (SSP3303)
SHBAR_ _	Barley grain feed for heifer calves (HSP3302)

[1] The two blanks in each of these code names indicate the position of the time period code needed to complete the name. The time period codes are: JA = January, FB = February, MA = March 1 to April 15, AM = April 16 to May 31, JN = June, JL = July, AG = August, SP = September, OT = October, NV = November, DC = December.

Appendix Table A-4. Names of general constraints (rows) and cattle number constraints (rows) in the linear programming model.

Row Code Name	Unit	Name or Description of Purpose
		General Constraints:
NETRTN	$1.00	Net returns: the objective row, to be maximized
MEADCNT	cwt.	Relates meadow hay purchasing and feeding activities
ALFACNT	cwt.	Relates alfalfa hay purchasing and feeding activities
BARLCNT	cwt.	Relates barley grain purchasing and feeding and Fall-calf activities
CSMCNT	cwt.	Relates cottonseed meal purchasing and Fall-calf activities
PELLCNT	cwt.	Relates pelleted alfalfa purchasing and Fall-calf activities
RANGEAM	lb.	Restricts range forage new growth D.M. from April 16 to May 31
RANGOAM	lb.	Restricts range forage old growth D.M. from April 16 to May 31
RANGEJN	lb.	Restricts range forage D.M. in June
RANGEJL	lb.	Restricts range forage D.M. in July
RANGEAG	lb.	Restricts range forage D.M. in August
RANGESP	lb.	Restricts range forage D.M. in September
RANGEOT	lb.	Restricts range forage D.M. in October
GRZRST	acre	Restricts total acres of range land available
		Cattle number constraints for Fall-herd:
CNTFCG	head	Relates numbers of cows and "gestation" heifers
CNTFGR	head	Relates numbers of "gestation" heifers and young replacements
CNTFST	head	Relates numbers of cows and steer calves born
CNTFHE	head	Relates numbers of cows and heifer calves born
SSTEER	head	Relates number of steer calves born to number sold
SHEIFER	head	Relates number of heifer calves born to number sold
		Cattle number constraints for Spring-herd:
GESHFR	head	Relates numbers of cows and "gestation" heifers
RPLHFR	head	Relates numbers of "gestation" heifers and young replacements
SSP330	head	Relates numbers of cows and steer calves weaned, fed and sold
HSP330	head	Relates numbers of cows and heifer calves weaned, fed and sold
SNV450	head	Relates numbers of steers fed in Sept. and Oct. to numbers sold
HNV420	head	Relates numbers of heifers fed in Sept. and Oct. to numbers sold

Appendix Table A-5. Generalized names of nutrient requirement constraints (rows) in the linear programming model.

Row Code Name[1]	Nutrient Intake Affected by Constraint
	Nutrient requirement constraints for Fall-calving herd:
FC_ _DM	Fall-calving cow's dry matter
FC_ _TN	Fall-calving cow's T.D.N.
FC_ _DP	Fall-calving cow's D.P.
FG_ _DM	"Gestation" heifer's dry matter
FG_ _TN	"Gestation" heifer's T.D.N.
FG_ _DP	"Gestation" heifer's D.P.
FR_ _DM	Young replacement heifer's dry matter
FR_ _TN	Young replacement heifer's T.D.N.
FR_ _DP	Young replacement heifer's D.P.
FX_ _DM	Fall-born calves' dry matter (before going on range)
FX_ _TN	Fall-born calves' T.D.N. (before going on range)
FX_ _DP	Fall-born calves' D.P. (before going on range)
	Nutrient requirement constraints for Spring-calving herds:
C_ _DRM	Spring-calving cow's dry matter
C_ _TDN	Spring-calving cow's T.D.N.
C_ _DGP	Spring-calving cow's D.P.
G_ _DRM	"Gestation" heifer's dry matter
G_ _TDN	"Gestation" heifer's T.D.N.
G_ _DGP	"Gestation" heifer's D.P.
R_ _DRM	Young replacement heifer's dry matter
R_ _TDN	Young replacement heifer's T.D.N.
R_ _DGP	Young replacement heifer's D.P.
S_ _DRM	Spring-born steer's dry matter (after weaning)
S_ _TDN	Spring-born steer's T.D.N. (after weaning)
S_ _DGP	Spring-born steer's D.P. (after weaning)
H_ _DRM	Spring-born heifer calves' dry matter (after weaning)
H_ _TDN	Spring-born heifer calves' T.D.N. (after weaning)
H_ _DGP	Spring-born heifer calve's D.P. (after weaning)

[1] Where the blanks in the row code names indicate the position of time period codes.

