A MODEL FOR OPTIMAL MANAGEMENT DECISIONS IN INTEGRATED BEEF STOCKING-FINISHING OPERATION

by

Warren B. Jessee, Jr.

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APPROVED:

Steven T. Buccola, Chairman

Ralph G. Kline

David E. Kenyon

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CHAPTER I

INTRODUCTION TO STUDY

The production of beef cattle is a vital segment of Virginia's agricultural sector. Since 1950, the value of livestock and livestock products has accounted for over 50% of the value of all agricultural products sold in Virginia. The value of cattle and calves in Virginia increased almost 100% from 1964 to 1974. During this same period, the number of farms associated with beef production declined over 38%. As farm numbers decreased, the production and size of the herd on a typical beef farm increased. This rise in per farm production has increased the need for better management guidelines for beef operators.

Beef cattle are very versatile animals and can be fed a wide variety of feeds under a wide variety of feeding conditions. In the past three decades, cattle have primarily been fed high energy rations due to the lower costs per unit gain associated with high energy rations relative to those on rations consisting of a larger proportion of forages. During the latter part of 1974 and the first quarter of 1975, however, prices of all energy-related inputs, especially fertilizer, climbed to unprecedented highs. Since grains are heavier fertilizer users than forages, this caused feed grain production costs to increase substantially more than forage production costs. In addition, new varieties of pastures and forages have been introduced that offer superior productive efficiency to those varieties used in the past. Hence, serious questions have been raised about cattle rations typically fed cattle in past years.

Frequently, analysts divide cattle production into three distinct production phases: (1) cow-calf, (2) stocker, and (3) feedlot. Although management practices vary throughout the state, the following are typical management practices employed by Virginia's cattlemen.

In the cow-calf production phase, heifers and cows are bred in the spring and early summer. At a weaning weight of approximately 500 pounds for steers and about 470 pounds for heifers, the calves enter the stocker or feedlot phase.

In the stocker phase the weaned calves are grazed on pasture, then sold either as medium-weight feeders (approximately 700 pound steers or 660 pound heifers) or as heavy-weight feeders (approximately 850 pound steers or 800 pound heifers).

The feedlot phase can be divided into two subsystems; (1) finishing beef calves and (2) finishing yearling cattle. In the first subsystem weaned calves are placed in the feedlot and finished for slaughter at about 990 pounds for steers and 880 pounds for heifers. The second subsystem entails purchasing medium- or heavy-weight stocker animals and feeding them to weights of about 1170 pounds for steers and 1030 pounds for heifers.

Although there is some vertical integration of these functions in Virginia, beef operators here predominantly specialize in one or two of the above phases (Table 1.1). The present study considers a representative Virginia beef farm which has integrated stocker and feedlot phases into one operation.

Table 1.1. Number and Percentage of Beef Farms Reporting Various Kinds of Beef Enterprises, by Area of Virginia, 1968

	All cow-calf		All stocker		All feedlot		Cow-calf and stocker		Cow-calf and feedlot		Stocker and feedlot		Cow-calf, stocker and feedlot		Not identified		Total farms	
	number of farms	per-cent	num-ber	per-cent	num-ber	per-cent	num-ber	per-cent	num-ber	per-cent	num-ber	per-cent	num-ber	per-cent	num-ber	per-cent	num-ber	per-cent
Appalachian Area	4,202	67.9	--	0	79	1.3	238	3.8	79	1.3	--	0	317	5.1	1269	20.5	6184	100
Piedmont and Shenandoah Area	2,670	48.7	--	0	154	2.8	403	7.4	143	2.6	--	0	212	3.9	1895	34.6	5477	100

SOURCE: Charles P. Butler, Economic and Operational Characteristics of the Southern Beef Cattle Industry, Southern Cooperative Series Bulletin, October, 1972, Table 16, p. 23.

Objectives of the Study

The present study seeks to determine for a representative farm:

(1) profit maximizing buying and selling weights of stocker and feedlot cattle;

(2) profit maximizing rations employed in each production phase;

(3) profit maximizing resource mixes for production of feed inputs;

(4) optimal feed production and cattle feeding responses to alternative feed production costs and feed prices;

(5) optimal cattle production response to alternative feeder cattle prices.

The study utilizes Virginia data, but the management information provided should be of value for other areas in the Southeastern United States with similar topography and climate.

The next chapter provides a brief review of literature on the economics of cattle feeding. Chapter III follows with a discussion of the model to be used in the present study. Procedures used to collect and process the required data are examined in Chapter IV. Chapters V and VI present the results of the analysis. The last chapter presents a summary of the findings along with the conclusions of the study.

CHAPTER II

REVIEW OF LITERATURE IN BEEF PRODUCTION ECONOMICS

Several types of models have been used to study the economics of United States beef production. In one approach, production functions and the marginal cost curves for beef production are derived from functions relating feed to animal growth. Another approach minimizes costs, either in the form of a feed cost/gain ratio or in the form of total farm costs. A third approach instead maximizes total farm profits.

Growth Function Approach

Wilson (1976) employed a cattle growth function model in an effort to derive average and marginal cost curves that would reflect the economic efficiencies of alternative ration energy mixes. The cost curves employed feeds or feed energy as the only input. Wilson found that cattle production lies in stage I of the feeding process, primarily because the stomach capacity of the animal restricts intake of feed to that stage. An economic implication is that, if beef producers seek to maximize profits or minimize feed costs, they should maximize their herd's average daily gains. This would mean, in effect, that if a potential for profit exists, higher energy rations are always preferred to lower energy rations.

Linear Programming Cost Minimization Approach

Feed Cost/Gain Minimization

A model with the criterion of minimizing feed costs per unit gain has been developed by Melton (1977). The feeding period is broken into five discrete intervals and the feed/gain relationship used is based on feed tests done in Iowa. The model selects the minimum-cost ration from among 505 possible rations for each of the five feeding intervals. Using various combinations of feed costs, Melton found that the cattle producer became indifferent in the forage-versus-grain feed decision when the price ratio of forages to grains was about 1.037 on a unit dry matter basis. When the ratio was greater than 1.037, a mixture of forages and grains was the preferred ration; at a lower ratio the ration consisted entirely of forages.

A similar model was developed by Carlson (1977) to determine least-cost rations under a multiple net energy system. In this system, energy in feeds is allocated either for maintenance of weight or for weight gains. Since the growth functions Carlson used were nonlinear, they were employed in a linear programming framework by iterative linear approximation. Carlson compared the least-cost-ration framework with that of a profit maximizing model and found that least-cost rations which exlucde overhead costs are suboptimal.

Total Cost Minimization

Although there are many examples of total cost minimization models, only those relating to Virginia are mentioned here. Kline and Cameron (1975) developed a linear programming model of this nature for the western portion of Virginia in which the objective was to identify the minimum-cost beef system that would produce $7000 annual net returns. They considered an integrated operation with the possibility of producing calves, stockers, and slaughter animals. The optimal ration predominantly consisted of silages during the winter months and pastures in the summer and spring. The authors found that to maintain $7000 in annual income, the optimal program included selling light slaughter steers and heifers at 990 and 880 pounds respectively. Chiang, Jensen, Kenyon, and Kline (1974) designed a livestock operation cost minimization model for the Shenandoah area of Virginia in which an operator income of $7000 was also maintained. They found that, for large Shenandoah beef farms, cow-calf operations are less profitable than either stocker or slaughter systems.

Profit Maximization Approach

An example of the profit maximization approach to beef operation analysis is provided by Dillard (1972), who focused on alternative forage systems in a Mississippi cow-calf operation. Using a linear programming model with linear digestible energy and protein growth functions, Dillard found that "all grazing" systems were not as profitable as those in which the ration consisted of pastures and silages. He also found that holding weaned calves for later sale as stockers was less profitable than selling the calves at weaning weight.

Anderson and Walker (1976) developed a linear programming, beef firm profit maximization model in which energy density and three forage quality groupings were used to classify feeds and beef animal nutritional requirements. This unique method of feed evaluation was employed in an effort to more accurately identify the relative values of forages and grains in a cattle feeding operation. The authors found that, under southcentral Oklahoma conditions, the optimal farm plan involved holding calves produced in the cow-calf production phase, feeding them on high quality forages, and selling the animals as heavy feeders.

Ely and Allison (1977) developed a model which solves for the profit maximizing buying and selling weights, and optimal rates of gain, of stocker or feedlot cattle. This model also identifies the associated optimal ration. Discrete animal weight groups and rates of gain are evaluated in a linear programming framework. The study is primarily concerned with a dry lot cattle operation and does not consider lower energy feeds such as pastures. Assuming minimum protein and energy input levels to ensure that cattle nutritional needs are met, Ely and Allison found that the optimal rate of gain varies inversely with the weight of the cattle. That is, as heavier cattle are produced, the optimal rate of gain decreases. They also found that alteration of protein requirements has a negligible effect on the optimal feeding and growth programs.

Summary

The objectives of the above studies were either profit maximization, cost minimization, or derivation of cost curves from growth functions. In the derivation of cost curves, feed costs were the only variable input considered; such an approach may be suboptimal when the total farm is considered. Cost minimization models may also arrive at suboptimal solutions if overhead costs are omitted. In the present study the profit maximizing linear programming model is used.

All of the studies mentioned were concerned with accurate evaluation of feeds in a cattle feeding operation. The traditional measures of feed nutritional content are (a) metabolizable or digestible energy and (b) total digestible nutrients. Carlson's approach of using a multiple net energy system is a more accurate method of evaluating feeds in a beef operation [National Academy of Sciences, 1976, p. 4]. This method accounts for the changing efficiency of feed conversion as forage content in the ration changes; hence, the present study will use this method of feed evaluation.

With the exception of Dillard's, all studies mentioned that considered a completely integrated beef operation found the production of stocker or feedlot cattle to be more profitable than sale of calves at weaning weight. With this in mind, the present study will focus only on the stocker and feedlot phases of beef production.

CHAPTER III

FORMULATION OF THE MODEL

All of the objectives of the present study stated in Chapter I involve maximizing returns to the operator's fixed resources. In this maximization, the optimal resource mix must be determined along with the specifics of the feed ration, rates of gain, and cattle sale and purchase weights. Objectives (4) and (5) can be satisfied by changing feed cost, feed price, and cattle price assumptions.

Considerations in Developing an Analytical Model

Formulating Alternatives on the Farm

Many options are available to Virginia's beef producers. In order to make economically sound decisions, guidelines as to the levels of utilization of various inputs need to be determined. In beef production activities, the ration is one of the important considerations since feed content and level have marked effect on animal weight gain, and since feed costs represent approximately 30% of most beef operation budgets. Constituents of the feed ration can either be purchased in surrounding markets or produced on the farm. Cattle production also entails the utilization of labor and capital as inputs. Some of the necessary labor may be satisfied by the operator's labor, but additional labor requirements may be met by hiring. Likewise, capital requirements may be met either through borrowing activities or by utilization of the operator's own funds.

If the operator decides to produce his own feed, he must decide what and how much of each crop to produce. Many uncontrollable factors, such as weather and insects, affect prospective yields. Some of the important controllable factors influencing yields are rate of fertilization and selection of soil type. Many studies have, for selected crops, estimated ranges over which there is a positive relationship between rate of fertilizer application and yield [Lutz, et. al., 1964]. Optimal levels of fertilization for each crop need to be simultaneously determined with other management decisions. A realistic decision model should reflect the possibility of selling excess crop production in surrounding markets; this is certainly a viable alternative facing beef farmers in Virginia.

More concisely, a realistic model of cattle production under Virginia conditions should include the following: (1) livestock purchase, sale, and production activities with variable rates of gain and variable purchase and sale weights; (2) feed purchase, sale, and production activities at variable levels of fertilization and on alternative soil classes; (3) capital borrowing activities; and (4) the option of hiring additional labor.

Activity Analysis Framework

As stated previously, the model's criterion is one of profit maximization; hence, the objective function consists of net returns to the operator for each of the above activities. It is readily observable that prices vary almost contiuously. An accurate representation of reality would involve the division of time into infinitesimally small periods; but in order to retain computational efficiency, the division of the calendar year into quarters appears best. This quarterly division allows accurate representation of actual price movements through time and permits construction of "feed availability calendars." Some feeds produced on the farm are only available to beef cattle during certain times of the year. Annual-basis programming models do not accurately reflect these constraints and hence do not provide adequate planning information to farmers.

The four types of enterprise activities represented in the present model are discussed below, followed by a discussion of the constraints employed.

Activity Specifications

Livestock Purchase, Sale, and Production Activities. The model specifies separate purchase activities for each of several different animal weight categories and for each sex (steers and heifers). The purchased animal is transferred to livestock production activities where ration components and average daily gain for the feeding period are determined. The animal is then transferred either to the next feeding period's livestock production activities or to the current period's livestock sale activities.

