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 MASTER OF SCIENCE in Agricultural Economics
Montana State University

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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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.

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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

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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

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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

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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: π = TR - TC and can be shown to be a function of the variable inputs:

$$\pi = pf(x_1x_2) - r_1x_2 - r_2x_2 - b \qquad 1\text{-}1$$

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:

$$\frac{\partial \pi}{\partial x_1} = \text{price } q \cdot MPPx_1 - r_1$$

1-2

$$\frac{\partial \pi}{\partial x_2} = \text{price } q \cdot MPPx_2 - r_2$$

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

$MPPx_1$ = the marginal physical product of input i

r_1 = the unit cost of input factors x_i 5/

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

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.

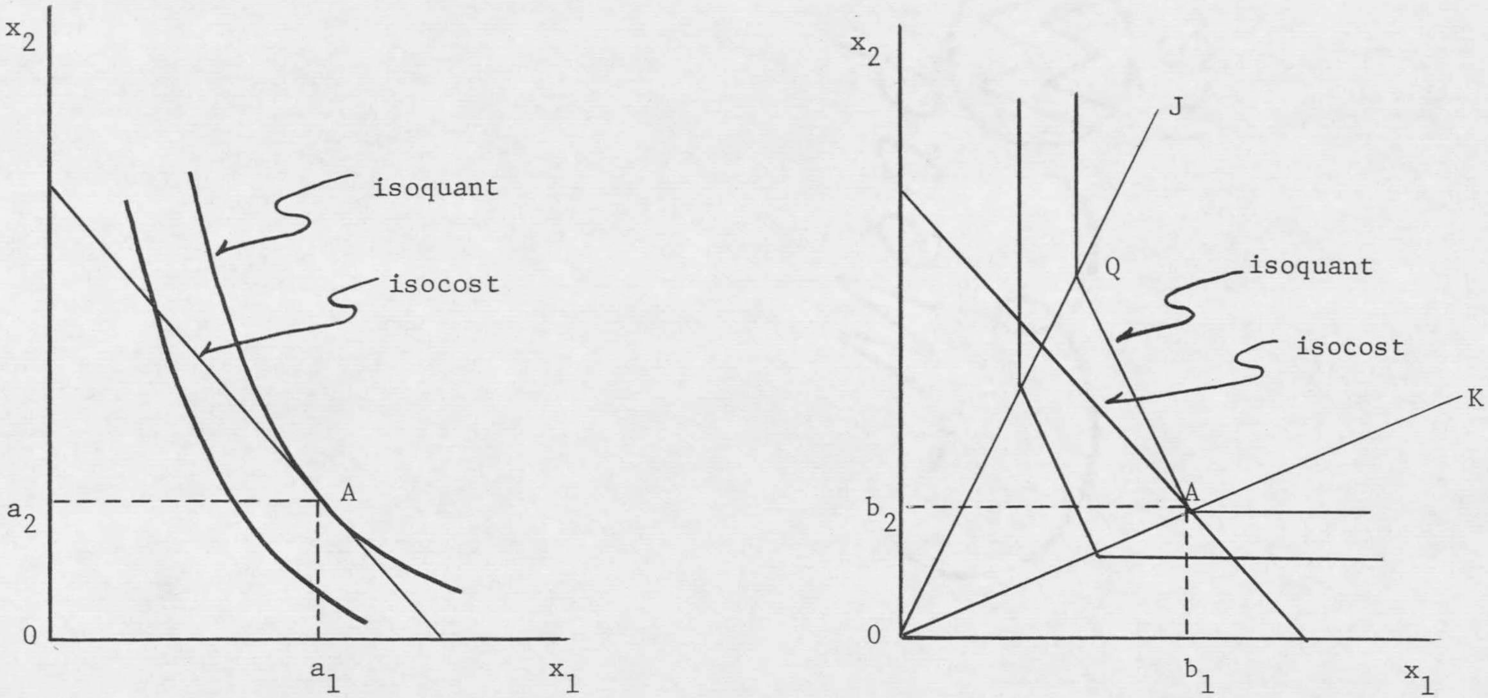
5/ Henderson and Quandt, Microeconomic Theory, McGraw-Hill, 1958, pp. 42-84.

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:

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

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

$$\vdots$$

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

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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