Appendix Table A-6. Computer input data for linear programming model.

```
ROWS
$NETRTN  GRZRST >FCJADM <FCJATN <FCJADP >FCFBDM
<FCFBTN <FCFBDP >FCMADM <FCMATN <FCMADP >FCOTDM
<FCOTTN <FCOTDP >FCNVDM <FCNVTN <FCNVDP >FCDCDM
<FCDCTN <FCDCDP >FGFBDM <FGFBTN <FGFBDP >FGMADM
<FGMATN <FGMADP >FGOTDM <FGOTTN <FGOTDP >FRJADM
<FRJATN <FRJADP >FRAGDM <FRAGTN <FRAGDP >FRSPDM
<FRSPTN <FRSPDP >FROTDM <FROTTN <FROTDP >FRNVDM
<FRNVTN <FRNVDP >FRDCDM <FRDCTN <FRDCDP >FXJADM
<FXJATN <FXJADP >FXFBDM <FXFBTN <FXFBDP >FXMADM
<FXMATN <FXMADP >FXNVDM <FXNVTN <FXNVDP >FXDCDM
<FXDCTN <FXDCDP MEADCNT ALFACNT BARLCNT CSMCNT
PELLCNT CNTFCG  CNTFGR  CNTFST  CNTFHE  SSTEER
SHEIFER RANGEAM RANGEJN RANGEJL RANGEAG
RANGESP RANGEOT <RANGOAM
>CJADRM <CJATDN <CJADGP >CFBDRM <CFBTDN <CFBDGP
>CMADRM <CMATDN <CMADGP >CNVDRM <CNVTDN <CNVDGP
>CDCDRM <CDCTDN <CDCDGP >RJADRM <RJATDN <RJADGP
>RFBDRM <RFBTDN <RFBDGP >RMADRM <RMATDN <RMADGP
>RSPDRM <RSPTDN <RSPDGP >ROTDRM <ROTTDN <ROTDGP
>RNVDRM <RNVTDN <RNVDGP >RDCDRM <RDCTDN <RDCDGP
>GSPDRM <GSPTDN <GSPDGP >GOTDRM <GOTTDN <GOTDGP
>GNVDRM <GNVTDN <GNVDGP >GDCDRM <GDCTDN <GDCDGP
>GJADRM <GJATDN <GJADGP >GFBDRM <GFBTDN <GFBDGP
>GMADRM <GMATDN <GMADGP >SSPDRM <SSPTDN <SSPDGP
>SOTDRM <SOTTDN <SOTDGP >HSPDRM <HSPTDN <HSPDGP
>HOTDRM <HOTTDN <HOTDGP  HSP330  HNV420  SSP330
 SNV450  GESHFR  RPLHFR
COLUMNS
FALCOW NETRTN -22.21 FCJADM 720 FCJATN 402 FCJADP 38.5
FALCOW FCFBDM 714 FCFBTN 399 FCFBDP 38.4 FCMADM 1066
FALCOW FCMATN 594 FCMADP 56.9 RANGEAM 389 RANGOAM 734
FALCOW RANGEJN 620 RANGEJL 723 RANGEAG 723 RANGESP 723
FALCOW FCOTDM 486 FCOTTN 232 FCOTDP 12.8
FALCOW FCNVDM 733 FCNVTN 409 FCNVDP 39.1 FCDCDM 723
FALCOW FCDCTN 404 FCDCDP 38.5 CNTFCG .14 CNTFST -.45
FALCOW CNTFHE -.45
FALGEST NETRTN -22.39
FALGEST FGFBDM 481 FGFBTN 199 FGFBDP 23.4
FALGEST FGMADM 750 FGMATN 324 FGMADP 39.2
FALGEST RANGEAM 415 RANGOAM 507 RANGEJN 630
FALGEST RANGEJL 665 RANGEAG 690 RANGESP 720
FALGEST FGOTDM 638 FGOTTN 264 FGOTDP 27.9
FALGEST CNTFCG -.994 CNTFGR 1.
FALREP NETRTN -13.51
FALREP FRJADM 465 FRJATN 230 FRJADP 25.8
FALREP FRAGDM 392 FRAGTN 174 FRAGDP 18.
FALREP FRSPDM 406 FRSPTN 179 FRSPDP 18.6
FALREP FROTDM 421 FROTTN 187 FROTDP 19.2
FALREP FRNVDM 435 FRNVTN 193 FRNVDP 20.1
FALREP FRDCDM 447 FRDCTN 198 FRDCDP 21.
FALREP CNTFGR -.995
FALCAS NETRTN -10.30
FALCAS FXJADM 84 FXJATN 32 FXJADP 0.3
FALCAS FXFBDM 122 FXFBTN 54 FXFBDP 1.5
```