Feed Purchase, Sale, and Production Activities. Any feeds purchased in surrounding markets are transferred directly to the livestock production activities. Feeds grown on the farm can either be sold in surrounding markets or consumed by the operator's livestock. Hence, dry matter produced in the feed production activities is transferred either to the livestock production activities or to the feed sale activities.

The model also determines optimal rates of fertilization for each of the feed production activities. It is assumed that rates of fertilizer application are positively and linearly related to yields. For each of the feed production activities, there is a fertilizer use activity that, if selected, increases the crop's dry matter production level per acre.

Capital Borrowing and Labor Hiring Activities. The operator is assumed to have a certain amount of labor and capital at his disposal. Additional capital and labor are provided through specification of borrowing and hiring activities. These activities supply capital and labor, respectively, to feed and cattle purchase and production activities in each time period.

Constraint Specifications

Various constraints or restrictions must be satisfied in the model solution. The constraints utilized ensure that: (a) land, labor, and capital usage do not exceed amounts available to the farmer; (b) each beef animal's nutritional requirements are satisfied without exceeding its stomach capacity; (c) feed production or purchase is at least as great as the amount of feed consumed by all beef animals; and (d) productive resources not sold or utilized in one period are available for use in subsequent periods. These constraints are here discussed by class of resource.

Land Types. One of the primary resources preventing unlimited production on beef farms is land. The land restriction is not limited to area alone; it entails the division of land into various groupings based on slope, fertility, and other factors that affect cattle and crop production. This classification of soils into various productivity groups permits more accurate representation of crop yield responses to fertilizer. Therefore, the model includes land restrictions for each of the various land productivity groupings.

Labor and Capital. Labor and capital availability are allowed to vary through hiring and borrowing activities. Hence, restrictions are necessary to ensure that the use of capital and labor by animal and crop production activities are satisfied either by the operator's resources or by the acquisition of outside labor and capital.

Livestock Nutrient Requirements. Rations are distinguished in this study by energy and protein content. Once the protein and energy requirements of the cattle are met, all other nutritional requirements are usually satisfied. In order to accurately represent cattle energy requirements, they are divided into two subgroups: energy for cattle weight maintenance, and energy for cattle weight gain.

The Analytical Model

Definitions of Terms

The model used in this study is now presented in mathematical form. Although the model in fact distinguishes steer from heifer production, the terms presented below avoid cattle sex distinctions in order to promote reporting simplicity. Each term relating to cattle production represents a value for steers and a value for heifers. Terms presented here are divided into subgroups by type.

Indices. The indices used in the model are defined as:

j: quarterly periods in the model, $j=1, 2, \ldots, n_j$;

m: potential cropping activities, $m=1, 2, \ldots, n_m$;[1/]

k: weight classes of steers or heifers that can be purchased, produced, or sold, $k=1, 2, \ldots, n_k$;

r: quarterly rates of gain that may be achieved in steer or heifer production activities, $r=0, 1, 2, \ldots, n_r$;

q: feeds that can be purchased, $q=1, 2, \ldots, n_q$;[1/]

ℓ: feeds that can be sold, $\ell=1, 2, \ldots, n_\ell$;[1/]

i: farm land classifications, $i=1, 2, \ldots, n_i$.

Activities. The various activities in the model are defined as:

X_{krj}: number of steers or heifers the kth weight class gaining weight at the rth level of weight gain during the jth period, in number of head;[2/]

Y_{mij}: amount of land devoted to the mth crop on the ith land class during the jth period, in acres;

YP_{qj}: amount of the qth feed purchased during the jth period, in pounds dry matter;

$YS_{\ell j}$: amount of the ℓth feed sold during the jth period, in pounds dry matter;

XP_{kj}: number of steers or hefiers in the kth weight class purchased during the jth period, in number of head;

1/ When ℓ=q=m, each refers to the same feed.

2/ The various levels of daily gain and the various cattle weight classes must be defined such that, if an animal of the kth weight class is produced at the rth rate of gain, the animal belongs to the (k + r)th weight class at the end of the period.

XS_{kj}: number of steers or heifers in the kth weight class sold during the jth period, in number of head;

L_j : amount of labor hired during the jth period, in hours;

CAP_j: money capital borrowed during the jth period, in dollars;

F_{mij}: amount of fertilizer purchased and applied to the mth crop produced on the ith land class during the jth period, in pounds;

T_{mj} : dry matter of the mth feed transferred from the jth period to the (j + 1)th period, in pounds;

NEM_{mj}: dry matter of the mth feed used for cattle weight maintenance during the jth period, in pounds;

NEG_{mj}: dry matter of the mth feed used for cattle weight gain during the jth period, in pounds;

TRC_j: money capital transferred from the (j - 1)th period to the jth period, in dollars.

Net Revenue Coefficients. The net revenue coefficients used in the objective function are defined as:

PC_{kj} : steer or heifer sale price (less sale costs) in the kth weight class during the jth period, in dollars per head;

BC_{kj} : steer or heifer purchase price (plus purchasing expenses) in the kth weight class during the jth period, in dollars per head;

CAT_{krj}: operating cost, exclusive of feed, capital, and labor, of producing steers or heifers in the kth weight class at the rth level of gain during the jth period, in dollars per head;[3/]

CY_{mij} : operating cost, exclusive of fertilizer, capital, and labor, of producing the mth crop on the ith land class during the jth period, in dollars per acre;[4/]

CYP_{qj} : purchase price of the qth feed during the jth period, in dollars per pound dry matter;

$CYS_{\ell j}$: sale price of the ℓth feed during the jth period, in dollars per pound dry matter;

W_j : wage rate for hired labor during the jth period, in dollars per hour;

R_j : price of borrowed capital during the jth period, in cents per dollar;

CF_{mij} : price of fertilizer purchased and applied to the mth crop on the ith land class during the jth period, in dollars per pound;

CT_{mj} : cost of storing the mth feed from the jth period until the $(j + 1)$th period, in dollars per pound dry matter.

Resource Availabilities. The operator's resources available for use in beef production are defined as:

CAPITAL: amount of operator's money capital available, in dollars;

[3/] Cattle production operating costs include such expenses as veterinary fees, medicine, and machinery and equipment use.

[4/] Crop production operating costs include machinery and equipment, seed, herbicide and pesticide costs.

$LABOR_j$: amount of operator's labor available during the jth period, in hours;

$LAND_{ij}$: amount of land available in the ith farm land class during the jth period, in acres.

Capital Technical Coefficients. Capital utilization per unit of the various activities is represented by:

$CAPX_{krj}$: money capital required to produce steers or heifers in the kth weight class at the rth level of gain during the jth period, in dollars per head;

$CAPY_{mij}$: money capital required to produce the mth crop on the ith land class during the jth period, in dollars per acre;

$CAPYP_{qj}$: money capital required to purchase the qth feed during the jth period, in dollars per pound dry matter;

$CAPXP_{kj}$: money capital required to purchase steers or heifers of the kth weight class during the jth period, in dollars per head;

$CAPL_j$: money capital required to hire labor during the jth period, in dollars per hour;

$CAPF_{mij}$: money capital required to purchase fertilizer for application on the mth crop on the ith land class during the jth period, in dollars per pound;

$CAPXS_{kj}$: money capital acquired from sale of steers or heifers of the kth weight class during the jth period, in dollars per head;

$CAPYS_{\ell j}$: money capital acquired from sale of the ℓth feed during the jth period, in dollars per pound dry matter.

Labor Technical Coefficients. Utilization of labor by the model's activities is represented by:

LAX_{krj}: labor required to produce steers or heifers in the kth weight class at the rth level of gain during the jth period, in hours per head;

LAY_{mij}: labor required to produce the mth crop on the ith land class during the jth period, in hours per acre;

$LAXP_{kj}$: labor required to purchase steers or heifers in the kth weight class during the jth period, in hours per head;

$LAXS_{kj}$: labor required to sell steers or heifers in the kth weight class during the jth period, in hours per head;

LAF_{mij}: labor required to apply fertilizer to the mth crop on the ith land class during the jth period, in hours per pound.

Feed Nutrient Content Coefficients. Feeds, whether produced through the crop production activities or purchased in surrounding markets, provide dry matter, energy for weight maintenance, energy for gain, and protein to the cattle production activities. Because the multiple net energy system is used, it is necessary to distinguish in each case whether a unit of feed is used for gain or maintenance. A single unit of feed can be used either for animal maintenance or animal weight gain, but not for both. Thus we must specify two production activities in each period for each feed, one producing dry matter useful for cattle weight maintenance, and another producing dry matter useful for adding weight to the beef animal. The related coefficients are defined as:

$YNEM_m$: net energy available for maintenance from the mth feed, in megacalories per pound dry matter;

$YNEG_m$: net energy available for gain from the mth feed, in megacalories per pound dry matter;

YCP_m : crude protein content of the mth feed, in pounds per pound dry matter;

YDM_{mij}: dry matter yield of the mth crop (unfertilized) on the ith land class during the jth period, in pounds per acre;

D_{mij} : increase in dry matter resulting from application of fertilizer to the mth crop on the ith land class during the jth period, in pounds dry matter per pound fertilizer.

Livestock Nutritional Coefficients. Animal utilization of the various feed nutrients are represented by:

ENM_{kr}: net energy reuired to maintain weight of a steer or heifer in the kth weight class at the rth level of weight gain, in megacalories per head per period;[5/]

ENG_{kr}: net energy required to add weight to a steer or heifer in the kth weight class at the rth level of weight gain, in megacalories per head per period;

CP_{kr} : crude protein required to produce a steer or heifer in the kth weight class at the rth level of weight gain, in pounds per head per period;

[5/] Although rate of gain r is not normally specified as a determinant of net energy for maintenance or of crude protein requirements, it must be specified as such in the present model because, as rate of gain increases so does the quarterly average weight of the animal. For further explanation see Chapter IV.

SC_{kr} : stomach capacity of a steer or heifer in the kth weight class at the rth level of weight gain, in pounds dry matter per head per period.[6/]

Objective Function and Constraints

Using the above nomenclature, the obejctive function to be maximized can be represented as

(3-1) Profit = $\sum_{jk}\sum (PC_{kj})(XS_{kj})$ (cattle sale revenue) + $\sum_{j\ell}\sum (CYS_{\ell j})(YS_{\ell j})$ (feed sale revenue)

− $\sum_{jk}\sum (BC_{kj})(XP_{kj})$ (cattle purchase cost) − $\sum_{jq}\sum (CYP_{qj})(YP_{qj})$ (feed purchase cost)

− $\sum_{jm}\sum (CT_{mj})(T_{mj})$ (feed storage cost) − $\sum_{mij}\sum\sum (CF_{mij})(F_{mij})$ (fertilizer purchase cost)

− $\sum_{j} (W_j)(L_j)$ (labor purchase cost) − $\sum_{j} (R_j)(CAP_j)$ (money capital borrowing cost)

− $\sum_{jrk}\sum\sum (CAT_{krj})(X_{krj})$ (other cattle production costs)

− $\sum_{jim}\sum\sum (CY_{mij})(Y_{mij})$. (other crop production costs)

6/ Ibid.

Land, Labor and Capital Restrictions. The objective function is maximized subject to several restrictions. The first four listed ensure that land, labor, and money capital requirements are met.

(3-2) $LAND_{ij} \geq \sum_{m} Y_{mij}$, for each land class i and period j.

Land requirements of all production activities do not exceed land availability in each of the farm land classifications in each period.

(3-3) $LABOR_j$ (operator labor) $+ \; L_j$ (hired labor) $\geq \sum_{k}\sum_{r}(LAX_{krj})(X_{krj})$ (labor for cattle production)

$+ \sum_{m}\sum_{i}(LAY_{mij})(Y_{mij})$ (labor for crop production) $+ \sum_{k}(LAXS_{kj})(XS_{kj})$ (labor for cattle sale)

$+ \sum_{k}(LAXP_{kj})(XP_{kj})$ (labor for cattle purchase) $+ \sum_{m}\sum_{i}(LAF_{mij})(F_{mij})$ (labor for fertilizer application)

in each period j.

All labor needs are met by operator or hired labor in each period.

