



Feasibility of selected fall calving alternatives for the range-cattle industry of Montana
by Gary Allen Davis

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of
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Abstract:

The purpose of this study was to determine the economic feasibility of fall calving for range-livestock enterprises in Montana. Seven selected beef production alternatives were investigated in the western, eastern, and middle portions of the State. Four of the production alternatives investigated were similar to the traditional spring calving procedures presently practiced. The other three production alternatives considered fall calving in Montana.

A linear programming model was designed to determine the optimal production solution for each region when feed, labor, and capital resources were the constraining parameters on output. Three fall calf crop percentages were compared to an 85 percent spring calf crop under each resource structure. The data used to establish the input-output coefficients of the production alternatives were gathered from observing the resource structure of selected range-livestock ranches.

The results of this study indicated (1) fall calving is generally not economically feasible in the Northern Great Plains region of Montana, (2) fall calving is generally not economically feasible in Montana when winter feed constrains range-livestock enterprises, (3) fall calving is economically feasible in the western two-thirds of Montana if minimum production requirements are met when spring or summer feed resources constrain production.

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FEASIBILITY OF SELECTED FALL CALVING ALTERNATIVES
FOR THE RANGE-CATTLE INDUSTRY OF MONTANA

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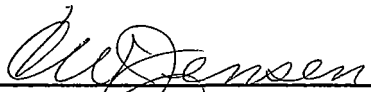
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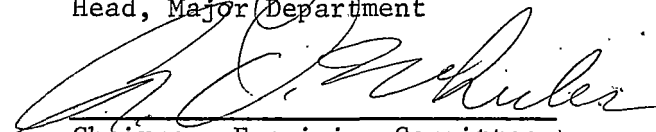
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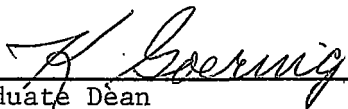
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ABSTRACT

The purpose of this study was to determine the economic feasibility of fall calving for range-livestock enterprises in Montana. Seven selected beef production alternatives were investigated in the western, eastern, and middle portions of the State. Four of the production alternatives investigated were similar to the traditional spring calving procedures presently practiced. The other three production alternatives considered fall calving in Montana.

A linear programming model was designed to determine the optimal production solution for each region when feed, labor, and capital resources were the constraining parameters on output. Three fall calf crop percentages were compared to an 85 percent spring calf crop under each resource structure. The data used to establish the input-output coefficients of the production alternatives were gathered from observing the resource structure of selected range-livestock ranches.

The results of this study indicated (1) fall calving is generally not economically feasible in the Northern Great Plains region of Montana, (2) fall calving is generally not economically feasible in Montana when winter feed constrains range-livestock enterprises, (3) fall calving is economically feasible in the western two-thirds of Montana if minimum production requirements are met when spring or summer feed resources constrain production.

CHAPTER I

INTRODUCTION

Montana is primarily an agricultural state. Nearly half of the State's population--49.8 percent--live in rural areas. Although wheat and cattle are its primary products, three-fourths of the State's 93 million acres is used for livestock production. Across the State, 31 acres are required to maintain one animal unit month. An increase in this relatively low yield will benefit both the range livestock industry and the State. 1/

Research Problem

Beef production in Montana follows ranching practices which have been handed down from generation to generation. Calves are traditionally born in the spring of the year and sold in the fall. There are two reasons for following this practice. First, cold and wet Montana winters restrict the calving period to the warmer months unless investments in building are increased or other shelter provided. Calving occurs as early as possible in the spring (February-April) of the year in an attempt to produce calves of maximum weight before the fall sale. Not only is the cheapest feed resource, summer grass, utilized; but the demand for fall feeders is met and the herd size is reduced before

1/ Basic Facts of Montana Agriculture, Cooperative Extension Service and Agricultural Experiment Station Bulletin 293, June 1962, pp. 10-36.

winter sets in. The feed requirements are thus minimized during the winter months. Second, a favorable demand price and a midwestern market outlet have been instrumental in maintaining the traditional production patterns in Montana.

In 1964, 57.6 percent of all cattle shipped out-of-state went to Illinois, Iowa, Minnesota, and Nebraska. Thirty-three percent of the calves and 29 percent of the yearlings went to Iowa alone. Seventy-six percent of the calves were sold in October and November, while the majority of yearling sales occurred during September and October. 2/ The age of the feeder calves varied from five to eight months, and their weights ranged between 300 and 500 pounds. Yearlings were sold in the fall, 12 months later than the calves, and weighed from 600 to 800 pounds.

During the last decade, modifications of resources and production processes were advanced by many agriculturalists. As the competition for resources increased, cattlemen realized the importance of investigating alternative production techniques.

Ranch operators in Montana have recently been considering fall calving as a potential production alternative. In fact, profitable fall calving operations have begun to appear in various locations in Montana. D. P. Fabrick, a Montanan who pioneered and empirically tested this technique, has shown during the last 15 years that this technique is profitable

2/ Montana Agricultural Statistics, Vol. XI, Montana Department of Agriculture in cooperation with the U. S. Department of Agriculture, August 1967, pp. 73-74.

for his ranch operations. Both fall and spring calves were produced on this ranch. His fall calves consistently averaged \$20 net revenue return above his spring calf returns. 3/

Mr. Fabrick's results have been supported by the limited number of other individuals using the fall calving technique. These producers are located along the eastern slopes of the Rocky Mountains and follow similar management practices which include:

- (1) providing an ample hay supply from December 1 to May 30;
- (2) prohibiting animal grazing of spring range until June 1;
- (3) consistently weaning a 95 percent calf crop.

In addition, at least one out-of-state study has indicated that fall calving was a feasible alternative to spring calving. This study was conducted in north-central and north-eastern Washington by R. G. Mueller and G. A. Harris. 4/ By using a partial budgeting approach, they found fall calving was more profitable than late or early spring calving. Their evidence showed that fall born calves will not experience the high mortality rate at birth nor the scour problems of spring calves.

The flexibility of selecting a time to market the fall products was considered an important advantage. With the prospect of warm weather and

3/ D. P. Fabrick, Fall Calving, Montana Beef Production School, Montana State University, November 30 - December 2, 1964.

4/ R. G. Mueller and G. A. Harris, "Economics of Selected Alternative Calving Dates", Journal of Range Management, Vol. 20, March 1967, pp. 67-69.

the relatively low cost of summer feed, the producer of fall calves can sell his calves in the spring or wait until fall. Maintaining the animals during the summer is not an irrevocable nor costly cash expenditure decision. This is not true, however, in the case of carrying spring calves through the winter months.

The results of fall calving are favorable and profitable in these reports. In addition, Mr. Fabrick's resource structure is similar to many Montana ranches. However, fall calving has not been readily adopted. Uncertainty with respect to fall calving has caused much consternation among potential producers of fall products. Many ranch managers have asked questions concerning resource rearrangements necessary to profitably produce fall calves. They are primarily concerned with winter and summer feed requirements. In addition, the climatic affects of winter weather upon calves and lactating cows has not been investigated thoroughly.

Objectives

The specific objectives of this study are:

- (1) to design a model that will select the optimal production alternative for a given resource situation;
- (2) to determine the resource structures favorable to fall and spring calving production alternatives;
- (3) to determine the required selling weights of the fall products and/or the percentage of weaned calves necessary if the fall alternatives were to be optimal in a given resource structure.

The economic problem in this study is profit maximization subject to given resource constraints. Given the assumptions of pure competition in the input and output markets, of a production function with a continuous first and second order partial derivatives where output is stated as a function of the variable inputs, the profit maximizing position can be determined through the use of partial derivatives. Economic theory assures that profits will be maximized in this framework when the marginal value product of the variable resources are equated to their factor costs. The following example is typical of the profits maximizing procedure.

Profit is defined as the difference between total revenue and total costs: $\pi = TR - TC$ and can be shown to be a function of the variable inputs:

$$\pi = pf(x_1x_2) - r_1x_1 - r_2x_2 - b \quad 1-1$$

where: $q = f(x_1x_2)$ = production function

q = output

p = price per unit of output

$r_1x_1 + r_2x_2 + b$ = total cost

x_i = the variable factors

r_i = the variable costs associated with the inputs

b = the fixed cost

Profits are maximized from Equation 1-1 by the use of partial derivatives. A maximum is guaranteed when two mathematical conditions are met.

The necessary condition requires that the first derivative must be equated to zero. The sufficient condition requires that the second derivative for that given level of output must be less than zero. The partial derivatives of the profit function, Equation 1-1, with respect to the variable factors x_1 and x_2 are shown below:

$$\frac{\partial \pi}{\partial x_1} = \text{price } q \cdot \text{MPP}x_1 - r_1$$

1-2

$$\frac{\partial \pi}{\partial x_2} = \text{price } q \cdot \text{MPP}x_2 - r_2$$

where: the price of q is the value of one unit of output

$\text{MPP}x_1$ = the marginal physical product of input 1

r_1 = the unit cost of input factors x_1 5/

The above states that in order for profits to be at a maximum the value of the marginal product ($\text{price } q \cdot \text{MPP}x_1$) must equal the cost of an additional unit of the resource x_1 .

Although the above procedure is the generally accepted method of maximizing profits subject to cost constraints under the conditions of perfect competition, it is not used in this study. Ranch data has been restricted to a limited number of observations, and the necessary production function required in the marginal analysis approach could not be established. For this reason a linear programming approach was used to maximize profits.

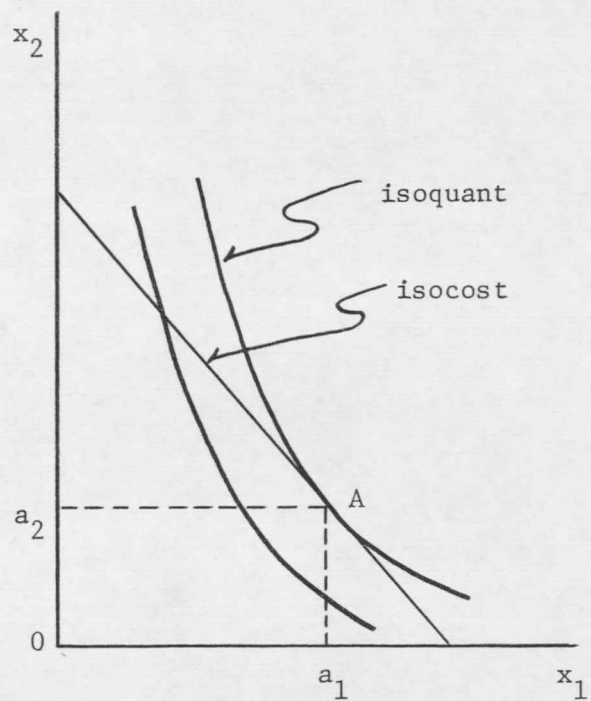
5/ Henderson and Quandt, Microeconomic Theory, McGraw-Hill, 1958, pp. 42-84.

A linear programming structure allows profit maximization subject to resource constraints. It is similar to the marginal analysis approach when maximizing profits, but it is based upon different assumptions. These similarities and differences have caused a grey area to exist between the two analytical approaches.

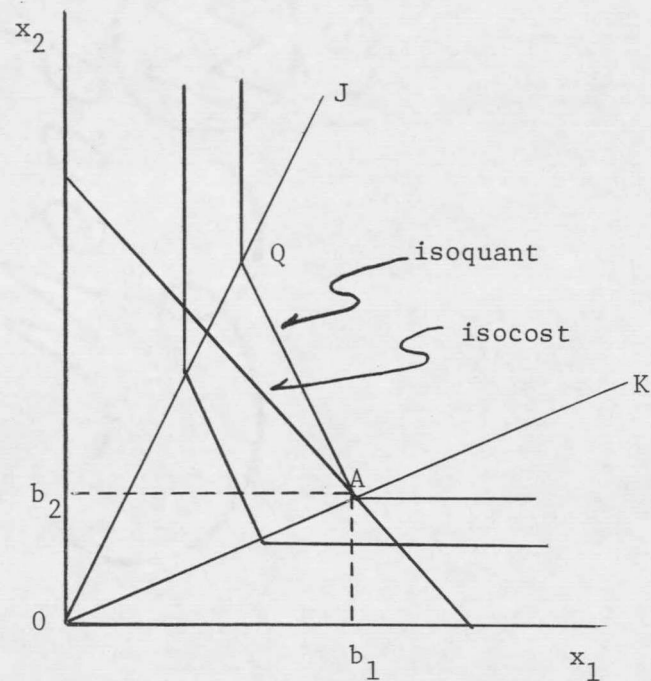
Marginal analysis requires a continuous production function to maximize profits where the marginal value product equals the factor cost. Linear programming requires only that a single input-output relationship be specified as opposed to a function that relates variable inputs to every output level. The linear program establishes an optimal relationship from which profits are maximized subject to the resource constraints by a solution technique called the simplex method. The economic interpretation of the marginal value product is identical in both optimizing models. However, as Henderson and Quandt have indicated, this does not imply that the concept of marginal productivity of an input is meaningful in a linear program. 6/

The difference between the marginal analysis and the linear programming approach is in the use of inputs. In the former, fixed inputs may be assumed at any level with variable inputs entering the production process to produce various levels of output that can be combined in an infinite number of proportions to determine a production surface. In the latter case, an input-output relationship is fixed and the resource level is varied. This difference is shown in Figure 1 for one output produced by two variable factors.

6/ Ibid., p. 76.



(a)
Marginal Analysis



(b)
Linear Program

Figure 1. Comparison of Profit Maximization Between Marginal Analysis and Linear Programming.*

*Source: R. H. Leftwich, The Price System and Resource Allocation, pp. 341-361.

The optimum level of output is at point A in both figures. The primary difference in these two figures is that output in Figure 1(b) will occur only if the inputs are combined in the ratio of K or J which restricts output combinations to lie between Q and A. However, output could occur in Figure 1(a) from any range of factor combinations. The empirical evidence from many situations indicates that the linear production assumption does not, however, limit the practical applications of this technique. 7/

The following two basic theorems of linear programming are considered the "analog of the 'equate your marginal productivities' dictum in the orthodox marginal analysis." 8/ These theorems are:

Theorem 1.--If in any problem there is any optimal feasible program, then there is an optimal feasible program which involves no more than k activities at nonzero levels, where k is the number of restrictions to which the solution must conform.