Appendix Table A-6. Computer input data for linear programming model (Cont.)

```
FALCAS FXMADM 242 FXMATN 113 FXMADP 3.2
FALCAS RANGEAM 216 RANGEJN 349 RANGEJL 363  RANGOAM 216
FALCAS FXNVDM  10 FXNVTN 5   FXNVDP 0.9
FALCAS FXDCDM 62  FXDCTN 30  FXDCDP 5.
FALCAS BARLCNT .4 CSMCNT .2  PELLCNT .4
FALCAS CNTFST 1.  SSTEER -.944
FALHEF NETRTN -10.10
FALHEF FXJADM 84 FXJATN 32 FXJADP 0.3
FALHEF FXFBDM 122  FXFBTN 54  FXFBDP 1.5
FALHEF FXMADM 242 FXMATN 113 FXMADP  3.2
FALHEF RANGEAM 205 RANGEJN 340 RANGEJL 354  RANGOAM  205
FALHEF FXNVDM 10 FXNVTN 5 FXNVDP 0.9
FALHEF FXDCDM 62 FXDCTN 30 FXDCDP 5
FALHEF BARLCNT .4 CSMCNT .2 PELLCNT .4
FALHEF CNTFHE 1. SHEIFER -.63
SELLSTR NETRTN 150.4 SSTEER 1.
SELLHEF NETRTN 121.08 SHEIFER 1.
MEADOW NETRTN -20 MEADCNT -20
ALFALFA NETRTN -30 ALFACNT -20
BARLEY NETRTN -50 BARLCNT -20
COTSEED NETRTN -95 CSMCNT -20
PELALF NETRTN -40 PELLCNT -20
FCMHYOT FCOTDM -90.2 FCOTTN -48 FCOTDP -4.1 MEADCNT 1
FCMHYNV FCNVDM -90.2 FCNVTN -48 FCNVDP -4.1 MEADCNT 1
FCMHYDC FCDCDM -90.2 FCDCTN -48 FCDCDP -4.1 MEADCNT 1
FCMHYJA FCJADM -90.2 FCJATN -48 FCJADP -4.1 MEADCNT 1
FCMHYMA FCMADM -90.2 FCMATN -48 FCMADP -4.1 MEADCNT 1
FCMHYFB FCFBDM -90.2 FCFBTN -48 FCFBDP -4.1 MEADCNT 1
FGMHYFB FGFBDM -90.2 FGFBTN -48 FGFBDP -4.1 MEADCNT 1
FGMHYMA FGMADM -90.2 FGMATN -48 FGMADP -4.1 MEADCNT 1
FGMHYOT FGOTDM -90.2 FGOTTN -48 FGOTDP -4.1 MEADCNT 1
FRMHYAG FRAGDM -90.2 FRAGTN -48 FRAGDP -4.1 MEADCNT 1
FRMHYSP FRSPDM -90.2 FRSPTN -48 FRSPDP -4.1 MEADCNT 1
FRMHYOT FROTDM -90.2 FROTTN -48 FROTDP -4.1 MEADCNT 1
FRMHYNV FRNVDM -90.2 FRNVTN -48 FRNVDP -4.1 MEADCNT 1
FRMHYDC FRDCDM -90.2 FRDCTN -48 FRDCDP -4.1 MEADCNT 1
FRMHYJA FRJADM -90.2 FRJATN -48 FRJADP -4.1 MEADCNT 1
FXMHYNV FXNVDM -90.2 FXNVTN -48 FXNVDP -4.1 MEADCNT 1
FXMHYDC FXDCDM -90.2 FXDCTN -48 FXDCDP -4.1 MEADCNT 1
FXMHYJA FXJADM -90.2 FXJATN -48 FXJADP -4.1 MEADCNT 1
FXMHYFB FXFBDM -90.2 FXFBTN -48 FXFBDP -4.1 MEADCNT 1
FXMHYMA FXMADM -90.2 FXMATN -48 FXMADP -4.1 MEADCNT 1
FCALFOT FCOTDM -90.5 FCOTTN -50.7 FCOTDP -10.9 ALFACNT 1
FCALFNV FCNVDM -90.5 FCNVTN -50.7 FCNVDP -10.9 ALFACNT 1
FCALFDC FCDCDM -90.5 FCDCTN -50.7 FCDCDP -10.9 ALFACNT 1
FCALFJA FCJADM -90.5 FCJATN -50.7 FCJADP -10.9 ALFACNT 1
FCALFFB FCFBDM -90.5 FCFBTN -50.7 FCFBDP -10.9 ALFACNT 1
FCALFMA FCMADM -90.5 FCMATN -50.7 FCMADP -10.9 ALFACNT 1
FGALFFB FGFBDM -90.5 FGFBTN -50.7 FGFBDP -10.9 ALFACNT 1
FGALFMA FGMADM -90.5 FGMATN -50.7 FGMADP -10.9 ALFACNT 1
FGALFOT FGOTDM -90.5 FGOTTN -50.7 FGOTDP -10.9 ALFACNT 1
FRALFAG FRAGDM -90.5 FRAGTN -50.7 FRAGDP -10.9 ALFACNT 1
FRALFSP FRSPDM -90.5 FRSPTN -50.7 FRSPDP -10.9 ALFACNT 1
FRALFOT FROTDM -90.5 FROTTN -50.7 FROTDP -10.9 ALFACNT 1
FRALFNV FRNVDM -90.5 FRNVTN -50.7 FRNVDP -10.9 ALFACNT 1
```