(3-4) TRC_j (capital transfer from the previous period) $+ \; CAP_j$ (borrowed capital)

$\geq \sum_{k}\sum_{r}(CAPX_{krj})(X_{krj})$ (capital for cattle production) $+ \sum_{m}\sum_{i}(CAPY_{mij})(Y_{mij})$ (capital for crop production)

$+ \sum_{q}(CAPYP_{qj})(YP_{qj})$ (capital for feed purchase) $+ \sum_{k}(CAPXP_{kj})(XP_{kj})$ (capital for cattle purchase)

$+ \quad (CAPL_j)(L_j) \quad + \quad \sum_{mi}\sum(CAPF_{mij})(F_{mij})$

(capital for labor hiring) (capital for fertilizer purchase)

$- \quad \sum_{k}(CAPXS_{kj})(XS_{kj}) \quad - \quad \sum_{\ell}(CAPYS_{\ell j})(YS_{\ell j})$

(capital from cattle sale) (capital from feed sale)

$+ \quad TRC_{(j + 1)}$ in each period j.

(capital transfered to the next period)

All capital needs are met through operator or borrowed capital or acquired through cattle and crop sale activities.

(3-5) $TRC_1 \leq CAPITAL$

This allows operator capital to enter the model in the first period.

Livestock Nutritional Restrictions. The next four constraints are necessary to ensure that cattle nutritional needs are met without exceeding the stomach capacity of each animal.

(3-6) $\sum_{m}(YNEM_m)(NEM_{mj}) \geq \sum_{kr}\sum(ENM_{kr})(X_{krj})$

(feed energy available for maintenance) (feed energy used for cattle maintenance)

in each period j.

This ensures that the net energy needs for cattle weight maintenance are met for each weight grouping in each period.

(3-7) $\sum_{m}(YNEG_m)(NEG_{mj}) \geq \sum_{kr}\sum(ENG_{kr})(X_{krj})$

(feed energy available for gain) (feed energy used for gain)

in each period j.

This constraint ensures that the net energy needs for cattle weight gain are met for each weight class and for each level of weight gain in each period.

(3-8) $\sum_{m}(YCP_M)(NEM_{mj} + NEG_{mj}) \geq \sum_{kr}\sum(LP_{kr})(X_{krj})$

(crude protein available) (cattle crude protein requirements)

in each period j.

This constrain ensures that the crude protein requirements of cattle are met in each weight class and for each level of weight gain in each period.

(3-9) $\sum_{m}(NEM_{mj} + NEG_{mj}) \leq \sum_{kr}\sum(SC_{kr})(X_{krj})$

(feed dry matter fed) (stomach capacity of all animals fed)

in each period j.

This ensures that the dry matter stomach capacity of each animal is not exceeded in any period.

Inter-Period Transfers. Finally, constraints are defined allowing for inter-period transfer of cattle and feeds.

(3-10) $\sum_{r} X_{krj}$

(cattle produced in the kth weight class in period j)

$\leq (X_{k,r=0,j-1} + X_{k-1,r=1,j-1} + X_{k-2,r=2,j-1})$

(cattle transferred at weight k from period (j-1))

$+ XP_{kj}$

(cattle purchased at weight k at beginning of period j)

$$- \quad SX_{k,(j-1)} \quad ;$$

(cattle sold at weight k at end of period (j-1))

for each weight class k and period j;

where k - 1 represents the weight difference between any two adjacent weight classes, k - 2 is defined <u>mutatis mutandis</u>, r = 0 implies zero quarterly weight gain, r = 1 and r = 2 refer to successively higher quarterly weight gains, and

$$k - (k - 1) = r_1$$

$$k - (k - 2) = r_2.$$

This constraint ensures that cattle produced in any period must either be purchased in that period or represent cattle produced and not sold in the previous period.

(3-11) $$\sum_i [(YDM_{mij})(Y_{mij}) \quad + \quad (D_{mij})(F_{mij})]$$

(feed produced without fertilizer in current period) (additional feed from fertilizer use in current period)

$$- \quad YS_{\ell j} \quad + \quad YP_{kj}$$

(feed sold in current period) (feed purchased in current period)

$$+ \quad T_{m(j-1)} \quad \geq \quad T_{mj}$$

(feed transferred from previous period) (feed transferred to next period)

$$+ \quad NEM_{mj} + NEG_{mj}$$

(feed fed to cattle in current period)

for each feed m and period j.

This constraint ensures that feeds transferred to the next period or fed to cattle in the current period must either be purchased, produced on the farm and not sold, or transferred from the previous period.

Assumptions of the Model

As with any study of this nature, various behavioral restrictions must be placed on the model to make it operationally feasible. Since the method of solving the problem involves linear programming, the basic assumptions of linear programming must be adhered to. These assumptions are:

(1) There are constant returns to scale, that is input levels remain in fixed proportions at any activity level.

(2) Input and output prices do not vary with level of output or utilization.

(3) The objective function is a linear function of the various activities.

Use of the mathematical model set forth above generates, by period, the profit maximizing crop mix and rates of fertilization, optimal buying and selling weights of cattle, the optimal ration, and the optimal average daily gains for cattle given a set of prices and costs. The specifics of data collection and generation are discussed in Chapter IV.

CHAPTER IV

DATA COLLECTION AND PROCESSING

This chapter presents a discussion of procedures used in collecting Virginia beef farm production and marketing data, and in interpreting these data such that they can be utilized by the model without violating the assumptions of linear programming mentioned in the previous chapter.

Delineation of Regions in the Study

Virginia is a diverse state with beef cattle produced in every area. However the state has highly variable topography, soil, and climatic conditions. In order to accurately represent typical beef operations in Virginia, the state must be divided into several relatively homogeneous zones. Southern Regional Research Project S-116, "Supply, Pricing, and Marketing Alternatives for Cattle, Beef Systems in the South," divides Virginia into three geographic areas: (1) Western or Appalachian, (2) Piedmont and Shenandoah, and (3) Eastern (Figure 4.1). The present study considers only the Western and Shenandoah-Piedmont areas since these account for about 92% of cattle and calf sales in the state (Table 4.1). The rolling hills and mountains in these areas have for the most part encouraged production of pastures and forages at the expense of grains, but a considerable amount of corn for silage is also produced there.

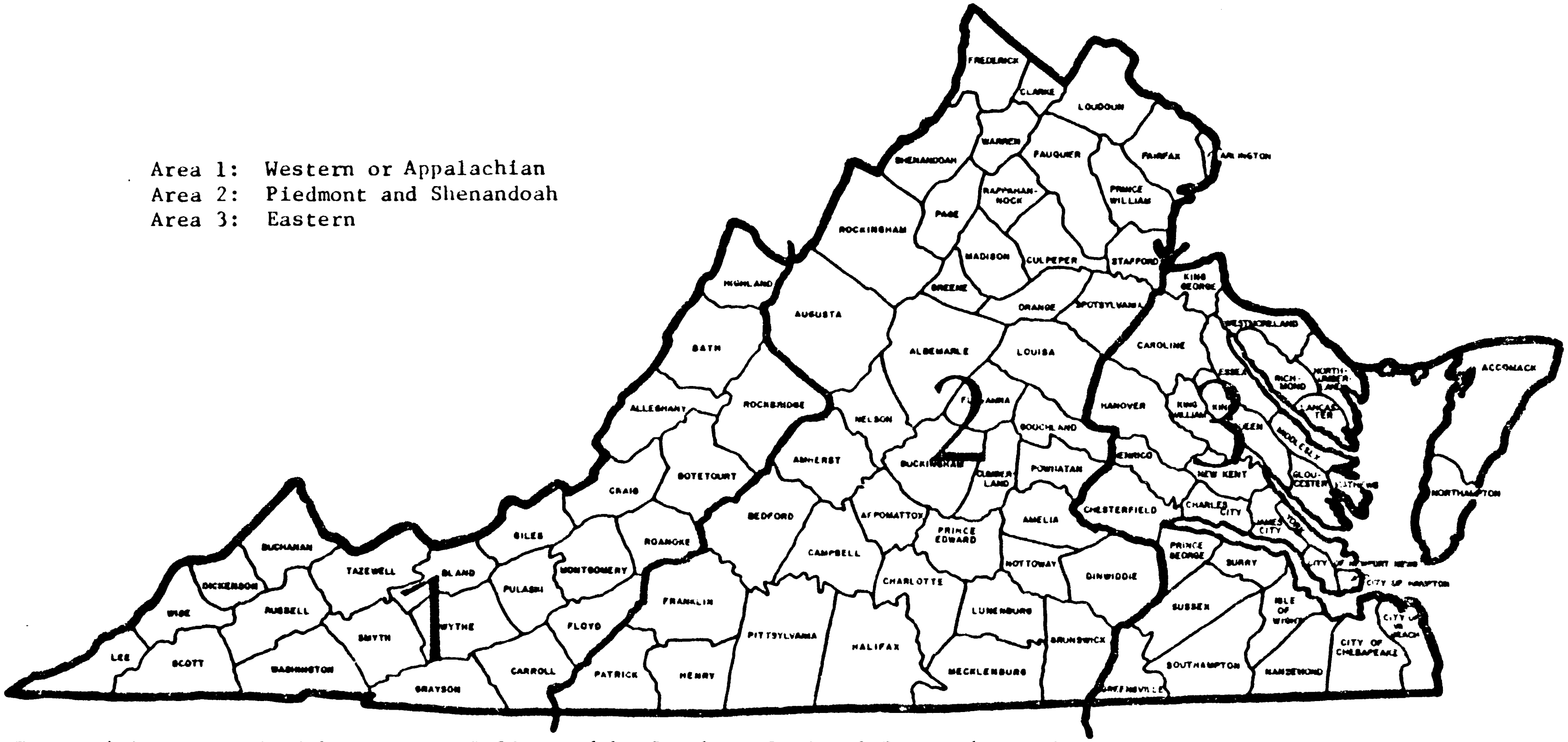

Figure 4.1. Virginia Subregions as Delineated by Southern Regional Research Committee.

Table 4.1. Cattle and Calf Sales in Virginia, by Area, 1974

	Appalachian Area	Shenandoah-Piedmont Area	Eastern Area	Virginia
Cattle and Calf Sales (thousand dollars)	40,945	83,042	11,459	135,411
Percentage of Total Virginia Sales	30.23	61.31	8.46	100

SOURCE: United States Census of Agriculture, part 46, Volume 1, 1974, U.S. Department of Commerce, Bureau of the Census.

Operator Resources

Various operator resources limit beef production on a typical farm. The present model considers three resource classes, land, labor and capital, for each region modeled.

Land

Since land productivity differs according to such features as aspect, slope, and depth, it is most realistic to specify land availability according to the presence of these features. The Soil Conservation Service, U.S.D.A., classifies soils into eight productivity groups. The first four groups (Class I through Class IV soils) are suitable for row crop or forage production, whereas the second four groups (Class V through Class VIII soils) are generally restricted to pasture production. For the purpose of this study, Classes V through VIII are aggregated into one class suitable only for pasture production. County-level soil surveys were used to obtain, for both Shenandoah and Appalachian areas, estimates of the relative amounts of land in each of the five land classes [U.S.D.A., Soil Conservation Service]. Results of a 1968 survey were used to estimate the total number of acres employed on the average sized beef farm in each area [Walker and Jobes]. Using these data, a representative farm was formulated for each of the regions studied (Tables 4.2 and 4.3).

Labor

It is assumed in these models that the farm operator supplies his own labor to the beef operation. Realistically, an operator may be able to supply 2400 hours of his own time per year, that is 300 eight-hour

Table 4.2. Land Available to a Representative Beef Operation, Appalachian Area of Virginia[a]

Soil Class	Land Area (acres)	Proportion of Total Area (%)
Class I	21.73	8.1
Class II	10.34	3.9
Class III	13.84	5.2
Class IV	49.28	18.5
Class V	110.80	41.5
Miscellaneous	61.01	22.9
TOTAL	267.0	100.0

[a] Includes wooded land, pits, dumps, and other land not utilized in a beef operation.

SOURCES: USDA Soil Conservation Service, and Walker and Jobes.

Table 4.3. Land Available to a Representative Beef Operation, Shenandoah-Piedmont Area of Virginia[a]

Soil Class	Land Area (acres)	Proportion of Total Area (%)
Class I	23.59	3.8
Class II	54.88	8.8
Class III	185.62	29.8
Class IV	108.91	17.5
Class V	141.50	22.7
Miscellaneous	108.99	17.5
TOTAL	623.50	100.0

[a] Includes wooded land, pits, dumps, and other land not utilized in a beef operation.

SOURCES: U.S.D.A. Soil Conservation Service, and Walker and Jobes.

days. This figure may be divided approximately equally among the four quarters of the year.

Capital

Operating capital available to the representative farms was calculated by taking the average net worth of a typical beef operator and deducting the value of land, buildings, machinery, and equipment. These dollar amounts, from Kline and Cameron (1975), are inflated at 8.5% per year to represent 1975 dollars. The available operating capital used in each model is $18,530.92.