Theorem 2.-- A feasible program is an optimal program if and only if it contains a list of included activities such that no excluded activity is more profitable than its equivalent combination in terms of those included activities. 9/

These theorems guarantee that if a basic feasible solution exists then the optimal combination of activities are such that no other combinations will achieve a higher output at a lower cost.

7/ Dorfman, Samuelson, and Solow, Linear Programming and Economic Analysis, McGraw-Hill, 1958, p. 161.

8/ Ibid., p. 165.

9/ Ibid., pp. 162-165.

Fundamental Linear Programming Structure

Definitions and Terminology of a Linear Program

The ability to communicate properly depends, in many cases, upon a common understanding of terminology and definitions. The language common to linear programming is as follows:

Activity--an activity is "merely the designation of one of the decision variables of the production plan." 10/

Basic Solution--a solution which has no more variables in it than the number of equations. 11/

Basic Feasible Solution--"when the values of the variables associated with a basic solution are nonnegative it is called a basic feasible solution." 12/

Optimal Solution--the maximum (minimum) value attainable from the basic feasible solutions. 13/

Objective Function--the "quantity to minimize or maximize." 14/

Assumptions of Linear Programming

Four basic underlying mathematical assumptions are required for linear programming formulation. The assumption of linearity requires that the input-output relationship of the variables must be proportionally constant.

10/ Ibid., p. 203.

11/ Ibid., p. 69.

12/ Ibid.

13/ Ibid.

14/ Ibid., p. 28.

This assumption restricts the linear programming problem to linear equations of the following form:

$$a_{11}x_1 + a_{12}x_2 + \dots + a_{1n}x_n \leq b_1$$

$$a_{21}x_1 + a_{22}x_2 + \dots + a_{2n}x_n \leq b_2$$

$$\begin{array}{ccccccc} & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \end{array}$$

$$a_{m1}x_1 + a_{m2}x_2 + \dots + a_{mn}x_n \leq b_m \text{ 15/}$$

where: a_{ij} = the input coefficients

x_i = the activities

b_i = the level of resources available

$x_i \geq 0$

The objective function will also have a linear relationship.

The assumption of divisibility allows the absolute value of the input-output coefficients to vary. This allows fractional units of an activity or a resource to be included in the optimal solution. This does not contradict the first assumption nor allow the proportional input-output relationship to change.

The additivity assumption assures that the sum of the resource used in each activity will be equal to the total amount of the resource used. This excludes the possibility of interaction between resources and activities.

15/ Samuel Karlin, Mathematical Methods and Theory in Games, Programming, and Economics, Vol. I, 1962, Addison-Wesley Publishing, p. 113.

The assumption of finiteness requires the feasible vectors included in the convex set to be bounded either above or below. This guarantees that an optimal solution exists.

This set of assumptions restricts the use of linear programming to certain types of problems as do other analytical tools. In many instances a linear approximation is not a poor estimation of pragmatic situations.

CHAPTER II

PRODUCTION COEFFICIENTS OF MONTANA'S RANGE-CATTLE INDUSTRY

Science begins with the observation of selected material. 16/ Ranch data were gathered to establish the input-output coefficients of the beef production process. This information had to be known if the purpose of this study--to improve the profit position of the range cattle industry--was to be accomplished. Resource conditions, animal growth rates, revenue, and costs were established before selected beef production alternatives were investigated. In particular, feed, labor, and capital costs per time period were inputs of most vital interest.

Ranch resources vary across the State. Montana is a large state that includes mountains and plains; its climate, topography, soil structure, and moisture differ from region to region. The number of consecutive frost-free days increases from the western mountains to the eastern plains, while hay production follows an inverse relationship. 17/ "North-central and eastern counties have the greatest (hay) deficit while western and south-central counties have the greatest surplus." 18/ Before general ranch structures can be approximated to determine the input-output relationships, the ranches must first be grouped according to basic similarities.

16/ E. Bright Wilson, Jr., An Introduction to Scientific Research, McGraw-Hill Book Co., 1952, p. 21.

17/ Montana Agricultural Statistics, op. cit., pp. 16-74.

18/ Basic Facts, op. cit., p. 23.

Two definite regions are distinguished by their topographical characteristics--the western mountains and the eastern plains area. Because of these characteristics, the climate is generally cooler and water is more abundant in the western regions. The boundary between these two regions is not clearly defined. A buffer zone composed of mountains and rolling foothills blends into both east and west. The State has been divided into three study areas which include the western mountains, Region W; the eastern plains, Region E; and the buffer zone between these regions, Region M.

Description of Regions

Region W

Region W is a mountainous area that lies near the Rocky Mountains. The western counties surveyed in this region are: Beaverhead, Jefferson, Powell, Broadwater, Lewis and Clark, and Cascade. The annual precipitation in this region is approximately 12 inches. Of these, 8 inches are expected between April 1 and October 1. Normally the temperature will remain above freezing for 100 consecutive days. 19/

A representative ranch in this region is situated among mountains and foothills, with ranch headquarters being located in a valley. The valley floor will vary in width from 100 to 3,000 yards. Winding through the valley is a small stream which is surrounded by brush and willows..

19/ Montana Agricultural Statistics, op. cit.

During the winter months, December 1 to May 1, the cattle are kept in the valley near the ranch headquarters where they are afforded the protection of the brush from winter storms. Grass and alfalfa hay are the major winter ration. Near the middle of June the cattle are moved to the mountain ranges.

Although ample amounts of water pass through the valley during the year, it is common for irrigation water to be unavailable in the late summer. Thus, the full potential of winter feed production is not realized.

Region M

Region M has a semi-mountainous-foothill topography where the rolling foothills meet steeply-rising mountains. The counties surveyed in this region are Fergus and Big Horn. One hundred and sixteen consecutive days are frost-free. The precipitation between April 1 and October 1 will average 13.7 inches, while another 1.8 inches will fall during the remaining months. 20/

A ranch in this region utilizes mountain range from the middle of May until the first of December. During the winter months, January to April, hay and grain constitute the winter ration. The ranch headquarters are near the mountains and are located in a small and relatively narrow, 100 to 300 yards valley. A small stream runs through the brush-dominated

20/ Ibid.

valley floor. This brush is used for livestock protection from the winter winds and snow.

Region E

Region E is indicative of the Northern Great Plains. The counties surveyed in this region, Rosebud, Powder River, and Custer, are similar to the portion of the Northern Great Plains included in Montana. The annual precipitation in these counties is 12.5 inches, of which 9.5 inches fall between April 1 and October 1. There are normally 136 consecutive frost-free days in this region. 21/

Water and wind are physical factors that have important economic significance in the Great Plains area. Winter snow is usually blown from the rangeland. The snow-free range is thus available for a year-round grazing program. The storage of feed resources in this form may well be the cheapest supply of winter feed but it is subject to much uncertainty. If a heavy snow is not blown from the range, grass hay is substituted as the winter feed source. Normally some hay is machine harvested in case such an event occurs. In many instances, stored hay is needed in limited quantities and is often only partially consumed in the spring of the year. This extra hay is usually not sold but stored as long as three years. Although the palatability of the hay decreases, it can be used as roughage with a protein supplement if the winter range is covered for an unusually long time period.

21/ Ibid.

Normally a high protein supplement is fed from January until May as the winter range is utilized as the primary feed resource. This is practiced to increase the prenatal protein intake of the brood cow and to maintain growth of the replacement animals.

Streams and springs for use by range livestock are not nearly as abundant in this area as compared to the rest of the State. For this reason, man-made reservoirs, and water tanks are prevalent throughout this area so that the livestock will not be restricted to feed sources along the river beds.

The number of ranches surveyed varied among the regions. In Region W, Region M, and Region E, there were 13, 4, and 3 observations, respectively.

In addition to physical differences among ranches, it was realized that management ability would vary within these regions. This variance was minimized by selecting the observations. The judgment of many county, state, and federal offices who were directly familiar with ranch operations for the given study area were used in the selection process. The criteria used for selecting a ranch observation were:

- (1) the ranch must follow the traditional spring calf production and marketing procedure;
- (2) the ranch must be a commercial range-cattle operation in contrast to a pure-bred, cattle-grain, feedlot or dairy operation and must have between 110 and 450 brood cows; and
- (3) the ranch must be producing beef products with a minimum cost in terms of manpower, equipment, and other available resources.

By selection, the management ability of the observations would be relatively homogeneous. Further, the one-year production period was divided into four 3-month intervals to account for variations in resource use during the year. These were:

Winter	January 1 to March 31
Spring	April 1 to June 30
Summer	July 1 to September 30
Fall	October 1 to December 31

The seasonal fluctuations of resource use must be known if all the objectives are to be accomplished. Figure 2 shows the division of the State into the three regions.

Input-Output Coefficients of Observed Ranches

Ranch data were used to establish the relationships among resource requirements per time period. The underlying assumption of processing the data was that each observation made the optimum use of all ranch resources in the production of the traditional spring products. This assumes that the primary data yields the optimum relationship between input-output coefficients. It specifies that the ranch observations were producing beef at the minimum cost for the given ranch resources.

The input-output coefficients of this study rely heavily upon the animal unit months associated with each ranch observation. Disagreement among researchers concerning the method of best determining animal unit months provides latitude in the research approach, but it does not improve the consistency of research results. Some maintain that the total

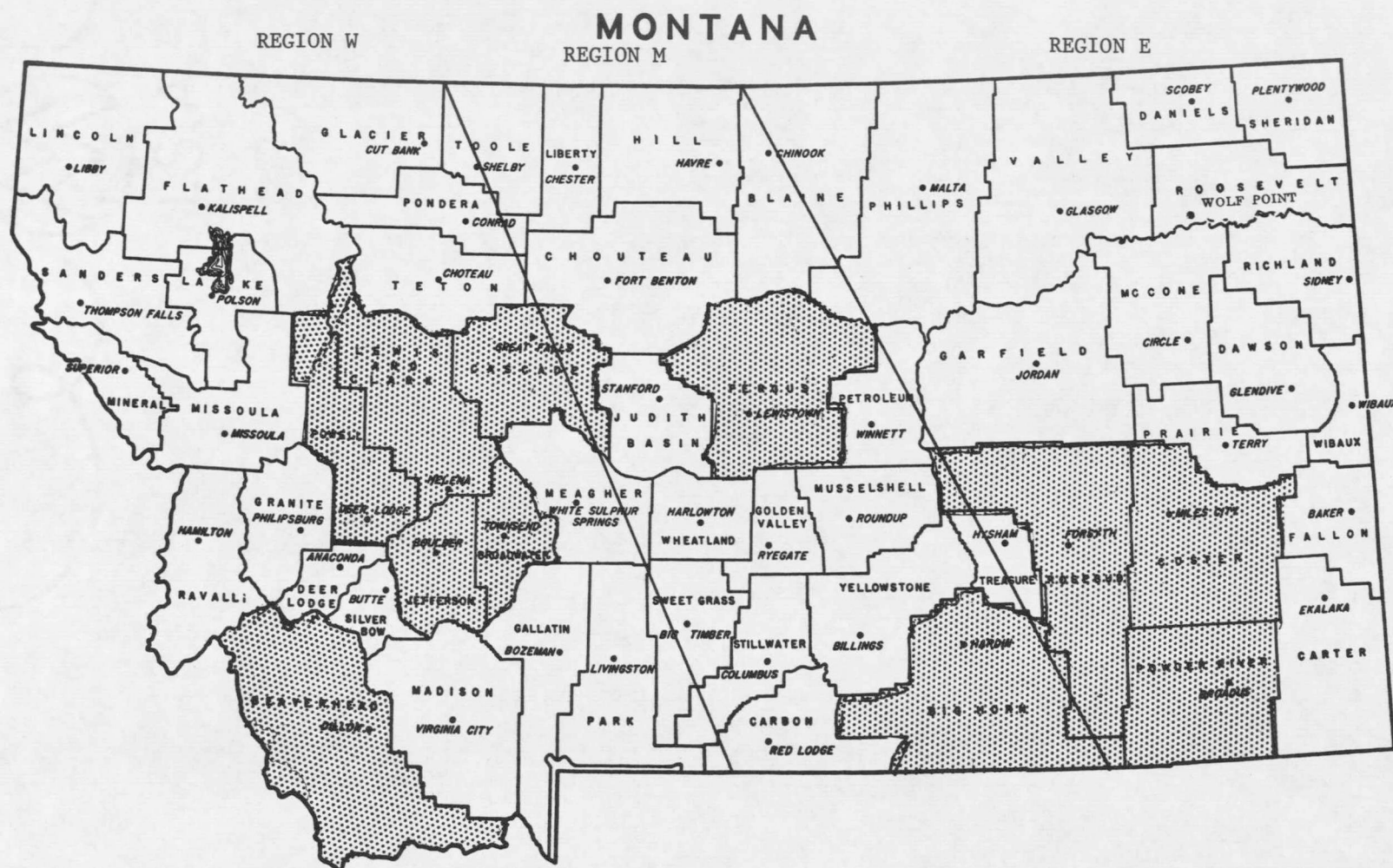


Figure 2. Investigated Regions of Montana.

 Collection of primary data

digestible nutrients required to maintain normal animal growth or condition is the most valid approach; others have suggested a flat year-round figure for each class of livestock. 22/

The method used to determine animal unit months in this study parallels the weight based approach used by A. L. Barr, W. Schultz, J. S. Plaxico, and A. B. Nelson. 23/ This approach requires that the average weight of steers, heifers, calves, and other beef classes be known for the study area in a given time period. For the purposes of this study it was assumed that the beef weights recorded from each ranch observation were normal for that observation, even though it was realized that the gains of young animals will fluctuate as the nutritional plane varies from year to year. 24/

Growth Rate of Spring Born Beef Animals

The survey data provided the selling weights of six-month steer and heifer calves, of 18-month steers and heifers, and the weight of

22/ R. O. Wheeler, Optimum Cattle Inventory Systems under Conditions of Certainty and Uncertainty--Southeastern Oregon, Ph.D. dissertation, Oregon State University, December 1967, pp. 37-38.