Appendix Table A-6. Computer input data for linear programming model. (Cont.)

```
FRALFDC FRDCDM -9Ø.5 FRDCTN -5Ø.7 FRDCDP -1Ø.9 ALFACNT 1
FRALFJA FRJADM -9Ø.5 FRJATN -5Ø.7 FRJADP -1Ø.9 ALFACNT 1
FXALFNV FXNVDM -9Ø.5 FXNVTN -5Ø.7 FXNVDP -1Ø.9 ALFACNT 1
FXALFDC FXDCDM -9Ø.5 FXDCTN -5Ø.7 FXDCDP -1Ø.9 ALFACNT 1
FCBAROT FCOTDM -89.9 FCOTTN -78.8 FCOTDP -6.9 BARLCNT 1
FCBARNV FCNVDM -89.9 FCNVTN -78.8 FCNVDP -6.9 BARLCNT 1
FCBARDC FCDCDM -89.9 FCDCTN -78.8 FCDCDP -6.9 BARLCNT 1
FCBARJA FCJADM -89.9 FCJATN -78.8 FCJADP -6.9 BARLCNT 1
FCBARFB FCFBDM -89.9 FCFBTN -78.8 FCFBDP -6.9 BARLCNT 1
FCBARMA FCMADM -89.9 FCMATN -78.8 FCMADP -6.9 BARLCNT 1
FGBARFB FGFBDM -89.9 FGFBTN -78.8 FGFBDP -6.9 BARLCNT 1
FGBARMA FGMADM -89.9 FGMATN -78.8 FGMADP -6.9 BARLCNT 1
FGBAROT FGOTDM -89.9 FGOTTN -78.8 FGOTDP -6.9 BARLCNT 1
FRBARAG FRAGDM -89.9 FRAGTN -78.8 FRAGDP -6.9 BARLCNT 1
FRBARSP FRSPDM -89.9 FRSPTN -78.8 FRSPDP -6.9 BARLCNT 1
FRBAROT FROTDM -89.9 FROTTN -78.8 FROTDP -6.9 BARLCNT 1
FRBARNV FRNVDM -89.9 FRNVTN -78.8 FRNVDP -6.9 BARLCNT 1
FRBARDC FRDCDM -89.9 FRDCTN -78.8 FRDCDP -6.9 BARLCNT 1
FRBARJA FRJADM -89.9 FRJATN -78.8 FRJADP -6.9 BARLCNT 1
AMRANGE GRZRST 1. RANGEAM -53  RANGOAM  -1ØØ
JNRANGE GRZRST 1. RANGEJN -12Ø.5
JLRANGE GRZRST 1. RANGEJL -145.5
AGRANGE GRZRST 1. RANGEAG -149.Ø
SPRANGE GRZRST 1. RANGESP -147.5
OTRANGE GRZRST 1. RANGEOT -146.Ø
SCMHYJA CJADRM -9Ø.2 CJATDN -48 CJADGP -4.1 MEADCNT 1
SCMHYFB CFBDRM -9Ø.2 CFBTDN -48 CFBDGP -4.1 MEADCNT 1
SCMHYMA CMADRM -9Ø.2 CMATDN -48 CMADGP -4.1 MEADCNT 1