Crop and Livestock Production Activities: Costs and Resource Utilization

The crop and livestock budgets used in this study are based on budgets developed by Moore, Brant, and Folmar. Slight modification of the budgets was necessary to incorporate them in the model.

Crop and Fertilizer Activities

Many crops may be produced and used as feed in a cattle operation. Crop production activities included in this study are: (1) corn for grain, (2) corn for silage, (3) alfalfa hay, (4) stockpiled fescue, and (5) orchardgrass-clover pasture. These feed production activities, along with their respective fertilizer response functions, are examined below.

Corn for Grain. Lutz, Jones, Moody and Hoepner estimated corn yield response to fertilizer under Virginia conditions and found that nitrogen application significantly affected corn yields, whereas rates of potash and phosphorus application did not significantly affect yields. The estimated corn yield response to nitrogen was:

$$(4\text{-}1)\quad Y = 53.0491 + \underset{(.07278)}{.88060N} - \underset{(.00027)}{.00210N^2} \qquad R^2 = .873,\quad n = 54$$

where

Y denotes corn grain yield in bushels per acre, and

N denotes application of nitrogen element, in pounds per acre,

standard errors are shown in parentheses, and n indicates sample size. The maximum yield obtained in the study occurred when nitrogen was applied at a rate of 250 pounds per acre.

To express relationship (4-1) in linear form for use in the present model, yield levels calculated from (4-1) were regressed as a linear function of nitrogen. The result of this transformation was

$$(4\text{-}2)\quad Y = \underset{(3.040)}{66.3491} + \underset{(.0260)}{.4606N} \qquad R^2 = .9429$$

where Y and N are as previously defined. Standard errors are again shown in parentheses.

To account for yield variation by soil class, the intercept of equation (4-2) was adjusted such that, for each soil class, the equation-predicted yield would coincide with a reduced "long-term average yield" associated with 75% of that soil's "nitrogen fertilizer recommendation." Nitrogen fertilizer recommendations and their associated long-term average yields are quoted for each soil class by Agricultural Experiment Station personnel, Virginia Polytechnic Institute and State University, and refer to relatively ideal growing conditions that obtain in test plots. It was assumed that average Virginia farmers would apply perhaps 75% of the recommended values. A corresponding reduction in long-term average yields was calculated by first calculating an average of the quoted long-term average yields for each area in which the average was weighted by the proportion of land in each soil class in each area. These weighted averages were then divided into the average corn yields observed in each area in the years 1972 through 1976, and the resulting proportions used to reduce each soil type's long-term average yield as quoted by the Agricultural Experiment Station (see Appendix A). Phosphorus and potash levels assumed for each soil class are those amounts recommended on corn for soils with a soil test class of medium for both of the nutrients.

Corn for Silage. Lutz, Jones, Moody, and Hoepner estimated Virginia corn silage response to nitrogen as:

$$(4\text{-}3) \quad S = 10.6911 + \underset{(.01746)}{.10965N} - \underset{(.00007)}{.0030N^2} \qquad R^2 = .556, \quad n = 54$$

where

S denotes silage yield, in tons per acre; and

N denotes the application rate of nitrogen element, in pounds per acre.

The maximum yield in the study was obtained when nitrogen was applied at a rate of 180 pounds per acre.

The above relationship was transformed into a linear function using the same procedure as described in the corn grain transformation above. The result of the linearization was

$$(4\text{-}4) \quad S = \underset{(.3740)}{12.2211} + \underset{(.00355)}{.05565N} \qquad R^2 = .9353$$

Again, compensation for differences in productivity across soil classes was accomplished by adjustment of the intercept. In the same manner as for corn grain, an adjusted long term average yield was calculated for each soil class. The intercept of equation (4-4) was then adjusted such that the equation-preducted yield using 75% of the recommended level of nitrogen was equated with the associated adjusted long term average yield for corn silage for each soil class (see Appendix A). Application rates of phosphorus and potash for each soil class are those amounts recommended on corn silage for soils with a soil test class of medium for both phosphorus and potash. Corn silage yields were not significantly related to phosphorus or potash fertilization.

Alfalfa Hay. Alfalfa hay is a legume, producing its own nitrogen. Hence, application of nitrogen fertilizer does not significantly affect alfalfa yield. Data for estimation of alfalfa yield response to phosphorus and potash were taken from three years of test plot data in Blacksburg, Virginia [Blaser]. A response function was fitted to the data to obtain:

$$(4\text{-}5) \quad \underset{}{A} = \underset{(632.08)}{4692.9756} + \underset{(3.5403)}{8.5024K} + \underset{(6.9531)}{13.5611P} \qquad R^2 = .5391, \; n = 9$$

where

A denotes yield of alfalfa, in pounds per acre;

K denotes application rate of potash, in pounds per acre; and

P denotes application rate of phosphoric acid, in pounds per acre.

To compensate for differences among the various soil classes, the intercept was adjusted such that the expected yield from equation (4-5), using the 75% recommended rates of phosphorus and potash on alfalfa for soils with a medium soil test class, coincides with the adjusted long term average yield for alfalfa (see Appendix A).

Fescue. Fescue yields show a significant response to nitrogen fertilizer application. Data from Hallock, Brown, and Blaser were used to estimate the fescue yield response to nitrogen:

$$(4\text{-}6) \quad F = \underset{(.4583)}{1.100} + \underset{(.00173)}{.0060N} \qquad R^2 = .923, \quad n = 3$$

where

F denotes yield of fescue, in tons per acre; and

N denotes application rate of nitrogen element, in pounds per acre.

Allowance was made for differences among soil classes by adjusting the intercept of equation (4-6) such that the equation-predicted yield at the recommended level of applied nitrogen was equated with the associated long-term average fescue yield (see Appendix A).[1/] The level of phosphorus and potash application on each soil class is that amount recommended on fescue for soils with a medium soil test class for both phosphorus and potash. Some reservation should be expressed about the accuracy of the above relation on account of the small sample size employed.

Orchardgrass-Clover Pasture. Pastures produced are assumed to consist of 70% orchardgrass and 30% ladino clover. Clover, like alfalfa, is a legume and supplies nitrogen to the pasture; hence, nitrogen application to these pastures had little effect on pasture yields. Data from Blaser and Brady were used to estimate the pasture response to fertilizer application:

[1/] Long-term average yields were not adjusted for fescue and pasture because of lack of data on average yields achieved by Virginia farmers in past years.

$$\text{(4-7)} \quad OC = \underset{(37.0)}{2588.5} + \underset{(.0053)}{12.4500K} \qquad R^2 = .9979, \; n = 3$$

where

OC denotes combined orchardgrass-ladino clover production, in pounds per acre; and

K denotes rate of potash application, in pounds per acre.

The intercept was adjusted to account for yield differences among soil classes such that the equation-predicted yield, at the recommended level of applied potash, was equated with the associated long-term average pasture yield (see Appendix A).[2/] Again the small sample size should be noted.

In fertilizer application there is a point where additional fertilization results in a decrease in yields. To prevent fertilizer application rates selected by the present model from reaching such a point, fertilizer application activities were restricted to the recommended rates or less (see Appendix A).

Other Crop and Livestock Costs

Budgets prepared by Moore, Brant, and Folmar provided estimates of production costs, labor, and capital utilization coefficients for each season for each of the above cropping activities. The operating cost coefficients used in the present study include all production costs associated with each cropping activity exclusive of land, labor, capital, and the cost of the fertilizers that have variable rates of application (see Appendix B).

[2/] *Ibid.*

Cattle purchase activities, like cattle production and sale activities, are expressed in number of head. Associated costs, labor, and capital utilization are developed from budgets prepared by Moore, Brant, and Folmar. The cost coefficients include purchase price of the animal and all other costs, exclusive of labor and capital, associated with purchasing a steer or heifer of a particular weight class (see Appendix B).

Net revenues, labor utilization, and capital utilization of the per-head-basis cattle production and sale activities are also based on budgets prepared by Moore, Brant, and Folmar. Net revenues include all costs except labor, capital and feed costs (see Appendix B).

Nutritional Data for Feeds

As was stated previously, feeds supply energy, protein, and dry matter to livestock. Estimates of the conversion factors expressing net energy for gain, net energy for maintenance, and crude protein per unit dry matter were obtained from data published by the National Academy of Sciences [1976]. These are reported in Appendix C. These data assume constant energy and protein content per unit of feed dry matter, regardless of the time of the year in which the feed is produced or consumed. In reality, forage energy and protein concentration varies by season.

Livestock Growth Functions

Energy Requirements

In the mathematical model presented in the previous chapter, beef cattle nutritional needs were measured by energy and protein requirements. In the system proposed by Loffgreen and Garrett [1968], functions expressing net energy for steer or heifer maintenance and growth are specified as:

(4-8) $NE_m = .077W^{.75}$

(4-9) $SNE_g = (.05272G + .00684G^2)W^{.75}$

(4-10) $HNE_g = (.05603G + .01265G^2)W^{.75}$.

where

NE_m denotes net energy required for steer or heifer weight maintenance, in megacalories per day;

SNE_g denotes net energy required for steer weight gain, in megacalories per day;

HNE_g denotes net energy required for heifer weight gain, in megacalories per day;

W denotes weight of the animal, in kilograms; and

G denotes average daily gain, in kilograms.

For purposes of this study's model, functions (4-8) and (4-9) were evaluated for steers at 100 pound weight increments from 500 to 1000 pounds and at 0, 1.1, and 2.2 pound average daily gains levels over a 90 day period. Functions (4-8) and (4-10) were evaluated for heifers at 75 pound weight increments from 450 to 900 pounds and at 0, .83, and 1.67 pound average daily gains levels over a 90 day period.[3/]

[3/] These functions were evaluated, for each rate of gain, at the average animal weight achieved during each period. Results were then multiplied by 90 to arrive at an estimate of the energy requirements for the entire 90 day period. This latter aggregation process produced slight errors in feed requirement estimates, although across all weight ranges and gain levels the errors averaged less than 0.05%.

Selection of these weight class and rates of gain was arbitrary and done only to simplify the model, although higher rates of gain may actually be achieved. The implications from using these rates of gain may be generalized to the other possible average gain rates.

Crude Protein Requirements

The assumed crude protein requirements of steers and heifers modeled in this study are based on relationships developed by Carlson [p. 645]. In his study, five percent of the crude protein ingested by beef cattle represents metabolic loss and is therefore not available to meet the animals' protein requirements. The relationships formulated by Carlson are, for steers,

(4-11) $CP_s = .002W_s^{.75} + (.365 - .00033W_s)G_s$,

and for heifers,

(4-12) $CP_h = .002W_h^{.75} + (.374 - .00044W_h)G_h$

where

$CP_{s,h}$ denotes crude protein requirements for steer or heifer, in kilograms per day;

$W_{s,h}$ denotes weight of steer or heifer, in kilograms; and

$G_{s,h}$ denotes average weight gain of steer or heifer, in kilograms per day.

Functions (4-11) and (4-12) were evaluated over the same weight groups and daily gain levels as were used in evaluation of steer and heifer energy requirements.[4/]

[4/] The evaluation and aggregation process used was the same as that employed for the energy requirement relations. Average aggregation error was approximately 1%.

Dry Matter Maxima

Rations fed to meet the above nutritional requirements must not exceed the stomach capacity of the animal. Nino and Hughes [p. 626] estimate the maximum dry matter intake function for steers and heifers as,

(4-13) $SC = .1W^{.75}$,

where

SC denotes maximum dry matter intake, in kilograms per 90 day period, and

W denotes weight of the animal, in kilograms.

Like the crude protein relations, function (4-13) was evaluated at the various weight groups and levels of gain specified for steers and heifers in the energy requirements relations.[5/]

Prices

Crop Prices

The present model allows only corn and alfalfa hay to be purchased or sold. Prices paid for corn meal and prices received for corn grain are reported in "Virginia Agricultural Statistics," Virginia Cooperative Crop Reporting Service, for years 1968 to 1977 (see Appendix D). Alfalfa prices utilized were quarterly prices paid or received in Virginia for years 1968 to 1977 as reported in the same source (see Appendix D).

[5/] This relation was also evaluated and aggregated in the same manner as for the energy relations, resulting in an average error less than 0.03%.