23/ A. L. Barr, et al., Beef Cattle Systems and Range Improvement Alternative: Estimated Production, Income, and Costs, Oklahoma State University Expt. Sta. Processed Series P-358, September 1960, p. 3.

24/ Walter R. Houston, Effects of Stocking Rates on Range Vegetation and Beef Cattle Production in the Northern Great Plains, Mont. Agr. Expt. Sta., and U. S. Department of Agriculture, 1966, Bulletin 1357, p. 30.

cull cows for each of the three regions. The average weight of a given product in each region was determined by dividing the total pounds of a product sold in the region by the number of animals producing the product. This procedure established the average weight of six and 18-month spring born animals for each region.

A concave rather than a linear interpolation between the weights of the six and 18-month old products was used to estimate the weights of the 12-month animals. St. C. S. Taylor and G. B. Young 25/ have found in their experiments that the growth rate of dairy heifers could not be forced to a linear pattern by controlling feed intake. Instead a sigmoid tendency was prevalent. To account for this tendency and the slowing of growth of Montana calves beyond six-months of age 26/ a linear interpolation between animal weights was used only to estimate the weight of 9 and 15-month old animals. This approximation procedure tends to average the growth rate over a six-month period and does not fully account for all the seasonal fluctuations in animal weights. The weights for animals at 6, 9, 12, 15, 18, 21, and 24 months of age were required if the animal unit months were to be determined for four time periods by the weight-based approach. Figure 3 represents the sigmoid tendency of animal growth rates used in this thesis.

25/ St. C. S. Taylor and G. B. Young, "Variation in Growth and Efficiency in Twin Cattle with Live Weights and Food Intake Controlled," Journal of Animal Science, Vol. 66, February 1966, pp. 67-85.

26/ M. J. Reed and R. A. Peterson, Vegetation, Soil, and Cattle Responses to Grazing on Northern Great Plains, Forest Service, 1961, U. S. Department of Agriculture Bulletin 1252.

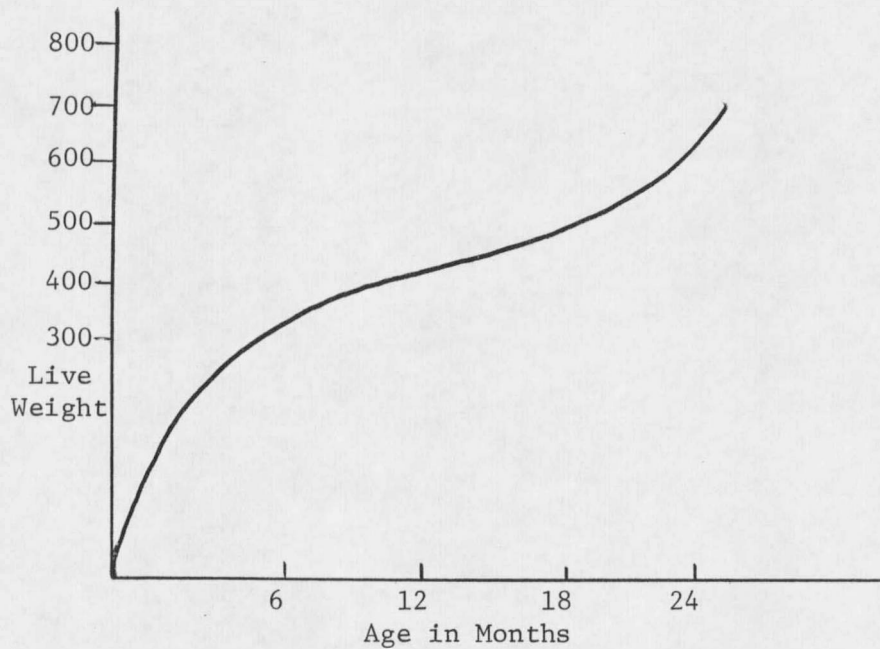


Figure 3. Sigmoid Tendency of Animal Growth

The primary data indicated that the weights of cull cows varied within regions and among regions. The sale of cull cows did not occur during one time period as do the sales of feeder animals. Cows sold after the winter usually weighed less than cows sold in the fall. In some instances cull cows were fed a grain ration before being sold. Different procedures of preparing cull cows for market caused considerable variance in selling weights. For this reason an approximate weight of 1,000 pounds was used for all cull cows.

Growth Rate of Fall Born Beef Animals

The absolute growth rate considered for the fall born calves is not as vital to this study as the absolute growth curve of spring born animals. When optimizing the production alternatives the spring calf growth rate will be accepted as given while the fall calf growth rate will be adjusted to investigate the effect of animal growth upon the profitability of fall alternatives.

With a limited quantity of fall calving data available, various information was combined to estimate the fall calf growth rate. R. G. Mueller and G. A. Harris 27/ found in their Washington research that fall born calves weighted 400 pounds or more near six-months of age and D. P. Fabrick produced fall born steer calves that averaged 625 pounds at 13 months of age. 28/ Mr. Fabrick's weights were adjusted downward to account for age and weight differences. His steers were sold at 13 months which required the weight of 12 month steers to be estimated. In addition, Mr. Fabrick's spring born steer calves weighed 465 pounds as compared to the average of Region W, which is 425 pounds. The weight of the six-month fall steer calves in this region was estimated to be 380 pounds, while the weight of the 12-month fall born steers was estimated as 500 pounds.

27/ R. G. Mueller and G. A. Harris, op. cit., p. 67.

28/ D. P. Fabrick, op. cit.

With these two reference points, a growth rate for fall born calves was estimated by assuming that:

- (1) the animal weights between regions for the fall alternatives would differ in the same manner as the spring alternatives;
- (2) the weight differences in the spring alternatives due to sex would also appear in the fall alternatives; and
- (3) the weight of all two-year old animals would be identical for each region regardless of the time of birth.

The weights of the spring and fall born animals are shown in Table I.

Regional Resource Coefficients

The animal unit months for each ranch observation were based upon the animal weights shown in Table I. The beef herd of an observation was known for each of the four time periods; spring, summer, fall, and winter. In instances where a sale or purchase of livestock occurred during any given time period, it was assumed that the transaction took place on the first day of that time period.

The animal unit months for each ranch were determined in three-month intervals as shown by Equation 2-3.

$$AU_{t=3} = \sum_{i=0}^N 3\left(\frac{x_i}{1000} J_i\right) \quad 2-3$$

TABLE I. EXPECTED GROWTH RATE FOR THE SPRING AND FALL ALTERNATIVES.

Animal :		Born in the Spring			Born in the Fall		
Age :		Region W:	Region M:	Region E:	Region W:	Region M:	Region E
		<u>Lbs.</u>	<u>Lbs.</u>	<u>Lbs.</u>	<u>Lbs.</u>	<u>Lbs.</u>	<u>Lbs.</u>
<u>Steer</u>							
6		425	420	360	380	380	320
9		465	460	400	450	450	390
12		500	500	440	520	520	460
15		575	585	545	565	575	535
18		650	670	650	610	630	620
21		725	745	725	705	715	705
24		800	820	800	800	820	800
<u>Heifer</u>							
6		380	400	330	340	360	280
9		410	440	365	400	430	350
12		440	480	400	460	500	420
15		520	565	505	510	555	490
18		600	650	610	560	610	560
21		680	725	685	660	700	660
24		760	800	760	760	800	760

where: t = three-month time interval under consideration

i = the classes of livestock on each ranch observation
in time t

x_i = the average weight of animal in class i in time t

N = number of livestock classes

J_i = number of animals in livestock class i

Operating Capital

If the ranch observations had either limited acres of cash-grain crops or some nonbeef livestock enterprise, the ranch operating costs were adjusted to account for these associated enterprises. The survey schedule was not constructed to distinguish between enterprise costs. It would not have been reasonable to expect a ranch operator to provide accounts by enterprise. When other enterprises were found on a ranch observation and the associated costs of producing these products were not distinguishable, then an acreage-use penalty was assigned to allocate nonbeef costs. Based upon a Michigan State University study, 29/ \$17 per acre was the cost of producing grain on a small dryland farm in Montana. This cost was charged against the nonbeef enterprise for each acre of grain or hayland used in the production of these products. If the feed inputs were not specified for the nonbeef livestock, Morrison's Feeds and Feeding handbook 30/ was used to determine the feed requirements.

29/ Merle E. Quenomoen, A Study of Costs and Returns for Dryland Farms in the Triangle Area of Montana with Emphasis on Operator's Labor, Machinery, and Land, Ph.D. dissertation, Michigan State University, 1966, p. 238.

30/ Morrison, Feeds and Feeding, 20th ed., Morrison Publishing Co., 1937, pp. 953-1058.

The acres used in cash-grain production were easily partitioned from the survey schedule data.

In addition certain annual ranch cash costs were not considered as variable beef costs. Items such as depreciation, insurance on property, interest on farm notes, mortgage payments, and real and property taxes were not included in the annual variable beef costs. The cash cost of the beef enterprise for each ranch observation is summarized in Equation 2-4.

$$\text{Annual Beef Cash Cost} = \text{Annual Ranch Cash Cost} - \$17 (\text{acres producing cash grain}) - \$17 (\text{acres used to produce hay and grain for nonbeef livestock}) - \text{real taxes} - \text{insurance costs} - \text{interest charges} \quad 2-4$$

The annual beef cash cost of each observation is divided by the animal unit months of the ranch observation to determine the annual cost per animal unit month. These annual costs per animal unit month are then summed and a simple average is determined for each region. The average animal unit month costs are shown below for each region.

<u>Region</u>	<u>Average Annual Cost/AUM</u>
W	\$3.26
M	\$3.42
E	\$3.10

Labor

In Montana, the supply of dependable hired labor has become a problem for many ranchers. Herd size often requires part-time help

throughout the year. However, it has been extremely difficult to hire qualified labor for a week or less during each month. Although the quality and quantity of hired labor varies considerably throughout the State, the man months of hired labor per observation are accepted as if they were identical in form.

Many different ownership combinations were prevalent in all regions of Montana. These combinations and the health and age of the owners, influenced the amount of labor hired. In several instances the ranch manager performed only limited physical tasks. Thus it was difficult to evaluate family labor applied to the beef enterprise.

A general guideline was used to adjust the man months of family labor use; this was: (1) if the rancher was limited by illness, i.e., heart trouble, he was allowed a maximum of six man months; (2) if a rancher was over 60 years of age and hired year-round help he was allowed a maximum of six man months; (3) if a rancher was over 55 years of age and hired six man months of labor he was allowed a maximum of nine man months. A man month was defined as that amount of work done for the beef enterprise by one man during a normal month.

This adjustment of family labor provided an estimation of actual labor, mental and physical, applied in the beef production process. However, the relationship between seasonal labor requirements could not be specified once this adjustment was made. This adjustment procedure was required for 40 percent of the observations.

For each observation the man months required per animal unit month were found by dividing the sum of hired and adjusted family man months by the animal units months associated with the observation. A regional average was computed by summing these ranch averages and dividing by the number of observations per region. The regional averages are shown below.

<u>Region</u>	<u>Man-Month Required/AUM</u>	<u>AU/Man Year</u>
W	.00581	172
M	.00521	191
E	.00526	190

Beef Prices

The price of each class of feeder livestock was based upon reported prices received at the Billings Livestock Market. The primary data were used to indicate the grade of animals sold by Montana ranchers. The prime feeder prices of this market were more near the prices received by the observations than any other feeder grade. The same set of prices was used across the entire State for all production alternatives.

A six-year average (1962-1967) of annual prices was used to estimate the expected price for each weight classification (i.e., 300-500, 500-700, etc.) of prime animals. An average price for each weight division was known and was assumed to be the price of the average weight for that weight division. A linear interpolation was made between these midpoints to determine the price per 10-pound increment of weight change.

There are three exceptions of the above procedure for determining the average price of a weight division. First, a two-year average (1966-1967) was used to determine the price of prime steers weighing 750 to 1,000 pounds due to the lack of data for this weight class. Second, a price had to be estimated for prime heifers weighing from 700 to 1,000 pounds. This price was determined by finding the price spread between 300-500 pound steers and heifers and subtracting this difference from the price of prime 750 to 1,000 pound steers. Third, the price of cull cows had to be determined. This price was determined from ranch data and held constant throughout all regions. Equation 2-5 shows the method used in the estimation of the cull cow price.

$$\text{Cull Cow Price} = \frac{\sum_{i=0}^N C_i P_i}{\sum C_i} \quad 2-5$$

where: C_i = the number of cull cows sold per observation

P_i = the average price received per cull cow per observation

Table II shows the prices determined for the various animal selling weights.

TABLE II. PRICES DETERMINED FOR THE VARIOUS FEEDER ANIMAL SELLING WEIGHTS.

Prime Feeder Steers		:	Prime Feeder Heifers	
Weight	: Price Per CWT	:	Weight	: Price Per CWT
<u>Lbs.</u>	<u>Dol.</u>		<u>Lbs.</u>	<u>Dol.</u>
350	30.04		330	26.27
360	29.87		340	26.17
370	29.70		350	26.07
380	29.53		360	25.97
390	29.36		370	25.87
400	29.19		380	25.77
410	29.02		390	25.67
420	28.85		400	25.57
430	28.67		410	25.47
440	28.50		420	25.37
450	28.32		430	25.27
460	28.15		440	25.17
470	27.97		450	25.07
480	27.80		460	24.97
490	27.62		470	24.87
500	27.44		480	24.67
510	27.27		490	24.57
520	27.10		500	24.47
530	26.92		510	24.37
540	26.75		520	24.27
550	26.57		530	24.17
560	26.40		540	24.07
570	26.22		550	23.97
580	26.05		560	23.87
590	25.87		570	23.77
600	25.70		580	23.67
610	25.52		590	23.57
620	25.34		600	23.48
650	25.15		610	23.38
670	25.10		650	23.07
800	24.95		760	22.30
820	24.86		800	22.00

CHAPTER III

PRODUCTION ALTERNATIVES

In Montana, calves, long-yearlings, and cull cows are the principal beef products of the range cattle industry. Calves and long-yearlings are approximately 6 and 18 months of age, respectively, when they are sold. Ranchers have combined these three products in various proportions in an attempt to maximize their profits. From the extremes of selling all calves or all yearlings, many other combinations of steers and heifers which are either 6 months or 18 months of age have been practiced. This study investigates seven beef product combinations. These seven production alternatives involve nine distinct products which include four spring born products (designated by an S) and four fall born products (designated by an F). These nine products are:

- (a) six-month spring-steer calf (S)
- (b) six-month spring-heifer calf (S)
- (c) 12-month fall-steer calf (F)
- (d) 12-month fall-heifer calf (F)
- (e) 18-month spring long-yearling steer (S)
- (f) 18-month spring long-yearling heifer (S)
- (g) 24-month fall-steers (F)
- (h) 24-month fall-heifers (F)
- (i) cull cows--brood cows over three years of age (S,F)

The proportional relationship among these products on a given ranch will vary from year to year depending upon the ranch resources available and beef prices. Within a region and across the State, the proportional combination of yearlings and calves did not follow a general pattern. The seven selected beef production alternatives include two product combinations in addition to a cull cow product.