SCMHYNV CNVDRM -9Ø.2 CNVTDN -48 CNVDGP -4.1 MEADCNT 1
SCMHYDC CDCDRM -9Ø.2 CDCTDN -48 CDCDGP -4.1 MEADCNT 1
SRMHYJA RJADRM -9Ø.2 RJATDN -48 RJADGP -4.1 MEADCNT 1
SRMHYFB RFBDRM -9Ø.2 RFBTDN -48 RFBDGP -4.1 MEADCNT 1
SRMHYMA RMADRM -9Ø.2 RMATDN -48 RMADGP -4.1 MEADCNT 1
SRMHYSP RSPDRM -9Ø.2 RSPTDN -48 RSPDGP -4.1 MEADCNT 1
SRMHYOT ROTDRM -9Ø.2 ROTTDN -48 ROTDGP -4.1 MEADCNT 1
SRMHYNV RNVDRM -9Ø.2 RNVTDN -48 RNVDGP -4.1 MEADCNT 1
SRMHYDC RDCDRM -9Ø.2 RDCTDN -48 RDCDGP -4.1 MEADCNT 1
SGMHYJA GJADRM -9Ø.2 GJATDN -48 GJADGP -4.1 MEADCNT 1
SGMHYFB GFBDRM -9Ø.2 GFBTDN -48 GFBDGP -4.1 MEADCNT 1
SGMHYMA GMADRM -9Ø.2 GMATDN -48 GMADGP -4.1 MEADCNT 1
SGMHYSP GSPDRM -9Ø.2 GSPTDN -48 GSPDGP -4.1 MEADCNT 1
SGMHYOT GOTDRM -9Ø.2 GOTTDN -48 GOTDGP -4.1 MEADCNT 1
SGMHYNV GNVDRM -9Ø.2 GNVTDN -48 GNVDGP -4.1 MEADCNT 1
SGMHYDC GDCDRM -9Ø.2 GDCTDN -48 GDCDGP -4.1 MEADCNT 1
SSMHYSP SSPDRM -9Ø.2 SSPTDN -48 SSPDGP -4.1 MEADCNT 1
SSMHYOT SOTDRM -9Ø.2 SOTTDN -48 SOTDGP -4.1 MEADCNT 1
SHMHYSP HSPDRM -9Ø.2 HSPTDN -48 HSPDGP -4.1 MEADCNT 1
SHMHYOT HOTDRM -9Ø.2 HOTTDN -48 HOTDGP -4.1 MEADCNT 1
SRALFJA RJADRM -9Ø.5 RJATDN -5Ø.7 RJADGP -1Ø.9 ALFACNT 1
SRALFFB RFBDRM -9Ø.5 RFBTDN -5Ø.7 RFBDGP -1Ø.9 ALFACNT 1
SRALFMA RMADRM -9Ø.5 RMATDN -5Ø.7 RMADGP -1Ø.9 ALFACNT 1
SRALFSP RSPDRM -9Ø.5 RSPTDN -5Ø.7 RSPDGP -1Ø.9 ALFACNT 1
SRALFOT ROTDRM -9Ø.5 ROTTDN -5Ø.7 ROTDGP -1Ø.9 ALFACNT 1
SRALFNV RNVDRM -9Ø.5 RNVTDN -5Ø.7 RNVDGP -1Ø.9 ALFACNT 1
SRALFDC RDCDRM -9Ø.5 RDCTDN -5Ø.7 RDCDGP -1Ø.9 ALFACNT 1
```

