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THE INCLUSION OF BEEF CATTLE IN THE OPTIMAL ENTERPRISE ORGANIZATION*

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Abstract

A profit maximizing model that included many of the diverse aspects of beef cattle production and interrelationships among beef cattle, forages and field crops was developed within a dynamic linear programming framework. The optimal resource organization was determined given price levels that existed during 1973-1977.

Key Words: Field crops, forages, beef cattle, dynamic linear programming and optimal programs.

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Optimal enterprise organization models based on linear programming analyses have been used extensively for agricultural planning by both policy makers and individual producers [2]. While these models have typically provided an adequate framework for the analysis of either cropping or livestock enterprises on the farm, their ability to depict farms combining the production of both field crops and beef cattle has often proved to be inadequate.

Much of this problem can be attributed to the fact that in those models in which the inclusion of beef cattle production (in conjunction with field crops) has been attempted, it has been accomplished by specifying the herd as the unit of the beef cattle production enterprise [1, 7]. As a result, if the maintenance of the average animal in the herd was non-optimal then the entire herd was non-optimal. The inclusion of the beef cattle herd in the optimal solution would then be achieved only by the inclusion of constraints forcing the maintenance of the herd. Such a method of inclusion not only negates the benefits of marginal analysis, but also fails to recognize that in any herd there is a distribution of animals with respect to both quality and profitability [3]. Hence, while the maintenance of the average animal may be non-optimal, better-than-average animals may still be optimally included in a final solution.

The diversity of the beef cattle herd is, of course, only one aspect of the production decision involving beef cattle and field crops. Major interrelationships between field crops and beef cattle production also exist with respect to land use and the timing of production. These interrelationships include the ability of beef cattle to utilize 1) forages produced on land that is less well suited to the production of crops, or on cropland that is unused in the production of crops during some season, 2) many of the by-products of crop production such as corn stubble and 3) crops that are often grown primarily as cover crops. Beef cattle are, therefore, able to produce desirable products from feeds and lands that might otherwise be unused and thereby contribute to the farm's net revenue.

The major objective of this study was the development of a profit maximizing model that included the consideration of field crops, forages and beef cattle production. To fully endogenize beef cattle in this model attention was given to the many diverse aspects of beef cattle production and to the many interrelationships among beef cattle, forage and field crop production.

Analysis

The firm-level planning model developed in this study involved an analysis of field crop, forage and beef cattle enterprises typical of North Florida [8]. A representative 500-acre farm was hypothesized for this purpose and recommended production practices for all crops and beef cattle enterprises having potential in the area were assumed.

Model Specification

To determine the optimal mix of these enterprises, the problem was formulated as a linear programming problem in which multiple production periods were considered and a single objective function was maximized. Specifically, production in each month of each year of a five-year planning horizon was considered for a profit maximizing producer.

The inclusion of time was necessitated by the longer-run nature of some farm enterprises. For example, two years are needed for a heifer to become a producing cow and improved perennial pastures require at least two years to reach high levels of forage production. It was also important to include time in the problem formulation since continued changes typically occur in biological (such as crop rotation and livestock production) and institutional constraints. Hence, a farming unit that considers livestock enterprises requires a planning period of several years to achieve optimal resource efficiency.

As an extension of linear programming, Loftsgard and Heady [4] proposed a model that would optimize over a series of time periods. This method, known as dynamic linear programming, is dynamic in the Hicksian sense that the factors and products are dated. The programming model used in the study was an extension of standard linear programming where the transformation from the standard to the "dynamic" model resulted from the use of annual submatrics. Mathematically this model may be expressed as follows:

$$\text{Maximize profit} = \sum_j \sum_t C_{jt} X_{jt}$$

$$\sum_j \sum_t a_{ijt} X_{jt} \leq b_{it} \text{ and } X_{jt} \geq 0$$

($j = 1,2, \ldots, n$ activities per year)

($t = 1,2, \ldots, 5$ years)

Where C_{jt} = the profit from producing one unit of activity j during time period t,

X_{jt} = the quantity of jth activity during time period t,

a_{ijt} = the technical coefficient relating to the use of the ith resource in the jth activity during time period t and

b_{it} = the total amount of the ith resource available during time period t.