Selected Product Combinations

The seven beef production alternatives were identified by a two-position alphanumeric field (shown on the left) and combine the nine beef products in the following manner:

S1--a,b,i--six-month steer calves, six-month heifer calves, and
cull cows

S2--a,f,i--six-month steer calves, 18-month long-yearling heifers,
and cull cows

S3--b,e,i--six-month heifer calves, 18-month long-yearling steers,
and cull cows

S4--e,f,i--18-month long-yearling steers and heifers, and cull cows

F1--c,d,i--12-month steer and heifer calves and cull cows

F2--c,h,i--12-month steer calves, 24-month heifers and cull cows

F3--d,g,i--12-month heifer calves, 24-month steers and cull cows

The actual selling weight of the nine products were determined from primary and secondary data as shown on pages 20-25 and are presented in Table III.

The seven selected beef production systems are identified by the types of product sold. Each system is flexible to the extent that the

TABLE III. SELLING WEIGHTS OF SELECTED BEEF PRODUCTS IN THREE REGIONS.

Product	Age	Region W		Region M		Region E	
		Selling Weight	Selling Weight	Selling Weight	Selling Weight	Selling Weight	Selling Weight
	Mo.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Steer	6	425	420	420	360		
Heifer	6	380	400	400	330		
Steer	12	520	520	520	460		
Heifer	12	460	500	500	420		
Steer	18	650	670	670	650		
Heifer	18	600	650	650	610		
Steer	24	800	820	820	800		
Heifer	24	760	800	800	760		
Cull Cow		1000	1000	1000	1000		

calf crop percentage can vary among the systems and between the regions. Thus, the quantity and the relationship among the products sold will fluctuate, but the types of beef products in each alternative's joint product will not vary.

The design of the beef production alternatives were based upon the following assumptions:

- (1) all beef products will be sold on October 1;
- (2) all spring calves will be born on April 1;
- (3) all fall calves will be born on October 1.

In addition, the calf crop percentage will always refer to the weaned calf crop. This percentage was calculated by dividing the number of weaned calves on October 1 by the number of brood cows on the appropriate calving date. Bulls were handled as a depreciable item and no allowance other than in the depreciation account was considered.

To allow easy identification of the quantity of a given product sold, the calf crop percentage and the region code will follow the identification code of the production alternative. If the production alternative, S1, six-month steers and heifers and cull cows, is being considered in the western region with an 85 percent calf crop, it will be identified as S185W.

Herd Unit of Production Alternatives

Associated with each production alternative is a herd unit. This unit includes all the necessary classes of livestock (i.e., replacement

heifers, calves, yearlings, etc.) required to produce the output of each alternative.

A herd unit is composed of two parts. The brood herd consists of cows, bulls, yearling replacement heifers, and replacement heifer calves. The remaining herd unit will fluctuate from season to season and depends upon the combination of products sold. Table IV indicates the class of livestock required for each product combination.

The herd unit relationships for the production alternatives were based upon the following assumptions:

- (1) the offspring of each herd unit will be 50 percent male with an allowed variation of one percent;
- (2) ten percent of the brood cows will be replaced annually from within the herd unit;
- (3) one bull can service 20 cows;
- (4) no animal death loss will occur after six months of age;
- (5) calf crop percentages will be between 80 and 95.

These assumptions allow the relationships among the livestock classes to be quantified. Once the calving percentage is known, the quantity of offspring entering each livestock class becomes well-defined. Each production alternative divides every calf crop into three categories--replacements, current products, and carryovers. This treatment is shown in Table V for three different calf crop percentages.

To complete the herd unit, only mature cows and bulls need to be included. The entire herd unit required for the production alternatives during each of the four seasons are shown in Appendix Tables I-III.

TABLE IV. HERD UNIT STRUCTURE BY CLASSES OF LIVESTOCK FOR SEVEN PRODUCTION ALTERNATIVES.

Product	:	:	:Replacement:	:Replacement:	:Yearling:	:	:	:	:
Combination:	Cows:	Bulls:	Yearling:	Heifer:	Yearling:	Heifer:	Steer:	Calves:	Calves:
			Heifers:	Calves:	Steers:	Heifers:	Calves:	Calves:	
S1	X	X	X	X	--	--	X	X	
S2	X	X	X	X	--	X	X	X	
S3	X	X	X	X	X	--	X	X	
S4	X	X	X	X	X	X	X	X	
F1	X	X	X	X	--	--	X	X	
F2	X	X	X	X	--	X	X	X	
F3	X	X	X	X	X	--	X	X	

TABLE V. PARTITIONING OF CALF CROP INTO INTENDED USE GROUPS FOR 80 PERCENT, 85 PERCENT, AND 90 PERCENT CALF CROPS.

	Current Calf Crop					Previous Year Calf Crop			
Production	Sell	Replacement	Carryover	Sell	Carryover	Replacement	Carryover		
Alternative	Steers	Heifers	Heifers	Steers	Heifers	Steers	Heifers	over Heifers	
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	
80% Calf Crop									
S180	40	30	10	x	x	x	x	10	
S280	40	x	10	x	30	x	30	10	
S380	x	30	10	40	x	40	x	10	
S480	x	x	10	40	30	40	30	10	
F180	40	30	10	x	x	x	x	10	
F280	40	x	10	x	30	x	30	10	
F380	x	30	10	40	x	40	x	10	
85% Calf Crop									
S185	43	32	10	x	x	x	x	10	
S285	43	x	10	x	32	x	32	10	
S385	x	32	10	43	x	43	x	10	
S485	x	x	10	43	32	43	32	10	
F185	43	32	10	x	x	x	x	10	
F285	43	x	10	x	32	x	32	10	
F385	x	32	10	43	x	43	x	10	
90% Calf Crop									
S190	45	35	10	x	x	x	x	10	
S290	45	x	10	x	35	x	35	10	
S390	x	35	10	45	x	45	x	10	
S490	x	x	10	45	35	45	35	10	
F190	45	35	10	x	x	x	x	10	
F290	45	x	10	x	35	x	35	10	
F390	x	35	10	45	x	45	x	10	

With the proportional relationships established among the livestock classes for each production alternative, the animal unit months of the herd unit in each time period were determined by Equation 3-6.

$$AU_{t=3} = \sum_{i=0}^N 3 \left(\frac{x_i}{1000} J_i \right) \quad 3-6$$

where: t = the season under consideration

i = the class of livestock on each ranch observation in time t

x_i = the average weight of the animal in livestock class i
during time period t

J_i = the number of animals in livestock class i

N = the number of livestock classes required in the
production alternative

This is the same procedure used to calculate animal unit months from the ranch observations. Using production alternative S180W in the summer time period as an example, the animal unit months would be determined by using Equation 3-6 as shown in Table VI. The animal unit months (AUM) in this table are for a three-month interval and represent the feed requirements of the herd unit used in this example. The animal unit months for the production alternatives are shown in Appendix Tables IV-VI for each season of the year.

Labor Requirements of Herd Units

The labor required for each production alternative in the four seasons was determined by using the appropriate regional labor coefficient

TABLE VI. ANIMAL UNIT MONTHS OF PRODUCTION ALTERNATIVE S180W DURING THE SUMMER TIME PERIOD.

<u>Herd Composition</u>	<u>:</u>	<u>Months</u>	<u>:</u>	<u>Weight-Based Approach</u>	<u>:</u>	<u>AUM</u>
Brood Cow		3		$[\frac{1000}{1000}(1)]$		3.000
Bull		3		$[\frac{1500}{1000}(.05)]$		.225
Calves		3		$[\frac{405}{1000}(.8)]$		.972
Replacement Heifer Yearlings		3		$[\frac{600}{1000}(.1)]$		<u>.180</u>
Total						4.377

as shown on page 29. The animal unit months per time period were multiplied by the corresponding regional labor coefficient. Again using the production alternative S180W as an example, the summer labor coefficient was found by:

Summer AUM = 4.377 (see Table VI, page 40)

Region W labor coefficient = .00581 month labor per AUM

$4.377 \times .00581 = .0254$ man month of labor

Feed Requirements of Herd Units

In all instances an animal unit equivalent of each spring production alternative required 12 animal unit months of feed. However, feed adjustments were made in the fall production alternatives.

If an animal were to calve in the fall, it must be bred in the middle of the Montana winter. To be assured that the desired conception rate of the fall alternatives could be obtained, the feed requirements were increased during the fall and winter months. The expected feed increase would be approximately 70 percent above normal for all mature cows. ^{31/} At this rate the amount of extra feed required during a three-month time period would be 2.1 animal unit months.

In the western and middle regions this recommendation was ascribed to. The fall feed requirement was increased 0.6 AUM and the winter feed was increased 1.68 AUM.

^{31/} Dr. O. O. Thomas, Animal Range and Science Department, Montana State University.

The normal feed pattern in the eastern region during the months of September, October, and November often causes mature cow weight loss. ^{32/} To counteract this trend, the fall feed for this region was increased by 1.00 AUM while the winter feed increase was maintained at 1.68 AUM.

Operating Capital of Herd Units

The capital required for each production alternative was based upon its animal unit months and the regional capital coefficient extracted from the primary data. The animal unit equivalents in each production alternative were multiplied times the cost per animal unit equivalent (page 28) to find total capital cost for each production alternative.

Total Revenue from Herd Units

The prices shown in Table II, page 31, were used in finding the total revenue for each production alternative. The total pounds of beef sold for each alternative depends upon the growth rate of the animals in each region and the calving percentage under investigation. The general Equation 3-7 was used to determine total revenue in the following manner:

$$TR = \sum_{i=0}^J P_a (A_i) P \quad 3-7$$

where: i = the type of product sold

P_a = the percent of calf crop allotted to the product

^{32/} M. J. Reed and R. A. Peterson, op. cit.

P = the price of the product

A_i = the average weight of product i

J = the products included in a production alternative

It is important to note that the price and weight of the cull cow does not vary among production alternatives. Regardless of the region and the calving percentage, 100 pounds of cull cow at \$14.60 per hundredweight is always included in the total revenue of every alternative. Table VII shows the pounds of each type of product sold and the associated price.

Appendix Tables VII-IX show the calculating procedure and the total revenue for all production alternatives in Regions W, M, and E, respectively.

TABLE VII. PRICE PER HUNDREDWEIGHT OF THE SELECTED PRODUCTS.

Product	Region W		Region M		Region E	
	Weight	Price/Cwt	Weight	Price/Cwt	Weight	Price/Cwt
	<u>Lbs.</u>	<u>Dol.</u>	<u>Lbs.</u>	<u>Dol.</u>	<u>Lbs.</u>	<u>Dol.</u>
6-mo. steer	425	28.76	420	28.85	360	29.87
6-mo. heifer	380	25.77	400	25.57	330	26.27
12-mo. steer	520	27.10	520	27.10	460	28.15
12-mo. heifer	460	24.97	500	24.47	420	25.37
18-mo. steer	650	25.15	670	25.10	650	25.15
18-mo. heifer	600	23.48	650	23.07	610	23.38
24-mo. steer	800	24.95	820	24.86	800	24.95
24-mo. heifer	760	22.30	800	22.00	760	22.30
Cull cow	1000	14.60	1000	14.60	1000	14.60

CHAPTER IV

OPTIMIZING MODELS

Linear programming was selected as the optimum procedure of maximizing profits of the selected beef alternatives subject to given resource constraints. Three models were designed to investigate the effects of different resources, of weaned calf crops, and of animal growth rates upon the selected production alternatives. Each model was sub-divided such that an optimal solution would be determined for all three regions in Montana. The objective function and the matrix of each model were composed of three distinct, noninteracting sections that specified the input-output structure for each region. The objective function of each model was structured as:

$$\begin{aligned} Q = & \$S1W + \$S2W + \$S3W + \$S4W + \$F1W + \$F2W + \$F3W + \$S1M + \\ & \$S2M + \$S3M + \$S4M + \$F1M + \$F2M + \$F3M + \$S1E + \$S2E + \\ & \$S3E + \$S4E + \$F1E + \$F2E + \$F3E - \$BSFW - \$BUFW - \$BFFW - \\ & \$BWFW - \$BWLW - \$BSLW - \$BULW - \$BFLW - \$BCW - \$BSFM - \\ & \$BUFM - \$BFFM - \$BWFM - \$BSLM - \$BULM - \$BFLM - \$BWLM - \\ & \$BCM - \$BSFE - \$BUFE - \$BFFE - \$BWFE - \$BSLE - \$BULE - \\ & \$BFLE - \$BWLE - \$BCE \end{aligned}$$

where: $\$S1W \dots \$F3W$ = the net profit from one herd unit of each production alternative in Region W

$\$S1M \dots \$F3M$ = the net profit from one herd unit of each production alternative in Region M

$\$S1E \dots \$F3E$ = the net profit from one herd unit of each production alternative in Region E

$\$BSFW \dots \BCW = the cost of purchasing an additional unit of a given resource beyond the initial constraint level in Region W

\$BSFM ... \$BCM = the cost of purchasing an additional unit of a given resource beyond the initial constraint level in Region M

\$BSFE ... \$BCE = the cost of purchasing an additional unit of a given resource beyond the initial constraint level in Region E

\$BSF = the cost of buying one unit of spring feed

\$BUF = the cost of buying one unit of summer feed

\$BFF = the cost of buying one unit of fall feed

\$BWF = the cost of buying one unit of winter feed

\$BSL = the cost of buying one unit of spring labor

\$BUL = the cost of buying one unit of summer labor

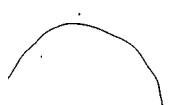
\$BFL = the cost of buying one unit of fall labor

\$BWL = the cost of buying one unit of winter labor

\$BC = the cost of buying one unit of capital

The net profit of each production alternative was determined by multiplying the cost per animal unit of the appropriate region by the number of annual animal units of the production alternative and subtracting this amount from the total revenue as derived on page 42 and as shown in Tables VII - IX of the Appendix.