Appendix Table A-6. Computer input data for linear programming model. (Cont.)

```
SGALFJA GJADRM -9Ø.5 GJATDN -5Ø.7 GJADGP -1Ø.9 ALFACNT 1
SGALFFB GFBDRM -9Ø.5 GFBTDN -5Ø.7 GFBDGP -1Ø.9 ALFACNT 1
SGALFMA GMADRM -9Ø.5 GMATDN -5Ø.7 GMADGP -1Ø.9 ALFACNT 1
SGALFSP GSPDRM -9Ø.5 GSPTDN -5Ø.7 GSPDGP -1Ø.9 ALFACNT 1
SGALFOT GOTDRM -9Ø.5 GOTTDN -5Ø.7 GOTDGP -1Ø.9 ALFACNT 1
SGALFNV GNVDRM -9Ø.5 GNVTDN -5Ø.7 GNVDGP -1Ø.9 ALFACNT 1
SGALFDC GDCDRM -9Ø.5 GDCTDN -5Ø.7 GDCDGP -1Ø.9 ALFACNT 1
SSALFSP SSPDRM -9Ø.5 SSPTDN -5Ø.7 SSPDGP -1Ø.9 ALFACNT 1
SSALFOT SOTDRM -9Ø.5 SOTTDN -5Ø.7 SOTDGP -1Ø.9 ALFACNT 1
SHALFSP HSPDRM -9Ø.5 HSPTDN -5Ø.7 HSPDGP -1Ø.9 ALFACNT 1
SHALFOT HOTDRM -9Ø.5 HOTTDN -5Ø.7 HOTDGP -1Ø.9 ALFACNT 1
SSBARSP SSPDRM -89.9 SSPTDN -78.8 SSPDGP -6.9 BARLCNT 1
SSBAROT SOTDRM -89.9 SOTTDN -78.8 SOTDGP -6.9 BARLCNT 1
SHBARSP HSPDRM -89.9 HSPTDN -78.8 HSPDGP -6.9 BARLCNT 1
SHBAROT HOTDRM -89.9 HOTTDN -78.8 HOTDGP -6.9 BARLCNT 1
SSP33Ø3 NETRTN -3.21
SSP33Ø3 SSPDRM 31Ø SSPTDN 196 SSPDGP 23 SOTDRM 34[illegible]
SSP33Ø3 SOTTDN 22Ø SOTDGP 25.8 SSP33Ø 1 SNV45Ø -.997
HSP33Ø2 NETRTN -2.95
HSP33Ø2 HSPDRM 3Ø5 HSPTDN 176 HSPDGP 18.9 HOTDRM 334
HSP33Ø2 HOTTDN 193 HOTDGP 21  HSP33Ø 1    HNV42Ø -.997
SSSP33Ø NETRTN 1Ø5.32 SSP33Ø 1
SSNV45Ø NETRTN 133.8Ø SNV45Ø 1
SHSP33Ø NETRTN 91 HSP33Ø 1
SHNV42Ø NETRTN 1Ø7.87 HNV42Ø 1
SPRCOW NETRTN -25.39
SPRCOW CJADRM 51Ø CJATDN 231 CJADGP 12.9
SPRCOW CFBDRM 5Ø6 CFBTDN 227 CFBDGP 12.7
SPRCOW CMADRM 925 CMATDN 416 CMADGP 31
SPRCOW RANGEAM 47Ø RANGUAM 888 RANGEJN 861
SPRCOW RANGEJL 867 RANGEAG 875 RANGESP 758
SPRCOW RANGEOT 753
SPRCOW CNVDRM 518 CNVTDN 239 CNVDGP 13.2
SPRCOW CDCDRM 513 CDCTDN 234 CDCDGP 13
SPRCOW SSP33Ø -.41 HSP33Ø -.268 GESHFR .14
SPRGEST NETRTN -13.49 GESHFR -.994 RPLHFR 1
SPRGEST GJADRM 6Ø3 GJATDN 29Ø GJADGP 3Ø.6
SPRGEST GFBDRM 621 GFBTDN 298 GFBDGP 31.4
SPRGEST GMADRM 634 GMATDN 3Ø4 GMADGP 32.Ø
SPRGEST GSPDRM 54Ø GSPTDN 259 GSPDGP 27.5
SPRGEST GOTDRM 556 GOTTDN 267 GOTDGP 28.1
SPRGEST GNVDRM 572 GNVTDN 275 GNVDGP 29.Ø
SPRGEST GDCDRM 588 GDCTDN 232 GDCDGP 29.9
SPRREPL NETRTN -26.64 RPLHFR -.995
SPRREPL RJADRM 375 RJATDN 18Ø RJADGP 19.1
SPRREPL RFBDRM 394 RFBTDN 189 RFBDGP 2Ø.
SPRREPL RMADRM 623 RMATDN 299 RMADGP 31.8
SPRREPL RANGEAM 352 RANGOAM 43Ø RANGEJN 5Ø2
SPRREPL RANGEJL 52Ø RANGEAG 523
SPRREPL RSPDRM 3ØØ RSPTDN 144 RSPDGP 15.2
SPRREPL ROTDRM 32Ø ROTTDN 154 ROTDGP 16.2
SPRREPL RNVDRM 337 RNVTDN 163 RNVDGP 17.3
SPRREPL RDCDRM 357 RDCTDN 172 RDCDGP 18.2
RHS
REMGTF GRZRST 1ØØØØ
```