Cattle Prices

Steer and heifer prices utilized in the base solution for the fall and spring quarters of 1977 and the fall quarter of 1976 were based on the following relationships estimated in an unpublished study by Buccola:

Fall, 1976

$$\text{(4-14)} \quad PS = 4101 + \underset{(.2347)}{.00813528W} - \underset{(.000089)}{.00069869W^2} \qquad R^2 = .5295, \; n = 6579$$

$$\text{(4-15)} \quad PH = 2061 + \underset{(.24673)}{2.358963W} - \underset{(.000222)}{.001692W^2} \qquad R^2 = .4582, \; n = 2652$$

Spring, 1977

$$\text{(4-16)} \quad PS = 4913 - \underset{(.19563)}{2.02529W} + \underset{(.000147)}{.000602W^2} \qquad R^2 = .7206, \; n = 1937$$

$$\text{(4-17)} \quad PH = 2729 + \underset{(.28379)}{1.53843W} - \underset{(.000250)}{.001401W^2} \qquad R^2 = .6073, \; n = 1085$$

Fall, 1977

$$\text{(4-18)} \quad PS = 4353 - \underset{(.11614)}{.140204W} - \underset{(.0000845)}{.000572W^2} \qquad R^2 = .5420, \; n = 6397$$

$$\text{(4-19)} \quad PH = 1995 + \underset{(.27112)}{4.15953W} - \underset{(.000249)}{.00363W^2} \qquad R^2 = .5891, \; n = 2847$$

where

PS denotes the respective quarterly average Fancy and Choice steer price at Virginia state-graded sales in cents per hundredweight;

PH denotes the respective quarterly average Fancy and Choice heifer price at Virginia state graded sales, in cents per hundredweight;

W denotes weight of steer or heifer, in pounds; and

standard errors are given in parentheses.

Since special feeder cattle sales are not conducted in the winter months in Virginia, the intercepts of equations (4-14) and (4-15) were adjusted as follows to reflect equivalent winter, 1977 steer and heifer price functions. Simple quarterly averages of weekly prices of Good and Choice grade, 500-750 pound steers were first calculated from Market News Service reports for fall, 1976 and winter, 1977. The difference between the latter and the former was then added to the intercept of (4-14). A comparable adjustment was made for heifer prices in (4-15)

The prices used for steers and heifers for the summer quarter of 1977 were prices for various weights of steers and heifers as reported in "Results 1977 Virginia Summer Cattle Sales" (see Appendix D).

Estimates of price-weight relations, also from Buccola, were used to generate cattle prices for the fall quarter of 1973 and the fall and spring quarters of 1974. These were:

Fall, 1973

$$(4\text{-}20)\quad PS = 7820 - \underset{(.041456)}{3.75655W} + \underset{(.00001206)}{.00052047W^2} \qquad R^2 = .7584,\; n = 5088$$

$$(4\text{-}21)\quad PH = 5193 + \underset{(.427628)}{.1297726W} - \underset{(.0004108)}{.00132199W^2} \qquad R^2 = .4667,\; n = 1916$$

Spring, 1974

$$(4\text{-}22)\quad PS = 7346 - \underset{(.340384)}{4.6430414W} + \underset{(.0002626)}{.00128655W^2} \qquad R^2 = .8120,\; n = 1062$$

$$(4\text{-}23)\quad PH = 5339 - \underset{(.355598)}{2.91871389W} - \underset{(.0002699)}{.00136205W^2} \qquad R^2 = .5464,\; n = 869$$

Fall, 1974

$$(4\text{-}24)\quad PS = 3428 + \underset{(.19002)}{1.0456738W} - \underset{(.000138)}{.00115912W^2} \qquad R^2 = .4053, \; n = 5334$$

$$(4\text{-}25)\quad PH = 2156 + \underset{(.29184)}{2.0309464W} - \underset{(.000271)}{.00165471W^2} \qquad R^2 = .4754, \; n = 1926$$

where PS, PH, and W are as defined before, and standard errors are reported in parentheses.

Again the intercepts of the above relations were adjusted to reflect equivalent winter and summer prices for 1974. The procedure used was the same as that described above for the 1976-77 period. That is, simple quarterly averages of weekly prices of Good and Choice grade, 500-750 pound steers were first calculated from Market News Service reports for fall, 1973 and, winter, 1977. The difference between latter and former was then added to the intercept of (4-20). A comparable adjustment was made for heifer prices in (4-21). Adjustment of the intercepts of equations (4-22) and (4-23) were carried out in a similar manner to reflect equivalent summer price-weight relations.

Average spring and fall price-weight relations were also estimated by Buccola for the years 1968 to 1977 and expressed in 1977 dollars. These are, in linear form:

Spring

$$(4\text{-}26)\quad PS = 6634 - 2.0269W$$

$$(4\text{-}27)\quad PH = 5260 - 1.2823W$$

Fall

(4-28) $PS = 6349 - 1.9067W$

(4-29) $PH = 4618 - .6331W$

where:

PS denotes the respective period average Good grade steer price at Virginia state graded sales, in cents per hundredweight;

PH denotes the respective period average Good grade heifer price at Virginia state graded sales, in cents per hundredweight; and

W denotes the weight of the steer or heifer in pounds.

Since these functions are averages of several years' equations standard errors and R^2 statistics do not exist.

The intercepts of equations (4-26) and (4-27) were also adjusted to develop comparable price-weight relations for the summer quarter. This adjustment was accomplished by calculating the average spring-summer price differential for each sex for the years 1968-1977, as expressed in 1977 dollars, and adding these differentials to the intercepts of equations (4-26) and (4-27), respectively. Equations (4-28) and (4-29) were adjusted likewise to produce equivalent price-weight relations for the winter quarter. The fall-winter price differentials were calculated from data reported by the Virginia Market News Service, and spring-summer price differentials from data reported by the Cooperative Extension Service, Department of Animal Science, Virginia Polytechnic Institute and State University.

Storage, Capital, and Labor Prices

Per bushel costs of corn storage and drying used in the present model refer to a storage-drying system with a capacity of 13,440 bushels [Bauer, Donald, and Smith, p. 10]. These costs, exclusive of labor and capital expenses, are 24.74¢ per bushel and 0.65¢ per bushel per 90 day period, respectively (see Appendix D).

The rate of interest on operating capital used in the model is 9.5 per cent per year. This figure is drawn from results of a preliminary study by Reynolds and Kohl on agricultural interest rates in Virginia.

Average hourly wages paid to hired labor on Virginia farms are those reported in "Virginia Crops and Livestock," Crop Reporting Service, U.S. Department of Agriculture, for years 1976 to 1978 (see Appendix D).

CHAPTER V

ANALYTICAL RESULTS UNDER 1976-1977 AND 1973-1974 PRICE STRUCTURES

In this chapter, solution results are reported for both Appalachian and Shenandoah areas and corresponding to two scenarios, one utilizing actual 1976-1977 feed and cattle price structures in Virginia, and the other utilizing actual 1973-1974 cattle and feed price structures.

Description of the 1976-1977 Scenario

In the 1976-1977 scenario, crops are considered to be produced in 1976 and, with the exception of pasture, available as livestock feed or for sale on October 1. Pasture is produced continuously from October 1, 1976 to September 30, 1977. Livestock may be produced in the same October 1, 1976-to-September 30, 1977 time interval with average daily gains of 0, 1.1, or 2.2 pounds per day for steers and 0, .867, or 1.667 pounds per day for heifers.

Virginia feeder cattle prices increased continuously but moderately during the October 1, 1976-to-September 30, 1977 period. Six hundred pound Good grade steers, for example, increased from $36.45 to $40.03 per hundredweight. Corn prices in Virginia decreased from $2.52 to $1.88 per bushel.

Description of the 1973-1974 Scenario

The models employed in the 1973-1974 scenario were similar to the 1976-1977 models in that non-pasture crop production was considered to occur during the spring and summer of the first year (1973) and to become available for sale or use as a livestock feed on October 1 of that year. Pasture was avialable for continuous grazing from October 1, 1973 through September 30, 1974. Cattle production was considered to occur over the same period. Average daily gains for steers and heifers were the same as those used in the 1976-1977 scenario.

During the October 1, 1973-to-September 30, 1974 period, Virginia cattlemen experienced a rapid decline in all cattle prices. Six hundred pound Good grade steers, for example, dropped from $54.59 to $32.38 per hundredweight. At the same time, corn prices facing Virginia farmers increased from $2.26 to $3.46. Alfalfa hay prices increased slightly from $49.50 to $53.00 per ton.

Analytical Results of the 1976-1977 Scenario

Appalachian Area

The optimal farm plan for the Appalachian Area in the 1976-1977 scenario generated $23,670 in returns to the operator's land, labor, and capital. The livestock production activities, along with the amounts of feed offered to livestock in the optimal farm organization, are presented in Table 5.1. Associated crop production activities are presented in Table 5.2. The optimal farm plan required borrowing $58,233 on January 1, 1977. In the Appalachian model, the largest number of cattle were produced in the January-March period with some of these cattle being held for sale in June at heavier weights.

Shenandoah Area

A summary of the livestock purchase, sale, and production activities for this scenario is presented in Table 5.3. The associated crop

Table 5.1. Livestock Purchase, Sale, and Production in the Optimal Farm Plan; Appalachian Area, 1976-1977 Scenario

	October 1, 1976	October 1- January 1, 1977	January 1 1977	January 1- April 1, 1977	April 1, 1977	April 1- July 1, 1977	July 1, 1977	July 1- October 1, 1977	October 1, 1977
Purchase or Sale	Purchase 47 heifers at 450 pounds		Sell 47 heifers at 600 pounds Purchase 354 steers at 500 pounds		Sell 231 steers at 700 pounds		Sell 123 steers at 900 pounds Purchase 149 steers at 500 pounds		Sell 149 steers at 700 pounds
Gain		47 heifers at 1.67 pounds per day: 450-600 pounds		354 steers at 2.2 pounds per day: 500-700 pounds		123 steers at 2.2 pounds per day: 700-900 pounds		149 steers at 2.2 pounds per day: 500-700 pounds	
Ration per Head per Day (dry matter basis)		.9 pounds corn grain 12.5 pounds pasture		2.9 pounds corn silage 5.9 pounds corn grain 5.6 pounds corn stover		3.8 pounds corn silage 5.4 pounds corn grain 8.4 pounds pasture		7.8 pounds corn silage 3.1 pounds corn grain 4.0 pounds pasture	

Table 5.2. Crop Production Activities, Yields, and Crop Fertilization Activities in the Optimal Farm Plan, Appalachian Area, 1976-1977 Scenario

Crop	Land Class	Acres	Yield Per Acre	Fertilization N (lbs/ac)	Fertilization P_2O_5 (lbs/ac)	Fertilization K_2O (lbs/ac)
Corn Grain	I	11.89	129 bu.b/	162.5	a/	a/
Corn Grain	III	13.84	95 bu.b/	112.5	a/	a/
Corn Grain	IV	49.28	73 bu.b/	87.5	a/	a/
Corn Silage	I	9.84	22 tonsc/	162.5	a/	a/
Corn Silage	II	10.34	20 tonsc/	137.5	a/	a/
Orchard Grass-Ladino Clover Pasture	V	110.8	.778 tond/	a/	a/	25

a/ Held constant at the recommended rate (see Appendix A).

b/ 84.5% dry matter.

c/ 27.9% dry matter.

d/ Dry matter basis, produced from October 1976 to October 1977.

Table 5.3. Livestock Purchase, Sale, and Production in the Optimal Farm Plan, Shenandoah Area, 1976-1977 Scenario

	October 1, 1976	October 1-January 1, 1977	January 1 1977	January 1-April 1, 1977	April 1, 1977	April 1-July 1, 1977	July 1, 1977	July 1-October 1, 1977	October 1, 1977
Purchase or Sale	Purchase 60 heifers at 450 pounds		Sell 60 heifers at 600 pounds Purchase 1449 steers at 500 pounds		Sell 1130 steers at 700 pounds		Sell 319 steers at 900 pounds Purchase 402 steers at 500 pounds		
Gain		60 heifers at 1.67 pounds per day: 450-600 pounds		1449 steers at 2.2 pounds per day: 500-700 pounds		319 steers at 2.2 pounds per day: 700-900 pounds		402 steers at 2.2 pounds per day: 500-700 pounds	
Ration per Head per Day (dry matter basis)		.9 pounds corn grain 12.5 pounds pasture		7.5 pounds corn grain 6.4 pounds corn stover		0.9 pounds corn silage 10.2 pounds corn grain 4.2 pounds pasture		6.1 pounds corn silage 5.5 pounds corn grain 1.9 pounds pasture	

production activities are presented in Table 5.4. Capital borrowing and labor hiring activities are presented in Table 5.5. Net returns to operator's land, labor, and capital in this model amounted to $70,442.

The land available to the typical beef producer in the Shenandoah Area is larger than that available to the typical beef producer in the Appalachian Area. Hence the optimal Shenandoah farm plan reported here represents a larger beef operation than in the Appalachian Area. Like the Appalachian model, the largest number of cattle in the Shenandoah model were produced during the January-March period, with some of these cattle being held until June for sale at heavier weights. And, as in the previous model, all cattle were produced at the maximum alloted gain per day.