The cost of buying resources was established by using observed and secondary data sources. The cost of hired labor was determined from the primary data. This cost was indicative of year-round labor and not temporary or day labor. Two values were assigned purchased feed. Spring, winter, and fall feeding periods can utilize stored feed, such as hay, straw, and grain. A minimum ration of 300 pounds of hay and 300 pounds



of straw per animal unit month was considered a reasonable ration for the short run. 33/

The primary data indicated a market price of \$25 a ton for hay was typical while the market price for straw, although not as well established was \$12 a ton. With the above hay and straw ration this results in a hay charge of \$3.75 and a straw charge of \$1.80 per animal unit month of feed. The purchase price for spring, winter, and fall feed was \$5.55 per animal unit month.

Purchased summer feed varies considerably in Montana depending upon whether private or public land is used. A private lease rate of \$4 per animal unit month was approximately the midpoint of the private grazing rate paid by the sample ranches. This charge was assigned in the models since most public grazing is presently allocated and not available as an additional forage source. The cost of borrowing capital was assigned an annual 8 percent rate. The initial resource constraints, the buying options, and the costs are shown in Table VIII.

The initial level of resource availability was established for each region from the primary data. The absolute level of each resource is not of prime importance, but the relative resource use among and within time periods is vital to the optimizing procedure of the linear program. There is no effect upon the optimal solution if the absolute level of all resources increase by the same multiple, but the proportional relationship among resources will effect which alternative is optimal for a given

33/ Daily Nutrient Requirements of Beef Cattle, National Academy of Sciences and National Research Council Publication, 1966, No. 1137, p. 2.

TABLE VIII. INITIAL RESOURCE CONSTRAINTS BY REGIONS FOR THE LINEAR PROGRAMMING MODELS.

Input	:	Region W	:	Region M	:	Region E
Winter feed		756 AUM		729 AUM		890 AUM
Spring feed		722 AUM		756 AUM		875 AUM
Summer feed		969 AUM		900 AUM		1100 AUM
Fall feed		771 AUM		890 AUM		870 AUM
Winter labor		3.0 mo. labor		3.0 mo. labor		3.0 mo. labor
Spring labor		3.0 mo. labor		3.0 mo. labor		3.0 mo. labor
Summer labor		3.0 mo. labor		3.0 mo. labor		3.0 mo. labor
Fall labor		3.0 mo. labor		3.0 mo. labor		3.0 mo. labor
Capital		\$10,000		\$14,500		\$14,250
<u>Buy</u>						
Input	Cost/Unit					
Winter feed	\$5.55	90 AUM		85 AUM		150 AUM
Spring feed	\$5.55	90 AUM		85 AUM		180 AUM
Summer feed	\$4.00	90 AUM		85 AUM		120 AUM
Fall feed	\$5.55	90 AUM		85 AUM		180 AUM
Winter labor	\$600	3.0 mo. labor		3.0 mo. labor		3.0 mo. labor
Spring labor	\$600	6.0 mo. labor		6.0 mo. labor		6.0 mo. labor
Fall labor	\$600	3.0 mo. labor		3.0 mo. labor		3.0 mo. labor
Capital	\$0.08	\$5,000		\$7,250		\$7,000

structure. Three observed ranch structures in each region were selected to establish the resource relationships in each region. This is referred to as the initial resource level.

These ranches were selected to establish the resource levels because of their relatively efficient use of resources among the observations. However, the resource levels established and shown in Table VIII for all resources purchased or otherwise are not representative of any one ranch. In particular, the buy activities would be applicable for only a limited number of ranches. The value of this approach which establishes resource levels is in the investigation of the effect the individual resource has upon the spring and fall production alternatives.

The input-output coefficients and the objective function were structured into the normal linear program tableau. This structure is shown in Table IX for one region of one model while the State structure is included in Appendix Table X. As the calving percentage changed from Model I to Model II to Model III, the input-output coefficients of the column vectors of the fall calving alternatives were revised to account for this adjustment.

Model I

This model was designed to investigate the effects of nine resource structures in the three regions of Montana with seven production alternatives. The calf crop for the production alternatives were identical--85 percent. Feed and labor were the constraining resources during each

TABLE IX. LINEAR PROGRAM REGIONAL MODEL FOR SEVEN PRODUCTION ALTERNATIVES (S1 ... F3) WITH NINE BUY ACTIVITIES (BSF ... BC).

Activities --		S1	S2	S3	S4	F1	F2	F3	BSF	BUF	BFF	BWF	BSL	BUL	BFL	BWL	BC																						
Maximize --		\$	+	\$	+	\$	+	\$	+	\$	-	C ₁	-	C ₂	-	C ₃	-	C ₄	-	C ₅	-	C ₆	-	C ₇	-	C ₈	-	C ₉											
Resource	Unit	P ₀																																					
Spring feed	AUM	R ₁	X ₁₁	X ₁₂	X ₁₃	X ₁₄	X ₁₅	X ₁₆	X ₁₇	-1																													
Summer feed	AUM	R ₂	X ₂₁	X ₂₂	X ₂₃	X ₂₄	X ₂₅	X ₂₆	X ₂₇	-1																													
Fall feed	AUM	R ₃	X ₃₁	X ₃₂	X ₃₃	X ₃₄	X ₃₅	X ₃₆	X ₃₇			-1																											
Winter feed	AUM	R ₄	X ₄₁	X ₄₂	X ₄₃	X ₄₄	X ₄₅	X ₄₆	X ₄₇			-1																											
Spring labor	AUM	R ₅	X ₅₁	X ₅₂	X ₅₃	X ₅₄	X ₅₅	X ₅₆	X ₅₇				-1																										
Summer labor	AUM	R ₆	X ₆₁	X ₆₂	X ₆₃	X ₆₄	X ₆₅	X ₆₆	X ₆₇					-1																									
Fall labor	AUM	R ₇	X ₇₁	X ₇₂	X ₇₃	X ₇₄	X ₇₅	X ₇₆	X ₇₇						-1																								
Winter labor	AUM	R ₈	X ₈₁	X ₈₂	X ₈₃	X ₈₄	X ₈₅	X ₈₆	X ₈₇								-1																						
Capital	Dol	R ₉	X ₉₁	X ₉₂	X ₉₃	X ₉₄	X ₉₅	X ₉₆	X ₉₇	-C ₁	-C ₂	-C ₃	-C ₄	-C ₅	-C ₆	-C ₇	-C ₈	-1																					
Purchase SF	AUM	R _{1a}										+1																											
Purchase UF	AUM	R _{2a}										+1																											
Purchase FF	AUM	R _{3a}												+1																									
Purchase WF	AUM	R _{4a}												+1																									
Purchase SL	AUM	R _{5a}														+1																							
Purchase UL	AUM	R _{6a}																+1																					
Purchase FL	AUM	R _{7a}																	+1																				
Purchase WL	AUM	R _{8a}																				+1																	
Purchase C	Dol	R _{9a}																							+1														

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time period to isolate the effects of these resources. Operating capital was used to constrain annual output and was not used as a seasonal constraint. The resource structure of Model I was adjusted by sequentially decreasing the resource level in all regions. This was accomplished by decreasing capital and feed resources approximately one-third. Labor constrained output when the buying option was discontinued for each time period. Labor resources were never below three man months for any time period. As each resource level was decreased, all other resources were restored to the initial level. These structural changes are shown in Table X.

Model II

This model was designed to investigate the effect of an increased fall calf crop upon the optimal solutions. Previous research has indicated that fall calving experiences lower death loss at birth than spring calving. ^{34/} This model was structured to investigate the feasibility of discontinuing spring calving practices when a 5 percent increase in the calf crop was expected for fall production alternatives. The nine resource structures will be maintained in this model to examine calf crop differences under various resource conditions. The three regions of Montana are included in this model for the above production resource structure.

^{34/} R. G. Mueller and G. A. Harris, op. cit., p. 69.

TABLE X. ADJUSTMENTS OF RESOURCE CONSTRAINTS BY REGIONS.

Resource Investigated	Nine Resource Structures Investigated					
	Region W Resource Change		Region M Resource Change		Region E Resource Change	
	: From	: To	: From	: To	: From	: To
	AUM	AUM	AUM	AUM	AUM	AUM
Winter feed	756	500	729	480	890	600
Spring feed	722	480	756	500	875	600
Summer feed	969	645	900	600	1100	700
Fall feed	771	520	890	600	870	600
Buy winter labor	3	0	3	0	3	0
Buy spring labor	3	0	3	0	3	0
Buy summer labor	6	0	6	0	6	0
Buy fall labor	3	0	3	0	3	0
Buy capital	\$10,000	\$6,000	\$14,500	\$9,600	\$14,250	\$9,500

In addition to investigating the results of an increase in the fall calf crop, the fall calf growth rate will also be adjusted. The weight base approach (Barr, Plaxico, et al.) which is used to determine animal unit months in this study does not distinguish differences in the animals. The resource requirements are based upon the total weight of the animals in the production alternatives. If the animal unit months of a production alternative are evaluated by this approach, the resource requirement for 90 percent of a 500-pound animal or for 85 percent of a 529-pound animal would be identical. This means the resource requirements of an increased calf crop would be the same if a lesser calf crop will produce heavier animals. The objective of this adjustment is to be able to compare the results of Models II and III to those of Model I. If a change in the optimal solution occurs by increasing the fall calf crop in Models II and III, then the same optimal solution will occur in Model I if the fall calves weigh more.

To make this comparison, the total revenue of a given production alternative must be maintained. This was accomplished by allowing a vertical shift in the price-weight schedule previously established on page 31. The selling price of a 500-pound animal and a 529-pound animal must be identical before the results of this model can be compared in this manner. This price shift is not an unrealistic adjustment. This author found from the primary data that the prices for different weight beef products did not necessarily follow weight fluctuations of less than 50 pounds. This adjustment is of considerable value to a range-livestock

entrepreneur who is considering fall calving. Rather than face a choice of being able to increase his fall calf crop 10 percent over the spring calf crop or not to attempt fall calving, he has a choice of increasing the fall calf crop only 5 percent if he can produce heavier calves than the initial fall animal growth curve. This approach provides meaningful results concerning fall calving to a rancher who produces a 95 percent spring calf crop and could not expect much additional improvement in his fall calf crop.

Model III

This model is an extension of Models I and II. The fall calf crop was increased to 95 percent, while the spring calf crop was maintained at 85 percent. The nine resource structures were used to investigate the optimal fall and spring alternatives as in Model I. The purpose of this model was to broaden the applications of the calf crop percentage versus weight increase adjustments.

CHAPTER V

CONCLUSIONS AND RESULTS OF LINEAR PROGRAMMING MODELS

Results of Feed Resource Constraints

Region W

The effect of changes in the feed resources were investigated to establish the relative profit position of fall and spring calving production alternatives in each situation. The importance of each feed resource for the fall calving alternatives was established by constraining each resource sequentially and utilizing the sensitivity analysis provided as part of the linear programming reports.

In this region, the results indicated that ample winter feed was an important input if fall calving is to be practiced. A fall calf crop 10 percent higher than a spring calf crop with the same resource situation, was returning \$20 less profit per brood cow because winter feed constrained output. Fifty percent of the region's sampled observations specified that the water supply for hay production restricted the realization of the ranch's full hayland producing potential. This indicated that caution should be exercised before accepting fall calving in western Montana where the winter feed base is primarily hay.

After the first of the year, winter and spring are often one in the same in Montana. The weather determines the length of time the livestock must rely on the stored feed supply. The ranches surveyed in Region W indicated that spring feed availability was considered when optimizing

production, and 15 percent specified spring feed as the primary resource constraining output.

The production of six-month calves, which is the traditional spring alternative, is the optimal solution in this region if spring feed is the limiting resource. The sensitivity analysis indicates that fall calving would not be optimal when the spring feed resource constrained output unless the fall calf crop could be 15 percent higher than the spring calf crop. This 15 percent increase in the fall calf crop is not the only condition which would cause the production of fall products to be optimal when spring feed constrains production. An identical profit position could be obtained by reducing the difference in fall and spring calf crop to zero and increasing the selling weights of the fall products by the adjustment procedure shown on pages 50-53. Table XI shows the weight, price, and calf crop relationship necessary if the fall calving alternatives were to be more profitable than the spring alternatives when spring feed constrains output. The profit returns of the fall alternatives decreases as alternatives F3, F2, and F1 are produced in this respective order.

Shortages of summer feed was reported as the primary resource problem in 50 percent of the observations. With this resource constraining output, fall calving was more applicable than in any other feed constraining situation. However, fall calving was not included in the optimal solution when all calf crops are the same. With a 5 percent increase in the fall calf crop, a combination of spring and fall alternatives was the optimal solution. This solution produced:

TABLE XI. ADJUSTMENTS IN FALL PRODUCTION ALTERNATIVES NECESSARY IF THE FALL ALTERNATIVES ARE TO BE OPTIMAL WHEN COMPARED WITH 85 PERCENT SPRING CALF CROPS AS SPRING FEED CONSTRAINS OUTPUT.