APPENDIX B

The details of the animal nutrient requirements assumed for the model are given here. As mentioned in Chapter III, though a number of references were used, none of them were strictly followed in making the nutrition assumptions for this study.

National Research Council [8] nutrient requirement figures were the main basis for estimating the requirements of cows, bulls and pregnant replacement heifers in both Spring and Fall-calving herds. An article by Preston [10] was referred to in estimating the digestible protein requirements for all the growing animals (calves and all replacement heifers) in the model. Figures worked up by Lofgreen and Garrett [5] were used in estimating the energy (T. D. N.) requirements of the growing animals, at different weights and rates of gain. Morrison's Feeds and Feeding [6] was used for estimating the requirements of the very young Fall-born calves and as a general cross-check on the requirement estimates for the other animals.

Personnel at the Squaw Butte Experiment Station provided guidance in estimating the nutrient requirements of range cattle in the high desert rangeland environment. However, the nutrient requirement figures shown in this appendix should not be viewed as estimates made by the Squaw Butte Experiment Station personnel.

This is an appropriate place for a note on the nutrient requirement assumptions made for young calves in the model. In the case of Spring-born calves, their requirements have been counted as part of the cow's requirements until weaning. They are assumed not to consume much range forage before they are one and a half months old, after which they gradually increase their consumption, reaching eight or nine pounds per day by weaning. During this time, the Spring-calving cow is gaining some weight and her milk production is steadily declining. Also, over this period, the range foliage quality diminishes so that an animal with constant nutrient needs would have to consume increasing quantities of forage to meet those needs. In consideration of all these changing variables, it was assumed that the sum of the requirements of a Spring-calving cow, plus her calf, would follow the pattern shown in Table B-2.

In the Fall-calving herd, between the time a calf is born and the time it goes out on range forage (April 16), milk is a very important element in its diet. During this period the calf receives a creep-fed ration and consumes some alfalfa and meadow hay as well. On the range, from April 16 to August 1, the calf still receives milk from its dam, at only about 15 percent of the cow's peak earlier milk production. During this period the Fall-born calves rely heavily on the range forage for meeting their nutritional needs.

Appendix Table B-1. Nutrient requirements assumed for a Fall-calving cow.[1]

Month	Minimum Digestible Protein (lbs/day)	Minimum T.D.N. (lbs/day)	Maximum Dry Matter (lbs/day)
January	1.23	12.89	22.8
February	1.23	12.81	22.6
March 1-April 15	1.21	12.69	22.5
April 16-May 31	1.09	11.90	23.8
June	0.91	10.80	19.5
July	0.90	10.65	22.9
August	0.46	8.32	26.8
September	0.45	8.24	26.8
October	0.49	8.40	17.6
November	1.25	13.12	23.2
December	1.23	12.97	22.9

[1] An entire cow, not including bulls' requirements.

Appendix Table B-2. Nutrient requirements assumed for a Spring-calving cow.[1]

Month	Minimum Digestible Protein (lbs/day)	Minimum T.D.N. (lbs/day)	Maximum Dry Matter (lbs/day)
January	0.45	8.45	18.6
February	0.44	8.30	18.4
March 1-April 15	0.71	9.70	21.5
April 16-May 31	1.25	13.04	29.0
June	1.27	13.30	27.5
July	1.29	13.50	27.7
August	0.87	13.60	28.0
September	0.25	8.23	28.2
October	0.13	8.03	28.0
November	0.46	8.76	18.9
December	0.45	8.57	18.7

[1] An entire cow plus a calf from April 1 to Sept. 1, not including bulls' requirements.