The objective function used in this study called for the maximization of producer's profit over the entire five-year planning horizon. Profit was defined as the pre-tax, undiscounted return over variable costs, which may be interpreted as the return to land, management and other fixed factors of production.

Factors of production such as land, labor, management, and operating capital, were constrained in the model. The coefficients for the nutritional requirements of beef cattle were specified in terms of dry matter, digestible protein and metabolizable energy. These values varied with the size and structure of the beef cattle herd and were not constrained in the model.

Land use in the model was divided into three categories: cropland, pasture land and native land. For this study, one-third of the land was initially assigned to each category. Cropland could be used for both field crops and seasonally cultivated forages, or could be converted to pasture. Pasture land was reserved for the production of perennial forages and those seasonal forages not requiring intensive cultivation. Native land could only be used for clearing and the establishment of pasture.

A full-time farm manager was required to provide management and labor for the various enterprises, with an option to hire additional labor on an hourly basis as needed. Peanut and tobacco allotments were constrained to 15 and 5 acres per year respectively, while operating capital was restricted to $100,000 per year.

Field crop and forage activities for early and late plantings and early harvesting varieties were included, where forage production and field crop by-product activities provided the principle nutrients for the sustenance of the beef cattle enterprise. Forages were permitted to be produced on cropland and pasture. The nutrient output of the forage production enterprise was then treated as an intermediate product and transferred to the beef cattle production enterprises.

The beef cow herd in this study was assumed to be comprised of Brahman cross-bred animals. The production period included a 90-day breeding season, spring calving, a 210-day lactation cycle and October sales. A procedure developed by Melton was used to account for the physical and biological differences in production and nutrient requirement due to differences in age, lactation status and quality of the animal [5]. The beef cattle herd was divided into nine age groups (ranging from 2 to 18 years of age) and each animal was classified according to lactation status (whether the animal was lactating or not the year before).

Quality differences among cows was reflected in terms of the weight of calf produced, which was considered to be normally distributed [3]. Animals were then partitioned into five quality groups within each age group corresponding to the mean weight of calf produced and either 45 or 90 pounds above and below the mean [6]. Each of these quality groups was assumed to be associated with a lactation potential of 22, 17.6, 13.2, 8.8 and 4.4 pounds of milk per day, respectively. Calving percentages were estimated from known probabilities with respect to breed, age and prior year lactation.

Beef cattle inventory activities were used in the fifth input-output submatrix (year 5) to allow for the retention of beef cows when their production is profitable. The inventory value of each animal reflected its undiscounted average future earnings from continued production.

Results

The optimal enterprise organization for the five-year planning period included field crops, forages and beef cattle enterprises. The production levels of field crops were relatively consistent over time with the exception of early harvest irrigated corn, soybeans and late soybeans during the later part of the planning period, as shown in Table 1. In 1976 and 1977, soybeans replaced corn as declining corn prices significantly reduced the returns over variable costs. Tobacco and peanuts were produced at their maximum alloted acreage in each year.

Forage activity levels were affected by changing field crop and beef cattle production levels. Coastal Bermuda and Argentina Bahia pastures and early winter rye-ryegrass forages were most consistently produced to fulfill the nutrient demands of the beef cattle herd. In addition, Coastal Bermuda hay and small amounts of irrigated corn stubble were also utilized. In 1976, however, forage activities changed when corn prices decreased and soybeans replaced corn in the solution, making cropland available from winter until mid-spring for the production of the lower cost winter annuals. The additional forages produced during 1977 as a result of the change in field crop activities were winter rye-ryegrass-clover and late winter rye-ryegrass. The production of winter forages on cropland was more profitable than permanent pasture.