				:Increase in Fall Calf Selling Weights :for Four Fall Calf Crop Percentages :Fall Calf Crop Percentages above 85 :Percent Spring Calf Crop			
Price Per Cwt:	Initial:			15%	10%	5%	0%
of Product	Weight:	Products					
<u>Dol.</u>	<u>Lbs.</u>			<u>Lbs.</u>			
27.10	520	12-mo. steer	520	556	581	620	
24.97	460	12-mo. heifer	460	486	531	567	
24.95	800	24-mo. steer	800	853	893	960	
22.30	760	24-mo. heifer	760	803	878	937	

20,983.2 lbs. of 6-month steers @ \$28.75/cwt
22,015.1 lbs. of 18-month heifers @ \$23.48/cwt
2,971.6 lbs. of 12-month steers @ \$27.10/cwt
3,377.9 lbs. of 24-month heifers @ \$22.30/cwt
12,736.1 lbs. of cull cows @ \$14.60/cwt

which returned \$7,139.09 of net profit.

When the fall calf crop was 95 percent and the spring calf crop was maintained at 85 percent, the optimal solution shifted to another fall alternative because of the 1 percent advantage given steers when the 95 percent calf crop was split into 48 percent steers and 47 percent heifers.

This solution produced:

20,803.3 lbs. of 6-month steers @ \$28.75/cwt
21,826.4 lbs. of 18-month heifers @ \$23.48/cwt
2,142.5 lbs. of 12-month heifers @ \$24.97/cwt
4,839.6 lbs. of 24-month steers @ \$24.95/cwt

which returned \$7,211.11 of profit. This minor net difference would probably not be sufficient reason to note production pattern shifts for the study population.

Limited summer feed resources are common to many Montana ranches. Many ranchers have thought this constraint to be the limiting factor which prohibits the practice of fall calving in this region. Their intuition appears partially correct. Fall calves will consume more summer feed than spring calves. This means that with the same set of resources the fall brood herd will be smaller than the spring brood herd. However, this does not imply, as ranchers believe, that profit must also decrease. On the

contrary, this study has shown that the optimal fall calving alternative would be more profitable with a smaller brood herd than the most profitable spring alternative.

If the fall calf crop is equal to the spring calf crop, the minimum selling weights of the fall products must be:

585 lbs. for 12-month steers

530 lbs. for 12-month heifers

895 lbs. for 24-month steers

880 lbs. for 24-month heifers

if fall calving is to be optimal in the western region when summer feed constrains output. These weights do not appear to be extremely high as D. P. Fabrick produces 625-pound steer calves at 13 months of age. ^{35/}

The optimal spring alternative when fall and winter feed constrained output was the production of six-month steers and 18-month heifers which is not a typical product combination in western Montana. However, all of the spring alternatives were near the optimal solution and quite sensitive to price changes.

The profit difference between spring alternatives was expected to be minimal as many product combinations are prevalent in this region. In addition, it is suspected that the prices used in this study, Billings Livestock Market, reflected a feeder and a replacement heifer value for

^{35/} D. P. Fabrick, op. cit.

the 18-month heifer while the other products' prices reflect only a feeder value. Given that the price of the 18-month heifer is only 10 cents per hundred pounds above the actual value of a feeder heifer, the optimal alternative would be the production of six-month calves. This is the most common product in Region W. Table XII summarizes the optimal alternatives for the three linear programming models for each feed constraint in this region.

It is necessary to point out that although fall calving would be the most profitable, given the summer feed conditions of these models, it is also true that the traditional spring calving practice of producing six-month calves is very near optimal. If the fall alternatives would require winter shelter to be constructed and the cost of this is not included in the model, then the traditional spring alternative would probably be more profitable. The primary result indicates for this region that summer feed constraints do not eliminate the fall calving alternatives, but the choice of producing fall or spring calves in western Montana depends upon the winter feed and livestock protection facilities either natural or constructed which must be available on the ranch. In addition it was found that the spring feed constraint caused the spring alternatives in the models to be relatively more profitable than the fall alternatives, the converse, if a fall feed constraint causing the fall alternatives to be relatively more profitable, is not true.

TABLE XII. RESOURCE USE AND PROFIT OF OPTIMAL PRODUCTION ALTERNATIVES IN REGION W FOR THE THREE LINEAR PROGRAMMING MODELS WHEN FEED RESOURCES CONSTRAIN OUTPUT.

Resource: : Optimal Activity	Profit:	Cost:	AUM Used				Month Labor Used				Resource
	:	:	:	:	:	:	:	:	:	:	Constraint
	:	:	WFED	SPEED	SUFED	FEED	WLAB	SPLAB	SULAB	FLAB	:
	Dol.	Dol.	:	:	:	:	:	:	:	:	:
Model I											
S285W	7285.26	7598.36	500.000	514.312	664.325	494.567	2.902	2.995	3.856	2.876	Winter feed
S185W	6903.69	7077.49	470.204	480.000	629.920	468.926	2.726	2.783	3.663	2.726	Spring feed
S285W	7125.54	7324.96	485.455	499.351	645.000	480.180	2.918	2.908	3.744	2.792	Summer feed
S285W	7432.47	8216.68	525.713	540.761	698.489	520.000	3.051	3.149	4.065	3.024	Fall feed
Model II											
S285W	7285.26	7598.36	500.000	514.312	664.325	494.567	2.902	2.995	3.856	2.876	Winter feed
S185W	6903.69	7077.49	470.204	480.000	629.920	468.926	2.726	2.783	3.663	2.726	Spring feed
S285W & F290W	7139.09	7482.72	516.825	511.316	645.000	485.216	3.000	2.976	3.744	2.821	Summer feed
S285W	7432.47	8216.68	525.713	540.761	698.489	520.000	3.051	3.149	4.065	3.024	Fall feed
Model III											
S285W	7285.26	7598.36	500.000	514.312	664.325	494.567	2.902	2.995	3.856	2.876	Winter feed
S185W	6903.69	7077.49	470.204	480.000	629.920	468.926	2.726	2.783	3.663	2.726	Spring feed
S285W & F395W	7211.11	7482.60	516.856	511.854	645.000	484.644	3.000	2.980	3.744	2.817	Summer feed
S285W	7432.47	8216.68	525.713	540.761	698.489	520.000	3.051	3.149	4.065	3.024	Fall feed

Region M

Summer and winter feed are the key resources in this region. They affected the production alternatives to a greater degree than any other resources. As winter feed constrained output, the fall calving alternatives were the least profitable in all models. Increasing the fall calf crop from 85 percent to 90 percent to 95 percent caused the fall alternatives to enter the optimal solution only when summer feed constrained output. Under this resource constraint, Model II selected an optimal solution comprised of alternatives S285M and F390M. This joint product required 53 percent of the brood herd to calve in the fall. The products of this solution were:

10,783.8 lbs. of 6-month steers	@ \$28.85/cwt
12,392.4 lbs. of 18-month heifers	@ \$23.07/cwt
8,795.5 lbs. of 12-month heifers	@ \$24.47/cwt
18,545.9 lbs. of 24-month steers	@ \$24.86/cwt
10,983.9 lbs. of cull cow	@ \$14.60/cwt

which produced \$6,893.56 of profit.

As summer feed constrained output, the fall alternative that was composed of 12-month heifers and 24-month steers was the optimal solution when the 85 percent spring calf crop was compared to 95 percent fall calf crops. This solution produced \$7,191.42 of profit with 99 brood cows. If the resource levels were duplicated the output and the brood herd would be exactly doubled and 198 brood cows would produce \$14,382.84 of profit. The production from this solution was:

18,337.9 lbs. of 12-month heifers @ \$24.47
39,054.9 lbs. of 24-month steers @ \$24.86
9,912.4 lbs. of cull cow @ \$14.60

The initial selling weight of the fall products were:

12-month steer	520 lbs.
12-month heifer	500 lbs.
24-month steer	820 lbs.
24-month heifer	800 lbs.

If the fall calf crop could not be expected to be 5 percent higher than the spring calf crop as summer feed constrained output, the results of Model II would be the same if the selling weights of the products were:

12-month steer	544 lbs.
12-month heifer	547 lbs.
24-month steer	858 lbs.
24-month heifer	875 lbs.

This situation which presents the heifer weights as heavier than the steer weights is improbable, but the relationship would still have to hold if the results of Model II were desired when the fall calf crop could not be increased.

Table XIII summarizes the profit analysis of the seven production alternatives in Region M. This sensitivity analysis does reflect the effects of the resource constraint upon each alternative. Activity S1, which produces six-month steers and heifers, returns more profit than any other nonoptimal production alternative when spring feed constrains output.

TABLE XIII. SUMMARY OF THE PROFIT CHANGE REQUIRED FOR THE HERD UNIT IF A PRODUCTION ALTERNATIVE IN REGION M WAS TO BE IN THE OPTIMAL SOLUTION.

Activity	:	Change in Profit Required per Herd Unit Before												
	:	Activity Would Enter Optimal Solution												
Constraining	:	:	:	:	:	:	:	:	:	:	:	:	:	
Resource	:	S1	:	S2	:	S3	:	S4	:	F1	:	F2	:	F3
-----Dol.-----														
Model I														
Winter feed		0.53		0.00		0.55		3.82		32.41		32.81		29.63
Spring feed		0.24		0.00		0.91		5.24		14.29		15.43		12.47
Summer feed		0.88		0.00		0.62		4.33		5.12		5.43		2.18
Fall feed		0.63		0.00		0.59		4.11		17.90		18.35		15.01
Model II														
Winter feed		0.53		0.00		0.55		3.82		27.55		27.97		24.63
Spring feed		0.24		0.00		0.91		5.24		9.52		10.76		7.64
Summer feed		0.85		0.00		0.62		4.29		3.04		3.38		0.00
Fall feed		0.63		0.00		0.59		4.11		12.77		12.85		9.90
Model III														
Winter feed		0.53		0.00		0.55		3.82		22.27		22.70		19.10
Spring feed		0.24		0.00		0.91		5.24		4.33		5.63		2.30
Summer feed		1.21		0.38		1.00		4.66		3.15		3.58		0.00
Fall feed		0.63		0.00		0.59		4.11		7.33		7.73		4.21

This is explained by the minimum herd size of this alternative during the spring time period. It was also expected that when fall feed constrains output, the fall alternatives would be the more profitable production alternatives, since the fall brood herd would be at a minimum at that time. However, this is not the case. The shortage of fall feed on a ranch in Region M does not imply that fall calving should be practiced. The reduction of the spring herd unit by selling the beef products in the fall apparently requires less feed during this time period than the fall alternatives.

In Region M, the spring alternatives were sensitive to price changes with the exception of the long-yearling-18-month-production alternative. Generally any of the other spring alternatives could be recommended for this region. As in Region W the price of the 18-month heifer probably reflects a feeder and a replacement heifer value and causes this product to be more profitable than normally expected by ranchers in this area. Winter feed followed the same discrimination pattern against the production of fall products in Region M. The resource use, the profit, and the cost of the optimal solutions in Region M are summarized in Table XIV.

Region E

In this Great Plains region, the production of 18-month steers and heifers, long-yearlings, was the optimal production alternative. This spring production alternative was clearly the optimal solution in this region for all resource structures. A fall alternative did combine with

TABLE XIV. RESOURCE USE AND PROFIT OF OPTIMAL PRODUCTION ALTERNATIVES IN REGION M FOR THE THREE LINEAR PROGRAMMING MODELS WHEN FEED RESOURCES CONSTRAIN OUTPUT.

Resource: Optimal Activity	Profit: Cost		AUM Used				Month Labor Used				Resource Constraint
	Dol.	Dol.	WFED	SPFED	SUFED	FFED	WLAB	SPLAB	SULAB	FLAB	
Model I											
S285M	7072.72	7329.53	480.000	494.180	638.704	473.351	2.497	2.572	3.000	2.472	Winter feed
S285M	7134.60	7437.25	485.656	500.000	646.230	478.929	2.526	2.602	3.364	2.501	Spring feed
S285M	6753.54	6776.21	450.913	464.231	600.000	444.667	2.345	2.416	3.123	2.322	Summer feed
S285M	8149.22	10106.95	608.428	626.398	809.594	600.000	3.165	3.260	4.214	3.133	Fall feed
Model II											
S285M	7072.72	7329.53	480.000	494.180	638.704	473.351	2.497	2.572	3.000	2.472	Winter feed
S285M	7134.50	7437.25	485.656	500.000	646.230	478.929	2.526	2.602	3.364	2.501	Spring feed
S285M & F390M	6893.41	7442.93	576.350	513.322	600.000	464.380	3.000	2.674	3.127	2.420	Summer feed
S285M	8149.22	10106.95	608.428	626.398	809.594	600.000	3.165	3.260	4.214	3.133	Fall feed
Model III											
S285M	7072.72	7329.53	480.000	494.180	638.704	473.351	2.497	2.572	3.000	2.472	Winter feed
S285M	7134.60	7437.25	485.656	500.000	646.230	478.929	2.526	2.602	3.364	2.501	Spring feed
F395M	7191.42	8452.54	697.935	562.531	600.000	477.581	3.638	2.934	3.122	2.488	Summer feed
S285M	8149.22	10106.95	608.428	626.398	809.594	600.000	3.165	3.260	4.214	3.133	Fall feed

this solution as the fall calf crop was increased to 95 percent. This optimal solution occurred when summer feed constrained output and it required that 16 percent of the brood herd calve in the fall. This product combination produced \$8,559.56 of profit from:

21,376.4 lbs. of 18-month steers @ \$25.15/cwt

20,040.4 lbs. of 18-month heifers @ \$23.38/cwt

3,013.4 lbs. of 12-month heifers @ \$25.37/cwt

7,465.3 lbs. of 24-month steers @ \$24.95/cwt

12,221.2 lbs. of cull cow @ \$14.60/cwt

The linear program which selected this spring-fall alternative combination did not include all the factors of production in eastern Montana. One factor in particular must be noted. This is winter protection. This factor has been assumed as prevalent on all ranches. If winter protection had to be constructed for 16 percent of the brood herd, the fall alternative could remain in the optimal solution only if the construction costs were minimal. Many ranches in this region estimate that the cost of adequate shelter would prohibit fall calving. In addition, if winter shelter were required for the fall calves, then the winter range could not be utilized by the fall brood herd, since they would be restricted to an area near the shelter. Thus, fall calving in eastern Montana would require a shift to a different winter feed source such as hay.