Analytical Results of the 1973-1974 Scenario

Appalachian Area

As previously stated, the 1973-1974 period was characterized by rapidly falling cattle prices and increasing grain prices. The optimum Appalachian solution reacted to this situation by suggesting cattle production only during the October 1-December 31, 1973 period, when cattle prices were highest. If cattle had been held longer than this, they would have been sold at significant capital losses. On October 1, the solution suggested purchasing 289 heifers at 450 pounds, feeding them to gain 1.67 pounds per day, then selling them at 600 pounds on December 31. The ration fed these cattle consisted, on a dry matter basis, of 1.2 pounds corn silage, 3.7 pounds corn grain, and 8.5 pounds corn stover per

Table 5.4. Crop Production Activities, Yields, and Crop Fertilization Activities in the Optimal Farm Plan, Shenandoah Area, 1976-1977 Scenario

Crop	Land Class	Acres	Yield Per Acre	Fertilization N (lbs/ac)	Fertilization P_2O_5 (lbs/ac)	Fertilization K_2O (lbs/ac)
Corn Grain	I	23.59	129 bu.[b]	162.5	[a]	[a]
Corn Grain	II	33.13	116 bu.[b]	137.5	[a]	[a]
Corn Grain	III	185.62	95 bu.[b]	112.5	[a]	[a]
Corn Grain	IV	108.91	73 bu.[b]	87.5	[a]	[a]
Corn Silage	II	21.75	20 tons[c]	137.5	[a]	[a]
Orchard Grass-Ladino Clover Pasture	V	141.5	.778 tons[d]	[a]	[a]	25

[a] Held constant at the recommended rate (see Appendix A).

[b] 84.5% dry matter.

[c] 27.9% dry matter.

[d] Dry matter basis, produced from October 1976 to October 1977.

Table 5.5. Operator Labor Use, Labor Hiring, and Capital Borrowing Activities in the Optimal Farm Plan, Shenandoah Area, 1976-1977 Scenario

	January-April 1976	April-July 1976	July-October 1976	October-January 1977	January-April 1977	April-July 1977	July-October 1977
Operator Labor Use (man days)	3.7	75.6	75.6	75.6	75.6	75.6	75.6
Labor Hired (man days)		4.8		77.6	230.1	3.6	
Borrowed Capital Outstanding ($)		10,694	13,585	23,736	284,809		

head per day. Corn grain produced but not fed to the cattle (5919 bushels) was stored at the October 1, 1973 harvest and sold on July 1, 1974.

The associated crop production activities are presented in Table 5.6. All of Class I through Class IV land was utilized, whereas Class V land remained idle. To facilitate cattle purchase on October 1, 1973, it was necessary to borrow capital on this date in the amount of $54,143. This farm plan produced net returns to the operator's resources amounting to $18,273.

Shenandoah Area

The optimal farm plan for the Shenandoah Area in the 1973-1974 scenario was similar to that in the Appalachian Area. Eleven hundred and thirty-three 450-pound heifers were purchased on October 1, 1973 and sold at 600 pound feeders on December 31, 1973. These heifers were fed to gain 1.67 pounds per day on a ration consisting, on a dry matter basis, of 1.2 pounds corn silage, 3.7 pounds corn grain, and 8.5 pounds corn stover per head per day. Associated crop production activities are presented in Table 5.7. As in the Appalachian Area optimal farm plan, Class V land remained idle. On July 1, 1974 corn grain produced but not fed to cattle (23,184 bushels) was sold in surrounding markets. Capital borrowing and labor hiring activities are presented in Table 5.8. Returns to the operator's resources under this farm plan were $65,668.

Summary

In light of these results, a few tentative generalizations can be noted.

Table 5.6. Crop Production Activities, Yields, and Crop Fertilization Activities in the Optimal Farm Plan, Appalachian Area, 1973-1974 Scenario

Crop	Land Class	Acres	Yield per Acre	Fertilization N (lbs/ac)	Fertilization P_2O_5 (lbs/ac)	Fertilization K_2O (lbs/ac)
Corn Grain	I	21.73	129 bu.[b]	162.5	a/	a/
Corn Grain	II	7.68	116 bu.[b]	137.5	a/	a/
Corn Grain	III	13.84	95 bu.[b]	112.5	a/	a/
Corn Grain	IV	49.28	73 bu.[b]	87.5	a/	a/
Corn Silage	II	2.66	20 tons[c]	137.5	a/	a/

a/ Held constant at the recommended rate (see Appendix A).

b/ 84.5% dry matter.

c/ 27.9% dry matter.

Table 5.7. Crop Production Activities, Yields, and Crop Fertilization Activities in the Optimal Farm Plan, Shenandoah Area, 1973-1974 Scenario

Crop	Land Class	Acres	Yield Per Acre	Fertilization N (lbs/ac)	Fertilization P_2O_5 (lbs/ac)	Fertilization K_2O (lbs/ac)
Corn Grain	I	23.59	129 bu.[b]	162.5	a/	a/
Corn Grain	II	44.46	116 bu.[b]	137.5	a/	a/
Corn Grain	III	185.62	95 bu.[b]	112.5	a/	a/
Corn Grain	IV	108.91	73 bu.[b]	87.5	a/	a/
Corn Silage	II	10.42	20 tons[c]	137.5	a/	a/

a/ Held constant at the recommended rate (see Appendix A).

b/ 84.5% dry matter.

c/ 27.9% dry matter.

Table 5.8. Operator Labor Use, Labor Hiring, and Capital Borrowing Activities in the Optimal Farm Plan, Shenandoah Area, 1973-1974 Scenario

	January-April 1973	April-July 1973	July-October 1973	October-January 1974	January-April 1974	April-July 1974	July-October 1974
Operator Labor Use (man days)	.9	75.6	36.2	75.6	25.5	-	-
Labor Hired (man days)	5.4		299.4				
Borrowed Capital Outstanding ($)	7,976	9,318	266,105				

(1) Higher rates of gain appear to be preferred to lower rates of gain. One possible explanation for this is that as the energy content of the feed, and hence the rate of daily gain, increases so does the efficiency of feed conversion to cattle weight maintenance or weight gain. This tends to support the conclusion reached by Wilson (1976) and to some extent by Brokken, et. al (1976) that cattle production lies in stage I of the feed-gain production process (see Chapter II).

(2) Relative profitability of cattle production is very sensitive to changes in the price-weight curve. To the extent that the negative impact of weight on per hundredweight price diminishes, heavier cattle are produced in the optimal farm plan (as in the April-June period of the 1976-1977 scenario).

(3) When the price-weight function continues to shift toward lower cattle prices (as in the 1973-1974 scenario) cattle production becomes less profitable to the point that they are not produced in the optimal plan at all.

(4) In all of the previous models, no cattle are produced to the heaviest weights. One explanation for this is that, as cattle get heavier, their total energy requirements (both energy for maintenance and energy for gain) increase. In addition, feeding to heavier weights is discouraged by the negative price-weight gradients employed.

CHAPTER VI

ANALYTICAL RESULTS UNDER PRICE AND YIELD PARAMETERIZATIONS

This chapter presents optimal farm plans for both the Appalachian and Shenandoah areas assuming average cattle and feed prices observed during the 1968-1977 period, as expressed in 1977 dollars. Selected price and cost changes are performed on the Appalachian model. These parametric changes are divided into two parts: those changes affecting feed costs and crop yields and those changes affecting cattle prices.

Analytical Results for the 1968-1977 "Average Year" Scenario

Appalachian Area

Under the assumption of average 1968-1977 cattle and feed prices, the optimal farm plan for the Appalachian Area generated $36,321 in returns to the operator's land, labor, and capital. The livestock purchase, sale, and production activities in this farm plan are presented in Table 6.1. Associated crop production and fertlization activities are given in Table 6.2; and utilization of the operator's labor, along with the capital borrowing and labor hiring activities, are presented in Table 6.3.

All cattle are, in this optimal plan, raised at the maximum allowable gain per day, that is 2.2 pounds per day for steers and 1.67 pounds per day for heifers. No cattle are produced in the January-March period and heifers are produced only in the April-July interval. Lack of steer production during these two periods is most likely due to the fact steer

Table 6.1. Livestock Purchase, Sale, and Production in the Optimal Farm Plan, Appalachian Area, 1968-1977 "Average Year" Scenario

	October 1 Year 1	October 1- January 1, Year 2	January 1 Year 2	April 1 Year 2	April 1-July 1, Year 2	July 1 Year 2	July 1- October 1, Year 2	October 1 Year 2
Purchase or Sale	Purchase 583 steers at 500 pounds		Sell 583 steers at 700 pounds	Purchase 83 heifers at 450 pounds		Sell 83 heifers at 600 pounds Purchase 53 steers at 500 pounds		Sell 53 steers at 700 pounds
Gain		583 steers at 2.2 pounds per day: 500-700 pounds			83 heifers at 1.67 pounds per day: 450-600 pounds		53 steers at 2.2 pounds per day: 500-700 pounds	
Ration per Head per Day (dry matter basis)		6.4 pounds corn silage 4.2 pounds corn grain 1.0 pounds pasture 3.1 pounds corn stover			.9 pounds corn grain 12.5 pounds pasture		3.5 pounds corn grain 11.1 pounds pasture	

Table 6.2. Crop Production Activities, Yields, and Crop Fertilization Activities in the Optimal Farm Plan, Appalachian Area, 1968-1977 "Average Year" Scenario

Crop	Land Class	Acres	Yield Per Acre	Fertilization[a/] (lbs/ac)
Corn grain	I	3.98	125 bu.[b/]	162.5 lbs. nitrogen
Corn grain	III	13.84	95 bu.[b/]	112.5 lbs. nitrogen
Corn grain	IV	49.28	73 bu.[b/]	87.5 lbs. nitrogen
Corn silage	I	17.75	22 tons[c/]	162.5 lbs. nitrogen
Corn silage	II	10.34	20 tons[c/]	137.5 lbs. nitrogen
Orchard grass-ladino clover pasture	IV	110.8	.778 tons[d/]	25 lbs. potash

[a/] Other fertilization held constant at the recommended rate (see Appendix A).

[b/] 84.5 percent dry matter.

[c/] 27.9 percent dry matter.

[d/] Dry matter basis, produced from October Year 1 to October Year 2.

Table 6.3. Operator Labor Use, Labor Hiring, and Capital Borrowing Activities in the Optimal Farm Plan, Appalachian Area, 1968-1977 "Average Year" Scenario

	January-April Year 1	April-July Year 1	July-October Year 1	October-January Year 2	January-April Year 2	April-July Year 2	July-October Year 2
Operator labor use (man days)	3.9	18.5	75.6	75.6	15.3	3.0	5.7
Labor hired (man days)	--	--	31.9	62.75	--	--	--
Borrowed capital outstanding ($)	--	--	--	151,934	--	--	--

price-weight functions on April 1 and July 1 marketing dates exhibit steeper negative slopes than do the steer price-weight functions on other sale dates or the heifer price-weight lines on any sale date. Lighter weight cattle are also preferred to heavier cattle in this solution. This is attributable to the decrease in efficiency of conversion of feed to weight gain associated with weight increase.

Shenandoah Area

The optimal farm plan for the Shenandoah Area, under average 1968-1977 feed and cattle prices, produced returns to the operator's land, labor, and capital of $119,947. Due to the nature of the model, this figure is somewhat exaggerated when compared to what the typical Shenandoah beef operator can expect to earn. The reason for the exaggeration is that, as stated in Chapters III and IV, the cost of capital in the model is a constant rate and there is no upper bound on the total amount of capital that can be borrowed at this rate. To achieve the returns stated above for this model, it is necessary to borrow in excess of $600,000, somewhat more than the typical beef farmer in this area would be able to borrow.

The livestock purchase, sale, and production activities for this solution are presented in Table 6.4. Associated crop production activities are presented in Table 6.5. Operator labor use, capital borrowing, and labor hiring activities in this plan are shown in Table 6.6.