Appendix Table B-3. Nutrient requirements assumed for a Fall-calving "gestation" heifer.[1]

Months	Minimum Digestible Protein (lbs/day)	Minimum T.D.N. (lbs/day)	Maximum Dry Matter (lbs/day)
February	0.78	6.63	16.0
March 1-April 15	0.87	7.20	16.7
April 16-May 31	1.30	12.59	20.5
June	1.29	11.30	21.0
July	1.00	9.60	22.2
August	0.95	8.15	23.0
September	0.91	8.50	24.0
October	0.93	8.80	21.3

[1] Requirements for a pregnant replacement heifer only.

Appendix Table B-4. Nutrient requirements assumed for a Spring-calving "gestation" heifer.[1]

Month	Maximum Digestible Protein (lbs/day)	Minimum T.D.N. (lbs/day)	Maximum Dry Matter (lbs/day)
September	0.92	8.63	18.0
October	0.94	8.90	18.5
November	0.97	9.17	19.1
December	1.00	9.40	19.6
January	1.02	9.67	20.1
February	1.05	9.93	20.7
March	1.07	10.13	21.1

[1] Requirements for a pregnant replacement heifer in last seven months of gestation only.

Appendix Table B-5. Nutrient requirements assumed for a young replacement heifer in the Fall-calving herd.

Month	Minimum Digestible Protein (lbs/day)	Minimum T.D.N. (lbs/day)	Maximum Dry Matter (lbs/day)
August	0.60	5.80	13.06
September	0.62	5.98	13.52
October	0.64	6.24	14.02
November	0.67	6.42	14.49
December	0.70	6.61	14.90
January	0.86	7.66	15.49

Appendix Table B-6. Nutrient requirements assumed for a young replacement heifer in the Spring-calving herd.

Month	Minimum Digestible Protein (lbs/day)	Minimum T. D. N. (lbs/day)	Maximum Dry Matter (lbs/day)
September	0.51	4.80	10.0
October	0.54	5.13	10.7
November	0.58	5.43	11.2
December	0.61	5.73	11.9
January	0.64	6.00	12.5
February	0.67	6.30	13.1
March 1-April 15	0.71	6.64	13.8
April 16-May 31	0.94	8.58	17.4
June	1.00	9.20	17.5
July	0.87	8.67	17.6
August	0.53	8.37	17.8

Appendix Table B-7. Nutrient requirements assumed for Fall-born calves from birth to weaning.[1]

Month	Rate of gain (lbs/day)	Minimum Digestible Protein (lbs/day)	Minimum T. D. N. (lbs/day)	Minimum Dry Matter (lbs/day)
Requirements for steers and heifers before going out on range:				
November	1.36	0.03	0.17	0.34
December	1.36	0.17	0.99	2.07
January	1.36	0.11	1.50	3.35
February	1.36	0.18	2.40	4.92
March 1-April 15	1.36	0.25	3.35	6.54
Requirements for steers on range forage:				
April 16-May 31	2.6	0.72	6.70	9.9
June	2.2	0.82	6.75	12.3
July	1.2	0.62	6.00	12.8
Requirements for heifers on range forage:				
April 16-May 31	2.1	0.59	6.12	9.29
June	1.8	0.66	6.59	12.00
July	1.0	0.52	5.36	11.7

[1] These requirements are what the calves were assumed to need after receiving milk from their dams. A cow's milk production was assumed to diminish from about 10 pounds per day at calving to just over 1 pound per day at weaning.

Appendix Table B-8. Nutrient requirements assumed for Spring-born calves from Sept. 1 to Nov. 1

Month	Minimum Digestible Protein (lbs/day)	Minimum T.D.N. (lbs/day)	Maximum Dry Matter (lbs/day)
For steers with 2 pounds average daily gain:			
September	0.77	6.53	10.3
October	0.86	7.33	11.6
For heifers with 1.5 pounds average daily gain:			
September	0.63	5.87	10.2
October	0.70	6.43	11.1

Appendix Table B-9. Nutrient requirements assumed for a bull.

Month	Minimum Digestible Protein (lbs/day)	Minimum T.D.N. (lbs/day)	Maximum Dry Matter (lbs/day)
January	1.33	12.50	30.0
February	1.33	12.50	30.0
March 1-April 15	1.33	12.50	30.0
April 16-May 31	1.33	12.50	30.0
June	1.33	12.50	30.0
July	1.33	12.50	30.0
August	.90	12.50	30.0
September	.30	12.50	30.0
October	.15	12.50	30.0
November	1.33	12.50	30.0
December	1.33	12.50	30.0