The observed ranches in this region did not use the optimal alternative of selling 18-month yearlings per se. They combined yearling and calf

products. However, yearling products are more common to this area than indicated by the primary data. During 1965 the surveyed counties in this region produced 130 percent more yearlings than calves. 36/ This has not been the traditional practice over the decades. Until 1961 the number of calves and number of yearlings sold in this area were approximately equal. 37/ During 1962 the number of yearlings and calves sold dropped to 95,088 which was considerably less than the previous year's total of 124,375. 38/ Since 1964, the number of yearlings sold have exceeded the number of calves sold. 39/ From observing ranches in this region in 1967 it appears that a structural change is still taking place.

Calf production is preferred by some ranches because of the unpredictable nature of winter weather and limited hay supplies. If winter range was not accessible due to heavy winter snows, a rancher with only the brood herd demanding feed is in a relatively better position than a rancher with cows and calves demanding care and feed.

The summary of profit, feed use, labor use, and operating costs are shown in Table XV for the optimal alternatives in each model.

36/ Montana Agricultural Statistics, op. cit., pp. 78-79.

37/ Ibid., Vol. IX, 1962, pp. 82-83.

38/ Ibid.

39/ Ibid., Vol. X, 1964, pp. 78-79.

TABLE XV. RESOURCE USE AND PROFIT OF OPTIMAL PRODUCTION ALTERNATIVE IN REGION E FOR THE THREE LINEAR PROGRAMMING MODELS WHEN FEED RESOURCES CONSTRAIN OUTPUT.

Resource \ Activity	Profit: Cost		AUM Used				Month Labor Used				Resource Constraint
	Dol.	Dol.	WFED	SPFED	SUFED	FFED	WLAB	SPLAB	SULAB	FLAB	
Model I											
S485E	9133.87	9301.06	600.000	613.177	838.704	453.351	3.162	3.387	4.234	3.091	Winter feed
S485E	8894.50	8272.51	558.729	600.000	750.756	546.506	2.944	3.154	3.943	2.878	Spring feed
S485E	8501.26	7505.15	520.956	559.436	700.000	509.559	2.745	2.941	3.676	2.694	Summer feed
S485E	9178.52	9670.13	613.420	658.730	824.242	600.000	3.232	3.463	4.329	3.160	Fall feed
Model II											
S485E	9133.87	9301.06	600.000	613.177	838.704	453.351	3.162	3.387	4.234	3.091	Winter feed
S485E	8894.50	8272.51	558.729	600.000	750.756	546.506	2.944	3.154	3.943	2.878	Spring feed
S485E	8501.26	7505.15	520.956	559.436	700.000	509.559	2.745	2.941	3.676	2.694	Summer feed
S485E	9178.52	9670.13	613.420	658.730	824.242	600.000	3.232	3.463	4.329	3.160	Fall feed
Model III											
S485E	9133.87	9301.06	600.000	613.177	838.704	453.351	3.162	3.387	4.234	3.091	Winter feed
S485E	8894.50	8272.51	558.729	600.000	750.756	546.506	2.944	3.154	3.943	2.878	Spring feed
S485E & F395E	8559.56	7774.18	569.544	575.006	700.000	527.521	3.000	3.023	3.678	2.778	Summer feed
S485E	9178.52	9670.13	613.420	658.730	824.242	600.000	3.232	3.463	4.329	3.160	Fall feed

Results of Labor and Capital Constraints

The purpose of this study was to investigate the effects of labor, capital, as well as feed as the constraining resource for output during a given time period. This was accomplished by surveying ranches with competent management to establish input-output coefficients which were assumed to be at a profit maximizing position for spring calving operations.

As mentioned previously in this study, the ranch labor required for a given observation depended upon the age, health, and the capital investments of the entrepreneur. Adjustments were made to discount the variance of labor use as these factors were combined in many forms. Because of this adjustment an annual average man-month labor requirement was used instead of a seasonal labor requirement.

The annual average labor coefficient was used in the models to determine the labor required per animal unit equivalent. Unfortunately, this approach in a linear programming model results in duplicate optimal solutions for a given time period. The feed input and labor input were both based upon the animal unit equivalents. These inputs were multiples of each other in all systems, where resource requirements were found by multiplying the regional coefficients times the animal unit equivalents. This procedure produced identical results for feed, labor, and capital. Only the feed resource effects have been discussed because they are most applicable.

The method of calculating animal unit equivalents based on animal weights is not an unreasonable approach to determine the feed requirements. However, this use of animal unit equivalents--even if the known labor coefficients are proportionally correct--between time periods is not recommended for further use in a study of this type. The comparison of selected beef production alternatives should have the labor coefficient established for a herd system unit or a class of livestock and not necessarily based on the same animal unit weight equivalents. This could have been done in a study such as this if the proportional labor requirement for each class of livestock (i.e., cow, bull, yearling) were known for all time periods.

Implications for Further Research

The linear programming model as designed in this thesis is recommended for further studies concerned with the range-livestock industry. The method of establishing input-output relationships needs additional research and refinement. This study investigated seven of the many possible production alternatives. Further research into the optimal proportional relationship among calf and yearling products for spring and fall alternatives should be investigated. The most profitable product combination among the fall alternatives for all feed resource structures included beef products greater than 12 months of age. This possibility has not been previously advocated as part of the flexibility of producing fall products.

The effect upon profits when fall products are sold in the spring and summer time periods warrants investigation. Although beef prices tend to vary during the year, ranchers presently producing fall products have not chosen to sell except in the fall. This may be due to market structures as well as price fluctuations. Several fall and spring production alternatives should be considered with more than one price structure for two or three time periods.

Further investigation into resource use and alternative methods of acquiring these resources is needed. In particular, research into rangeland improvements or substitutes for rangeland is suggested.

APPENDIX

APPENDIX TABLE I. HERD UNITS BY SEASON FOR 80 PERCENT CALF CROP.

		Current Year Calf Crop					Previous Year Calf Crop				
		Sell	Replace-	Carryover			Sell	Carryover			
Production :			ment						Replacement:		
Alternative:	Steer:	Heifer:	Heifer	Steer :	Heifer :	Steer :	Heifer :	Heifer :	Cow :	Bull	
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	
Spring											
S180	40	30	10	--	--	--	--	10	100	5	
S280	40	--	10	--	30	--	30	10	100	5	
S380	--	30	10	40	--	40	--	10	100	5	
S480	--	--	10	40	30	40	30	10	100	5	
F180	40	30	10	--	--	--	--	10	100	5	
F280	40	--	10	--	30	--	30	10	100	5	
F380	--	30	10	40	--	40	--	10	100	5	
Summer											
S180	40	30	10	--	--	--	--	10	100	5	
S280	40	--	10	--	30	--	30	10	100	5	
S380	--	30	10	40	--	40	--	10	100	5	
S480	--	--	10	40	30	40	30	10	100	5	
F180	40	30	10	--	--	--	--	10	100	5	
F280	40	--	10	--	30	--	30	10	100	5	
F380	--	30	10	40	--	40	--	10	100	5	
Fall											
S180	--	--	10	--	--	--	--	--	100	5	
S280	--	--	10	--	30	--	sold	--	100	5	
S380	--	--	10	40	--	sold	--	--	100	5	
S480	--	--	10	40	30	sold	sold	--	100	5	
F180	--	--	10	--	--	--	--	--	100	5	
F280	--	--	10	--	30	--	sold	--	100	5	
F380	--	--	10	40	--	sold	--	--	100	5	

(table continued)

APPENDIX TABLE I. (continued) HERD UNITS BY SEASON FOR 80 PERCENT CALF CROP.

Current Year Calf Crop					Previous Year Calf Crop				
Sell			Replace-		Carryover		Sell Carryover		
Production :			:ment		:		:Replacement:		
Alternative:	Steer:	Heifer:	Heifer	:	Steer :	Heifer :	Steer :	Heifer :	Cow : Bull
	Pct.	Pct.	Pct.		Pct.	Pct.	Pct.	Pct.	Pct. Pct.
Winter									
S180	--	--	10	--	--	--	--	--	100 5
S280	--	--	10	--	--	--	--	--	100 5
S380	--	--	10	40	--	--	--	--	100 5
S480	--	--	10	40	--	--	--	--	100 5
F180	--	--	10	--	--	--	--	--	100 5
F280	--	--	10	--	--	--	--	--	100 5
F380	--	--	10	40	--	--	--	--	100 5

APPENDIX TABLE II. HERD UNIT BY SEASON FOR 85 PERCENT CALF CROP.

Production Alternative:	Current Year Calf Crop					Previous Year Calf Crop				
	Sell		Replace-	Carryover		Sell		Carryover:		
	ment					Replacement:				
	Steer:	Heifer:	Heifer	Steer	Heifer	Steer	Heifer	Heifer	Cow	Bull
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Spring										
S185	43	32	10	--	--	--	--	10	100	5
S285	43	--	10	--	32	--	32	10	100	5
S385	--	32	10	43	--	43	--	10	100	5
S485	--	--	10	43	32	43	32	10	100	5
F185	43	32	10	--	--	--	--	10	100	5
F285	43	--	10	--	32	--	32	10	100	5
F385	--	32	10	43	--	43	--	10	100	5
Summer										
S185	43	32	10	--	--	--	--	10	100	5
S285	43	--	10	--	32	--	32	10	100	5
S385	--	32	10	43	--	43	--	10	100	5
S485	--	--	10	43	32	43	32	10	100	5
F185	43	32	10	--	--	--	--	10	100	5
F285	43	--	10	--	32	--	32	10	100	5
F385	--	32	10	43	--	43	--	10	100	5
Fall										
S185	sold	sold	10	--	--	--	--	--	100	5
S285	sold	--	10	--	32	--	sold	--	100	5
S385	--	sold	10	43	--	sold	--	--	100	5
S485	--	--	10	43	32	sold	sold	--	100	5
F185	sold	sold	10	--	--	--	--	--	100	5
F285	sold	--	10	--	32	--	sold	--	100	5
F385	--	sold	10	43	--	sold	--	--	100	5

(table continued)

APPENDIX TABLE II. (continued) HERD UNIT BY SEASON FOR 85 PERCENT CALF CROP..

Production : Alternative:	Current Year Calf Crop					Previous Year Calf Crop				
	Sell	Replace-	ment	Carryover		Sell	Carryover			
	Steer	Heifer	Heifer	Steer	Heifer	Steer	Heifer	Heifer	Cow	Bull
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Winter										
S185	--	--	10	--	--	--	--	--	100	5
S285	--	--	10	--	32	--	--	--	100	5
S385	--	--	10	43	--	--	--	--	100	5
S485	--	--	10	43	32	--	--	--	100	5
F185	--	--	10	--	--	--	--	--	100	5
F285	--	--	10	--	32	--	--	--	100	5
F385	--	--	10	43	--	--	--	--	100	5

APPENDIX TABLE III. HERD UNIT BY SEASON FOR 90 PERCENT CALF CROP.

Production : Alternative:	Current Year Calf Crop					Previous Year Calf Crop				
	Sell		Replace- ment		Carryover		Sell Carryover		Replacement	
	Steer	Heifer	Heifer	Steer	Heifer	Steer	Heifer	Heifer	Cow	Bull
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Spring										
S190	45	35	10	--	--	--	--	10	100	5
S290	45	--	10	--	35	--	35	10	100	5
S390	--	35	10	45	--	45	--	10	100	5
S490	--	--	10	45	35	45	35	10	100	5
F190	45	35	10	--	--	--	--	10	100	5
F290	45	--	10	--	35	--	35	10	100	5
F390	--	35	10	45	--	45	--	10	100	5
Summer										
S190	45	35	10	--	--	--	--	10	100	5
S290	45	--	10	--	35	--	35	10	100	5
S390	--	35	10	45	--	45	--	10	100	5
S490	--	--	10	45	35	45	35	10	100	5
F190	45	35	10	--	--	--	--	10	100	5
F290	45	--	10	--	35	--	35	10	100	5
F390	--	35	10	45	--	45	--	10	100	5
Fall										
S190	sold	sold	10	--	--	--	--	--	100	5
S290	sold	--	10	--	35	--	sold	--	100	5
S390	--	sold	10	45	--	sold	--	--	100	5
S490	--	--	10	45	35	sold	sold	--	100	5
F190	sold	sold	10	--	--	--	--	--	100	5
F290	sold	--	10	--	35	--	sold	--	100	5
F390	--	sold	10	45	--	sold	--	--	100	5

(table continued)

APPENDIX TABLE III. (continued) **HERD** UNIT BY SEASON FOR 90 PERCENT CALF CROP.

		Current Year Calf Crop				Previous Year Calf Crop					
		Sell		Replace-	Carryover	Sell		Carryover			
Production :	:	:	ment	:	:	:	:	Replacement:	:	:	:
Alternative:	Steer:	Heifer:	Heifer	:	Steer :	Heifer :	Steer :	Heifer :	Heifer :	Cow :	Bull
	<u>Pct.</u>	<u>Pct.</u>	<u>Pct.</u>		<u>Pct.</u>	<u>Pct.</u>	<u>Pct.</u>	<u>Pct.</u>	<u>Pct.</u>	<u>Pct.</u>	<u>Pct.</u>
Winter											
S190	--	--	10		--	--	--	--	--	100	5
S290	--	--	10		--	35	--	--	--	100	5
S390	--	--	10		45	--	--	--	--	100	5
S490	--	--	10		45	35	--	--	--	100	5
F190	--	--	10		--	--	--	--	--	100	5
F290	--	--	10		--	35	--	--	--	100	5
F390	--	--	10		45	--	--	--	--	100	5

APPENDIX TABLE IV. ANIMAL UNIT MONTHS FOR HERD UNITS WITH AN 80 PERCENT CALF CROP.