As in the Appalachian solution described above, the optimal farm plan for the Shenandoah Area consists of lighter weight cattle produced at the maximum gain per day. No cattle are produced in the January-March period

Table 6.4. Livestock Purchase, Sale, and Production in the Optimal Farm Plan, Shenandoah Area, 1968-1977 "Average Year" Scenario

	October 1 Year 1	October 1- January 1, Year 2	January 1 Year 2	April 1 Year 2	April 1-July 1, Year 2	July 1 Year 2	July 1- October 1, Year 2	October 1 Year 2
Purchase or Sale	Purchase 2207 steers at 500 pounds		Sell 2207 steers at 700 pounds	Purchase 106 heifers at 450 pounds		Sell 106 heifers at 600 pounds Purchase 67 steers at 500 pounds		Sell 67 steers at 700 pounds
Gain		2207 steers at 2.2 pounds per day: 550-700 pounds			106 heifers at 1.67 pounds per day: 450-600 pounds		67 steers at 2.2 pounds per day: 500-700 pounds	
Ration per Head per Day (dry matter basis)		4.4 pounds corn silage 5.8 pounds corn grain .3 pounds pasture 3.6 pounds corn stover			.9 pounds corn grain 12.5 pounds pasture		3.5 pounds corn grain 11.2 pounds pasture	

Table 6.5. Crop Production Activities, Yields, and Crop Fertilization Activities in the Optimal Farm Plan, Shenandoah Area, 1968-1977 "Average Year" Scenario

Crop	Land Class	Acres	Yield Per Acre	Fertilization (lbs/ac)
Corn grain	I	3.36	125 bu.[b]	162.5 lbs. nitrogen
Corn grain	III	185.62	95 bu.[b]	112.5 lbs. nitrogen
Corn grain	IV	109.91	73 bu.[b]	87.5 lbs. nitrogen
Corn silage	I	20.23	22 tons[c]	162.5 lbs. nitrogen
Corn silage	II	54.88	20 tons[c]	137.5 lbs. nitrogen
Orchard grass-ladino clover pasture	V	141.5	.778 tons[d]	25 lbs. potash

[a] Other fertilization held constant at the recommended rate (see Appendix A).

[b] 84.5 percent dry matter.

[c] 27.9 percent dry matter.

[d] Dry matter basis, produced from October Year 1 to October Year 2.

Table 6.6. Operator Labor Use, Labor Hiring, and Capital Borrowing Activities in the Optimal Farm Plan, Shenandoah Area, 1968-1977 "Average Year" Scenario

	January-April Year 1	April-July Year 1	July-October Year 1	October-January Year 2	January-April Year 2	April-July Year 2	July-October Year 2
Operator lbaor use (man days)	8.4	75.6	75.6	75.6	57.9	3.9	7.3
Labor hired (man days)	--	--	196.6	478.9	--	--	--
Borrowed capital outstanding ($)	--	10,436	20,458	618,218	--	--	--

and heifers are produced only in the April-July production period. Although the number of cattle produced in the Shanandoah solution is somewhat larger than that for the Appalachian are, rations fed per head of cattle are, with the exception of the October-December production period, the same as in the Appalachian model. In the latter period, the Shenandoah model feeds on a per head basis more corn grain and corn stover, but less corn silage, than does the Appalachian model. This difference in rations is caused by the fact that, during harvest, corn silage production is more labor intensive than corn grain. Whereas the operator's own labor was sufficient to harvest all crops in the Appalachian "average year" solution, wage labor was hired during the harvest season in the Shenandoah solution. Hence it is reasonable that the Shenandoah model should be more sensitive to differences among crops in harvest labor requirements.

Results of Parametric Changes on Crop Yields and Feed Input Prices

In this section, the effects on model outcomes of parametric changes in costs per unit of feed are examined. These cost changes are accomplished by altering the yields of corn grain, corn silage, and pasture produced on the farm, and by changing corn purchase and sale prices. Parametric changes are only carried out on the Appalachian model, in which the 1968-1977 "average year" solution described above serves as the base solution.

Pasture Yield Changes

The intercepts on the orchard grass-ladino clover yield relations were first increased and then decreased for each soil class by 50% of their initial values in 10% increments. Taking Soil Class V, for example, this resulted in a range of unfertilized pasture yields of .380 to 1.149 tons, evaluated in increments of .076 tons.

The model allows pasture to be produced continuously from October of the first model year through September of the following year with no provision for storage from one period to the next. As pasture yields were icnreased, the numbers of cattle produced in each production period in the optimal farm plan, with the exception of the January through March period, rose. The latter period evidenced no change in cattle numbers since pasture was scarcely made available for grazing during the winter months. The increases in cattle numbers associated with pasture yield increases in other production periods is demonstrated in Figure 6.1.

Rations fed to heifers during the April-June production period and to steers during the July-September production period remaind constant as pasture yields changed, but the October-December ration changed to some degree. Specifically, more pasture and less corn silage was fed per head as pasture yields rose, suggesting that corn silage and pasture are substitutes as feed inputs in the modeled beef operation. The amount of corn grain and corn stover fed per head also increased slightly in order to compensate for the lower energy density of pasture while maintaining maximum daily gains (see Figure 6.2).

Corn Yield Changes

Parametric changes on corn yields were performed simultaneously for corn silage and corn grain functions. The intercepts of the fertilizer-yield relations for these crops were increased and decreased in each soil

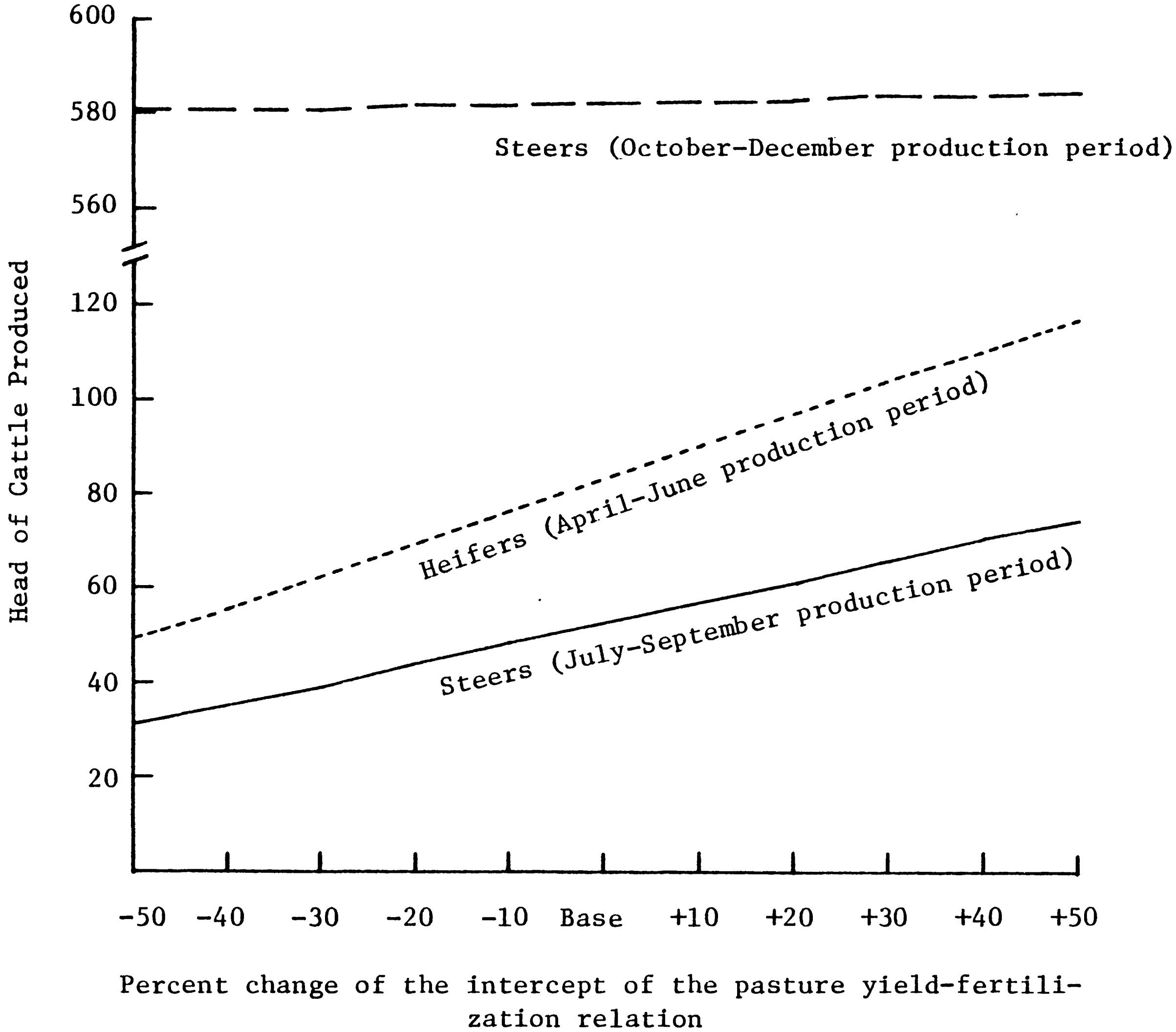

Figure 6.1. Optimal Steer and Heifer Numbers by Selected Pasture Yields, Appalachian Area 1968-1977 "Average Year" Scenario

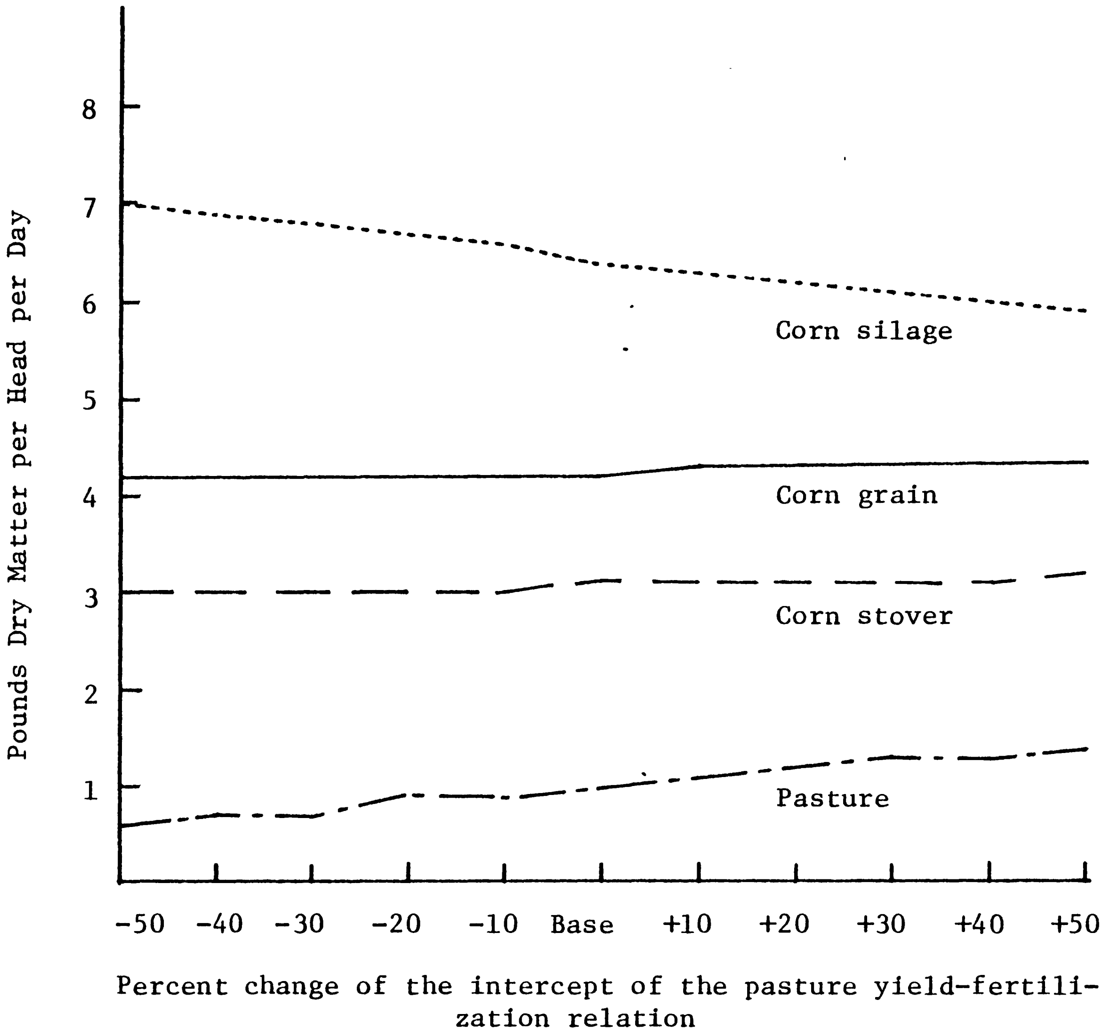

Figure 6.2. Optimal Ration for Steers Produced in the October-December Period, by Selected Pasture Yields, Appalachian Area, 1968-1977 "Average Year" Scenario

class by 50% of their base values in 10% increments. In Class I soils, for example, this produced a range of corn grain yields (unfertilized basis) from 26.93 to 80.79 bushels per acre, and a range of corn silage yields (unfertilized basis) from 6.61 to 19.83 tons per acre. Yields were altered incrementally in units of 5.39 bushels per acre for corn grain and 1.32 tons per acre for corn silage. The ranges and incremental changes in yields of unfertilized and fertilized corn on other soil classes can be calculated from the respective intercepts and slopes of the yield-fertilization relations (see Appendix A).