Beef cattle production varied over the five years of the planning horizon due to changing cattle prices, as shown in Table 2. Heifer and steer calf inventories fluctuated during the planning horizon because of fluctuations in 1) prices, 2) the number of cows in the herd and 3) the

Table 1 Optimal field crop and forage levels during the five-year planning horizon.

	1973	1974	1975	1976	1977
Revenue from Sale of Field Crops ($)	52,252.38	64,457.92	58,031.50	58,483.17	42,449.34
Field Crop Production					
Peanuts (acres)	15.00	15.00	15.00	15.00	15.00
Soybeans (acres)	36.00	40.33	23.25	22.14	76.70
Soybeans planted late[a] (acres)				9.02	28.44
Irrigated Corn (acres)	0.01	0.01	0.01	0.01	
Irrigated Corn Early Harvest (acres)	108.74	104.36	121.49	113.58	39.60
Tobacco Mechnical Harvest[b] (acres)	5.00	5.00	5.00	5.00	5.00
Forage Production					
Coastal Bermuda Pasture (acres)	45.56	47.05	37.73	37.17	77.50
Argentian Bahia Pasture (acres)	103.87	118.95	71.28	36.31	
Rye-Ryegrass Early[a] (acres)	36.00	40.38	23.25	22.14	32.41
Rye-Ryegrass-Clover[a] (acres)				9.02	13.44
Rye-Ryegrass Late[a] (acres)					15.00
Irrigated Corn Stubble September (pounds)	174.19	154.85	230.38	195.53	
Irrigated Corn Stubble October (pounds)	174.19			195.53	
Supplements Purchased					
Coastal Bermuda Hay (pounds)	76,591.75	88,139.97	16,046.40	43,998.17	51,539.54

[a]Soybeans planted late, rye-grass-clover and rye-ryegrass planted late are double-cropping activities that use the same cropland.

[b]Each unit of mechanically harvested tobacco requires 1.25 acres for production.

Table 2. Beef Cattle inventories immediately prior to culling (October) and sales in each year[a].

Item	1972[b]	1973	1974	1975	1976	1977
Calves						
Steers	32.50	37.74 (0.00)	40.82 (0.00)	12.60 (1.48)	27.41 (0.00)	29.19 (29.19)
Heifers	32.50	37.74 (0.00)	40.82 (0.00)	12.60 (0.00)	27.41 (0.00)	29.19 (29.19)
Yearlings						
Steers	0.00	32.50 (32.50)	37.74 (37.74)	40.82 (40.82)	11.12 (11.12)	27.41 (27.41)
Heifers	0.00	32.50 (10.04)	37.74 (25.58)	40.82 (1.67)	12.60 (0.00	27.41 (27.41)
Cows (by age)						
2	6.70	10.00 (0.00)	22.46 (0.00)	12.16 (0.00)	39.15 (0.00)	12.60 (0.00)
3	9.20	6.70 (0.00)	10.00 (5.5[illegible])	22.46 (0.00)	12.16 (0.00)	39.15 (0.00)
4	12.00	9.20 (0.00)	6.70 (4.63)	4.48 (0.00)	22.46 (0.00)	12.16 (0.00)
5	12.90	12.00 (0.00)	9.20 (8.58)	2.07 (0.00)	4.48 (0.00)	22.46 (0.00)
6	18.40	12.90 (0.22)	12.00 (11.41)	0.62 (0.00)	2.07 (0.00)	4.48 (0.00)
7	12.90	18.40 (0.24)	12.68 (12.68)	0.59 (0.00)	0.62 (0.00)	2.07 (0.00)
8-10	12.00	12.90 (0.24)	18.16 (18.16)	0.00 (0.00)	0.45 (0.00)	0.62 (0.00)
11-12	9.20	12.00 (0.19)	12.66 (12.66)	0.00 (0.00)	0.00 (0.00)	0.45 (0.00)
13-18	6.70	9.20 (9.20)	11.81 (11.81)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Total cows	100.00	103.30	115.67	42.38	81.39	94.00
Total cows sold		10.09	85.45	0.00	0.00	0.00
Beef cattle revenue		16,401.94	56,493.81	11,848.92	2,408.19	21,947.16