Activity	AUM Spring	AUM Summer	AUM Fall	AUM Winter	AUM Annual
S180W	3.381	4.377	3.303	3.312	14.373
S280W	3.849	4.917	3.672	3.708	16.146
S380W	4.017	5.157	3.861	3.912	17.001
S480W	4.539	5.697	4.230	4.308	18.774
F180W*	4.398	4.585	3.978	5.937	18.897
F280W*	4.992	5.268	4.437	6.441	21.138
F380W*	5.244	5.544	4.656	6.669	22.113
S180M	3.395	4.404	3.312	3.324	14.435
S280M	3.905	4.989	3.708	3.756	16.358
S380M	4.097	5.208	3.864	3.924	17.093
S480M	4.607	5.793	4.260	4.356	19.016
F180M*	4.446	4.644	3.992	5.976	19.058
F280M*	5.076	5.364	4.493	6.525	21.460
F380M*	5.304	5.628	4.682	6.732	22.346
S180E	3.377	4.236	3.290	3.300	14.203
S280E	3.833	4.785	3.620	3.660	15.898
S380E	4.031	5.016	3.770	3.828	16.645
S480E	4.487	5.565	4.100	4.188	18.340
F180E*	4.266	5.464	4.372	5.739	18.895
F280E*	4.860	5.148	4.813	6.297	21.120
F380E*	5.112	5.424	5.014	6.537	22.087

*AU for fall alternatives include the additional AU that could be carried in place of feed increase for mature cows.

APPENDIX TABLE V. ANIMAL UNIT MONTHS FOR HERD UNITS WITH AN 85 PERCENT CALF CROP.

Activity	AUM Spring	AUM Summer	AUM Fall	AUM Winter	AUM Annual
S185W	3.381	4.437	3.303	3.312	14.373
S285W	3.881	5.013	3.732	3.773	16.399
S385W	4.122	5.277	3.903	3.957	17.259
S485W	4.622	5.853	4.295	4.378	19.148
F185W*	4.463	4.659	3.978	5.992	19.092
F285W*	5.097	5.387	4.467	6.528	21.479
F385W*	5.372	5.691	4.707	6.778	22.548
S185M	3.395	4.466	3.312	3.324	14.497
S285M	3.939	5.091	3.773	3.826	16.629
S385M	4.151	5.330	3.934	3.999	17.414
S485M	4.695	5.958	4.330	4.431	19.414
F185M*	4.511	4.719	3.992	6.031	19.253
F285M*	5.183	5.487	4.523	6.616	21.810
F385M*	5.435	5.778	4.733	6.841	22.787
S185E	3.377	4.288	3.290	3.300	14.255
S285E	3.863	4.871	3.675	3.720	16.129
S385E	4.079	5.128	3.830	3.893	16.930
S485E	4.565	5.712	4.158	4.251	18.686
F185E*	4.321	4.529	5.372	5.838	19.060
F285E*	4.955	5.259	4.843	6.376	21.430
F385E*	5.230	5.561	5.068	6.639	22.500

*AU for fall alternatives include the additional AU that could be carried in place of feed increase for mature cows.

APPENDIX TABLE VI. ANIMAL UNIT MONTHS FOR HERD UNITS WITH A 90 PERCENT
AND 95 PERCENT FALL CALF CROP.

Activity	AUM Spring	AUM Summer	AUM Fall	AUM Winter	AUM Annual
S190W	3.381	4.497	3.303	3.312	14.493
S290W	3.929	5.127	3.792	3.838	16.686
S390W	4.156	5.377	3.931	3.987	17.951
S490W	4.704	6.007	4.360	4.448	19.519
F190W*	4.528	4.734	3.978	6.047	19.287
F290W*	5.222	5.528	4.512	6.631	21.893
F390W*	5.479	5.814	4.741	6.869	22.903
F190M	3.395	4.528	3.312	3.324	14.559
S290M	3.990	5.213	3.838	3.896	16.937
S390M	4.187	5.432	4.004	4.074	17.697
S490M	4.782	6.123	4.400	4.506	19.811
F190M*	4.576	4.794	3.992	6.086	19.448
F290M*	5.311	5.634	4.574	6.725	22.240
F390M*	5.544	5.903	4.767	6.932	23.146
S190E	3.377	4.340	3.290	3.300	14.307
S290E	3.953	4.975	3.730	3.780	16.438
S390E	4.111	5.220	3.890	3.958	17.179
S490E	4.687	5.857	4.216	4.314	19.074
F190E*	4.376	4.594	4.372	5.883	19.225
F290E*	5.070	5.393	4.888	6.472	21.820
F390E*	5.327	5.674	5.100	6.722	22.820
F195W	4.593	4.809	3.978	6.102	19.482
F295W	5.327	5.647	4.542	6.718	22.234
F395W	5.607	5.961	4.792	6.978	23.338
F195M	4.641	4.869	3.992	6.141	19.646
F295M	5.418	5.757	4.604	6.816	22.600
F395M	5.675	6.053	4.818	7.041	23.587
F195E*	4.431	4.659	4.372	5.928	19.390
F295E*	5.165	5.504	4.918	6.551	22.140
F395E*	5.445	5.811	5.154	6.824	23.234

*AU for fall alternatives include the additional AU that could be carried in place of feed increase for mature cows.

APPENDIX TABLE VII. TOTAL REVENUE FOR EACH SYSTEM USING EQUATION 3-7
WITH COEFFICIENTS INCLUDED--REGION W.

Activity:	TR	:	Pct. x Weight x Price +	Pct. x Weight x Price +	Cull Cow
S180W	\$92.87 =	40	425	\$28.76 + 30	380 \$25.77 + 14.60
S280W	105.76 =	40	425	28.76 + 30	600 23.48 + 14.60
S380W	109.37 =	30	380	25.77 + 40	650 25.15 + 14.60
S480W	122.25 =	40	650	25.15 + 30	600 23.48 + 14.60
F180W	105.43 =	40	520	27.10 + 30	460 24.97 + 14.60
F280W	121.81 =	40	520	27.10 + 30	760 22.30 + 14.60
F380W	128.90 =	40	800	24.95 + 30	460 24.97 + 14.60
S185W	98.67 =	43	425	28.76 + 32	380 25.77 + 14.60
S285W	112.31 =	43	425	28.76 + 32	600 23.48 + 14.60
S385W	116.46 =	32	380	25.77 + 43	650 25.15 + 14.60
S485W	130.10 =	43	650	25.15 + 32	600 23.48 + 14.60
F185W	112.00 =	43	520	27.10 + 32	460 24.97 + 14.60
F285W	129.49 =	43	520	27.10 + 32	760 22.30 + 14.60
F385W	137.14 =	43	800	24.95 + 32	460 24.97 + 14.60
S190W	103.81 =	45	425	28.76 + 35	380 25.77 + 14.60
S290W	118.84 =	45	425	28.76 + 35	600 23.48 + 14.60
S390W	122.56 =	35	380	25.77 + 45	650 25.15 + 14.60
S490W	137.60 =	45	650	25.15 + 35	600 23.48 + 14.60
F190W	117.50 =	45	520	27.10 + 35	460 24.97 + 14.60
F290W	137.33 =	45	520	27.10 + 35	760 22.30 + 14.60
F390W	143.87 =	45	800	24.95 + 35	460 24.97 + 14.60
S195W					
S295W					
S395W					
S495W					
F195W	124.79 =	48	520	27.10 + 37	460 24.97 + 14.60
F295W	145.01 =	48	520	27.10 + 37	760 22.30 + 14.60
F395W	152.85 =	48	800	24.95 + 37	460 24.97 + 14.60

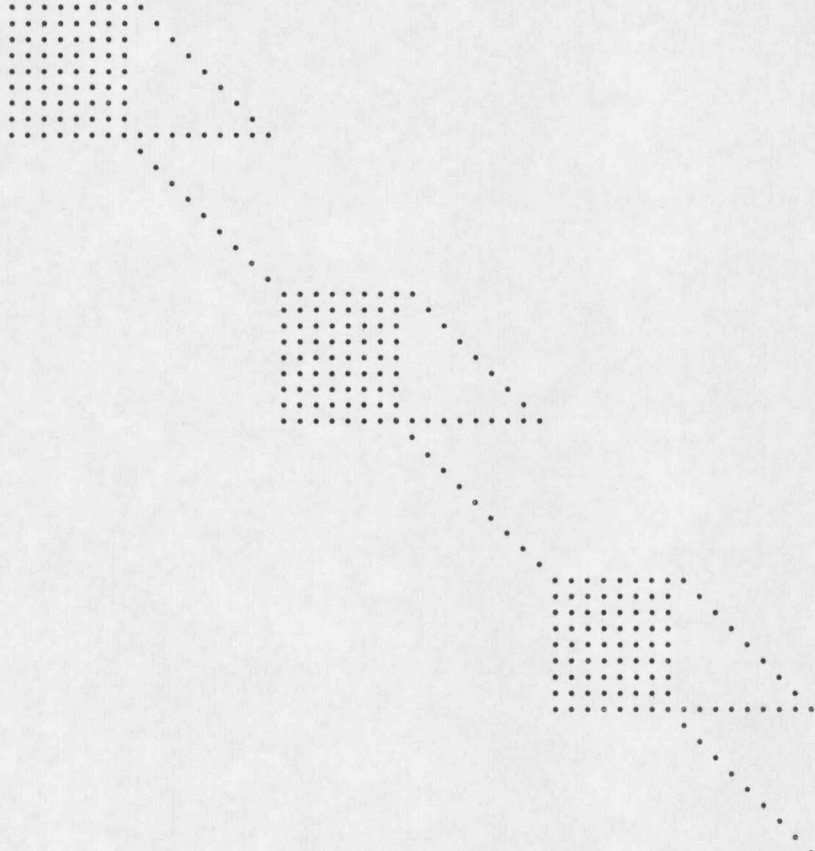
APPENDIX TABLE VIII. TOTAL REVENUE FOR EACH SYSTEM USING EQUATION 3-7
WITH COEFFICIENTS INCLUDED--REGION M.

Activity:	TR	:	Pct. x Weight	x Price	+	Pct. x Weight	x Price	+	Cull Cow
S180M	\$93.75	=	40	420	\$28.85	+	30	400	\$25.57 + 14.60
S280M	108.05	=	40	420	28.85	+	30	650	23.07 + 14.60
S380M	112.55	=	30	400	25.57	+	40	670	25.10 + 14.60
S480M	126.86	=	40	670	25.10	+	30	650	23.07 + 14.60
F180M	107.67	=	40	520	27.10	+	30	500	24.47 + 14.60
F280M	123.77	=	40	520	27.10	+	30	800	22.00 + 14.60
F380M	132.85	=	40	820	24.86	+	30	500	24.47 + 14.60
S185M	99.55	=	43	420	28.85	+	32	400	25.57 + 14.60
S285M	114.80	=	43	420	28.85	+	32	650	23.07 + 14.60
S385M	119.62	=	32	400	25.57	+	43	670	25.10 + 14.60
S485M	129.86	=	43	670	25.10	+	32	650	23.07 + 14.60
F185M	114.45	=	43	520	27.10	+	32	500	24.47 + 14.60
F285M	131.62	=	43	520	27.10	+	32	800	22.00 + 14.60
F385M	141.51	=	43	820	24.86	+	32	500	24.47 + 14.60
S190M	104.93	=	45	420	28.85	+	35	400	25.57 + 14.60
S290M	121.73	=	45	420	28.85	+	35	650	23.07 + 14.60
S390M	126.20	=	35	400	25.57	+	45	670	25.10 + 14.60
S490M	143.00	=	45	670	25.10	+	35	650	23.07 + 14.60
F190M	120.82	=	45	520	27.10	+	35	500	24.47 + 14.60
F290M	139.61	=	45	520	27.10	+	35	800	22.00 + 14.60
F390M	149.10	=	45	820	24.86	+	35	500	24.47 + 14.60
F195M	127.62	=	48	520	27.10	+	37	500	24.47 + 14.60
F295M	147.47	=	48	520	27.10	+	37	800	22.00 + 14.60
F395M	157.82	=	48	820	24.86	+	37	500	24.47 + 14.60

APPENDIX TABLE IX. TOTAL REVENUE FOR EACH SYSTEM USING EQUATION 3-7
WITH COEFFICIENTS INCLUDED--REGION E.

Activity:	TR	:	Pct. x Weight	x Price	+	Pct. x Weight	x Price	+	Cull Cow
S180E	\$ 83.62 =	40	360	\$ 29.87 +	30	330	\$ 26.27 +	14.60	
S280E	100.40 =	40	360	29.87 +	30	610	23.38 +	14.60	
S380E	106.00 =	30	330	26.27 +	40	650	25.15 +	14.60	
S480E	122.78 =	40	650	25.15 +	30	610	23.38 +	14.60	
F180E	98.37 =	40	460	28.15 +	30	420	25.37 +	14.60	
F280E	117.24 =	40	460	28.15 +	30	760	22.30 +	14.60	
F380E	126.41 =	40	800	24.95 +	30	420	25.37 +	14.60	
S185E	88.75 =	43	360	29.87 +	32	330	26.27 +	14.60	
S285E	106.49 =	43	360	29.87 +	32	610	23.38 +	14.60	
S385E	112.87 =	32	330	26.27 +	43	650	25.15 +	14.60	
S485E	130.61 =	43	650	25.15 +	32	610	23.38 +	14.60	
F185E	102.26 =	43	460	28.15 +	32	420	25.37 +	14.60	
F285E	122.45 =	43	460	28.15 +	32	760	22.30 +	14.60	
F385E	134.43 =	43	800	24.95 +	32	420	25.37 +	14.60	
S190E	93.46 =	45	360	29.87 +	35	330	26.27 +	14.60	
S290E	113.02 =	45	360	29.87 +	35	610	23.38 +	14.60	
S390E	118.76 =	35	330	26.27 +	45	650	25.15 +	14.60	
S490E	138.32 =	45	650	25.15 +	35	610	23.38 +	14.60	
F190E	107.79 =	45	460	28.15 +	35	420	25.37 +	14.60	
F290E	130.02 =	45	460	28.15 +	35	760	22.30 +	14.60	
F390E	141.72 =	45	800	24.95 +	35	420	25.37 +	14.60	
F195E	113.81 =	48	460	28.15 +	37	420	25.37 +	14.60	
F295E	137.15 =	48	460	28.15 +	37	760	22.30 +	14.60	
F395E	149.74 =	48	800	24.95 +	37	420	25.37 +	14.60	

APPENDIX TABLE X. DESIGN OF STATE LINEAR PROGRAMMING MODEL.

Objective Function		Activities			
←		→			
Resource	:	P_0	←Region W→	←Region M→	←Region E→
					

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