[a]The first value for each of the row entries indicates beef cattle inventory immediately prior to culling and the second value (in parenthesis) specifies the number of beef cattle sold in each year. The assumption of divisibility allows fractional units of beef cattle to be produced and sold.

[b]The 1972 inventory was given under the assumption of a normal age distribution. Varying this assumption does not affect the applicability of the results as the model was allowed to make any distributional changes required through culling and replacement.

percent of cows having calves. Most calves, however, were retained as yearlings during the five-year production period due to the profitability of these animals resulting from the efficient (low cost) weight gains made during this stage of their life.

In 1975 the heaviest steer calves were sold, while the rest of the steer calves and all heifer calves were retained. All heifer and steer calves during other years, were transferred to yearling activities, except at the end of the planning horizon (1977) when all calves were sold. Yearling steers were sold in each year since beef finishing activities are not included in the model. Yearling heifers, however, were allowed to be either kept as replacements for the beef cow herd or sold as yearlings.

The cow production activities changed during the five-year production period primarily due to changes in cattle prices. There was an increase in cow inventories until the end of 1974, as more heifers were retained for replacement than the number of cows culled. During this time cows were culled primarily based on age, as indicated by the 13-18 year-old age group. The only other cows culled during this time were poorest quality, non-lactating animals. In response to declining cattle prices in 1974, however, all cows greater than six years of age were culled, as were the poorer animals in all other age groups--thereby substantially reducing the herd size. During the last three years of the planning period no cows were culled as the herd was again expanded in response to increasing prices.

A comparison of total revenues from Tables 1 and 2 indicates that the total revenues from field crops were consistently greater and more stable than beef cattle revenues, which varied significantly with changes in cattle prices and herd structure. The total revenues from all production activities, however, tended to be moderately stable over time, except for 1974 when field crop prices were high and a large percentage of the beef cattle herd was liquidated in anticipation of decreasing cattle prices. It is significant to note that, on average, the production of beef cattle accounted for approximately one-third of total revenue.

The total costs of production were much less variable than total revenues, ranging from a high of $49,610 in 1974 to a low of $42,164 in 1973. Variations in the total costs of production may be attributed to increasing factor prices throughout the planning horizon coupled with changes in optimal production levels for the enterprises.

Summary and Implications

The optimal resource organization, given price levels that existed during 1973-77, resulted in producing a combination of beef cattle, forage and field crop enterprises. The results indicated that beef cattle can optimally be included in a profit maximization model if differences among animals with respect to age, lactation status, quality and other relevant factors are recognized. As such, it is believed that this effort constitutes the first analysis to optimally combine the production of field crops, forages and beef cattle enterprises in a dynamic linear programming framework.

Before adopting the model or extending the results, however, specific limitations must be recognized. The resource situation and production costs and estimates assumed can not be generalized for all situations. Recognizing the limitations of the model makes the user aware of the necessary improvements that would contribute to greater accuracy and precision in the model. In its present form, however, the model has many potential uses. Given the appropriate data set, the model has the flexibility to analyze any size of an agricultural operation or enterprise and resource combination relevant to any region.

As a "first generation" study it is obvious that further refinements might improve the model as an aid in firm-level decision making. Future research efforts should consider maximizing net worth and/or incorporating tax considerations to maximize after-tax profits. In addition, the inclusion of cash flows, investments and discounting merit thorough investigation. With these and other refinements, more detailed information about the optimal farm resource organization can be provided for firm-level decision making.

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