Changing corn yields had no effect on the number of cattle produced nor on the rations fed in the April-June or July-September production periods. The changes did have a substantial effect on the number of cattle produced and ration fed during the October-December production period. This implies that the increased feed volume resulting from increased corn yields is only made available to cattle in the fall season immediately following harvest. Although this may be due in part to the presence of storage costs, it is more likely that spring pastures represent a cheaper source of net energy than corn grain or silage at the yield levels observed.

Corn silage did tend to replace corn grain in the fall ration as both grain and silage yield intercepts shifted upward (see Figure 6.3). The reason for the substitution probably lies in the fact that proportionate increases in both yield relations result in larger increases in net energy production per acre from corn silage than from corn grain. Changes in corn silage production associated with shifts in intercepts of the yield relations are depicted in Figure 6.4. The nonlinearity of

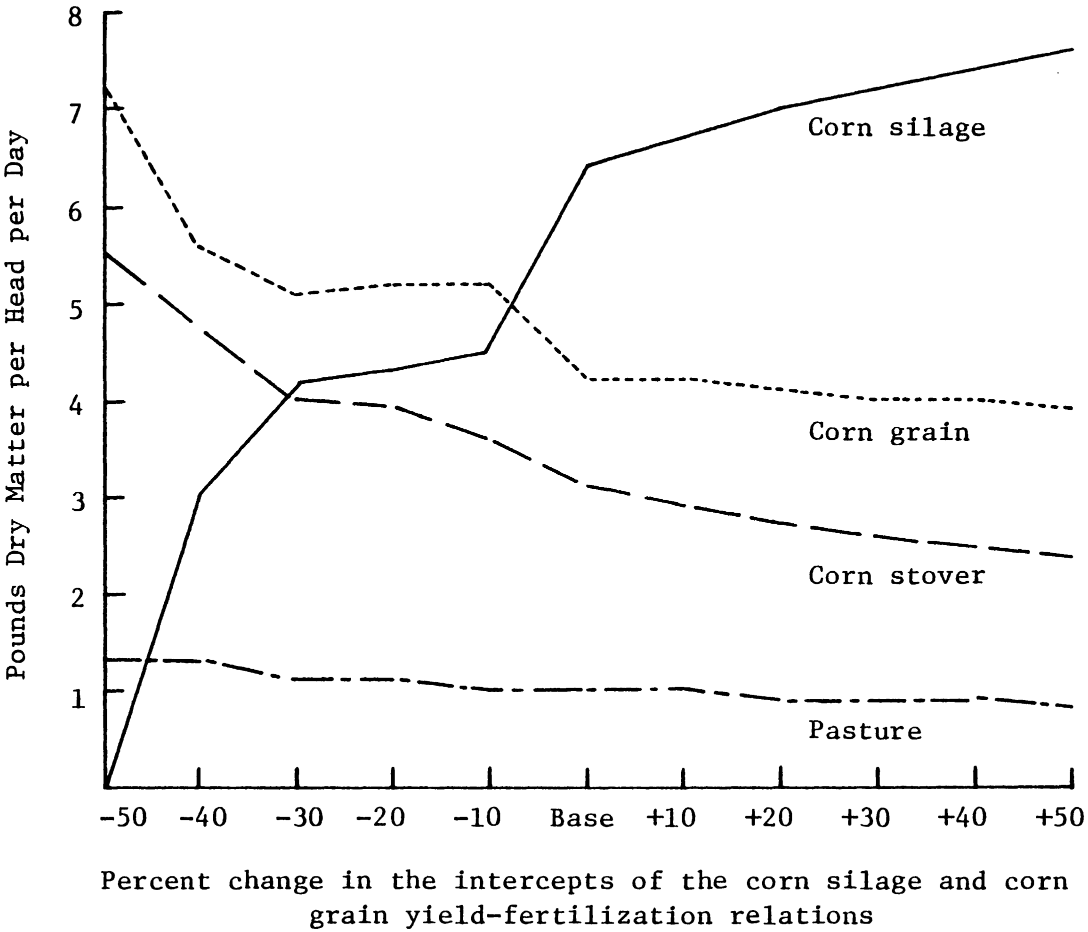

Figure 6.3. Optimal Ration for Steers Produced in the October-December Period, by Selected Corn Yields

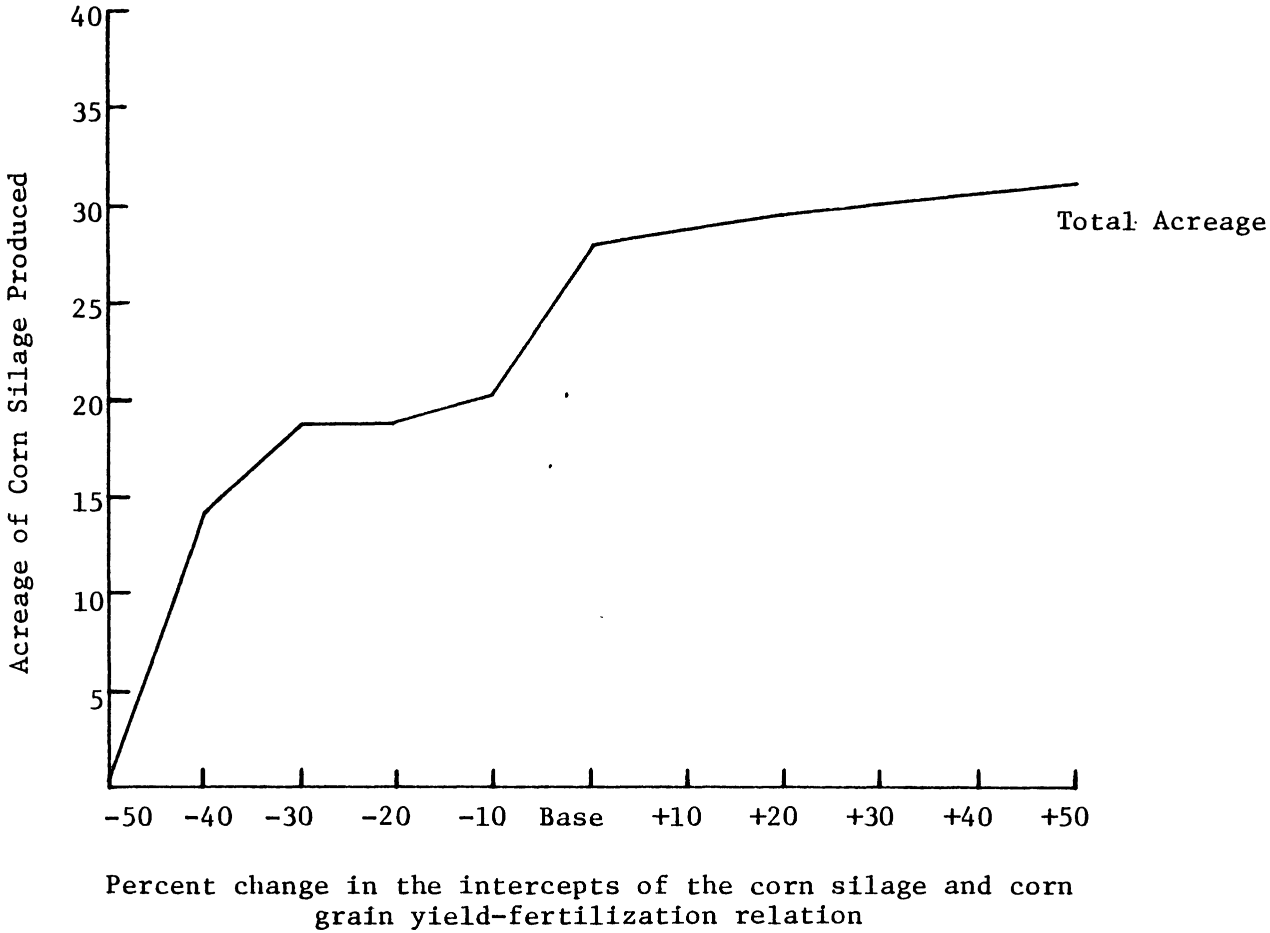

Figure 6.4. Optimal Corn Silage Acreage, by Selected Corn Silage and Grain Yield Levels

this curve is due in part to the high harvest labor requirements of corn silage. As mentioned previously, corn silage harvesting is more labor intensive, on a per-acre basis, than corn grain harvesting. As corn silage production increases, outside labor must be hired to meet these higher labor requirements, thus increasing the marginal cost of silage production.

Corn Price Changes

The 1968-1977 "average year" base solution for the Appalachian Area was next changed by parametrically increasing corn prices paid and received in each quarter by $0.60 per bushel in $0.20 per bushel increments. On October 1 of the first model year, the price of corn was increased from $2.57 to $3.17 per bushel. The optimal farm plan did not change at all in response to these corn price increases. This insensitivity indicated the superior profitability of feeding corn to cattle relative to selling the corn in surrounding markets. Presumably, if corn prices had been increased further, cash sale of corn would have entered the solution.

Corn prices paid and received were then decreased $0.80 per bushel in each quarter in $0.20 per bushel increments. No change in the optimal farm plan occurred until corn prices were decreased $0.60 per bushel (to equal $1.97 per bushel); at this point the optimal plan responded to the lower feed costs by purchasing corn meal and by carrying additional steers. A summary of the optimal rations in the October-December and July-September production periods when fall corn prices are $1.97 per bushel are provided in Table 6.7. The ration fed in the other periods did not change. Twenty additional steers were produced in the

Table 6.7. Number of Steers Produced and Optimal Rations Fed With Fall Corn Prices Received at $1.97 per Bushel, Appalachian Area, 1968-1977 Average Year Scenario[a/]

	October-December Year 1	July-September Year 2
Number steers produced[b/] (head)	603	61
Ration per head per day (pounds dry matter basis)		
Corn silage	6.8	--
Corn grain	4.1	1.0
Pasture	1.0	8.7
Corn stover	2.9	--
Purchased corn meal	--	5.0

[a/] Corn prices received per bushel in other periods are: Winter - $1.97, Spring - $1.94, and Summer - $2.09.

[b/] The ration fed to heifers did not change from the base solution, therefore it is not reported here.

October-December production period and eight additional steers were produced in the July-September production period. Corn meal in the amount of 301 hundredweight was purchased on January 1 of year 2, stored until July, and fed to all 61 steers produced in the July-September production period. At the same time, the amount of corn grain produced on the farm and fed to cattle declined somewhat.

This decrease in farm-produced corn grain in the optimal ration indicates, of course, the substitutability of purchased corn meal for farm-produced corn grain as a concentrate in the beef cattle diet. It is noteworthy that, although the decline in farm grain production was offset by increased roughage production in the form of corn silage, sufficient amounts of purchased corn meal were fed at low corn prices to slightly increase the steer ration energy density from 2.54 to 2.63 megacalories per kilogram in the July-September period.

Results of Parametric Changes on Cattle Prices

Cattle prices used in base and parametric solutions reported here are expressed as linear price-weight relations (see Chapter IV). Hence parametric changes on cattle prices involve intercept changes and/or slope changes. Intercept changes were sequantially carried out in three ways: (1) increasing intercepts of heifer price-weight relations in each quarter, (2) increasing and decreasing intercepts of steer and heifer price-weight relations in each quarter, and (3) increasing the July 1 intercept for steers.

Slope changes were then performed on the steer price-weight relation of October 1 of year 1 and January 1 of year 2 while holding all other cattle prices at zero level.

<u>Changing the Intercepts of the Price-Weight Relations</u>

<u>Increasing Heifer Prices</u>. The intercepts of the heifer price-weight relations in the Appalachian base solution were first increased in each quarter in $1 per hundredweight increments up to a total increase of $10 per hundredweight over the base solution intercepts. No change in the optimal farm plan occurred until the heifer intercepts had risen by $4 per hundredweight. At this point, steer production dropped from the October-December production period and was replaced with 713 heifers. The per-head ration fed the 713 heifers consisted (on a dry matter basis) of 6.0 pounds corn silage, 3.1 pounds corn grain, .8 pounds pasture, and 2.4 pounds corn stover. The associated crop production activities exhibited a slight increase in corn silage production, reflecting the preference of a somewhat lower energy ration for heifers at 1.67 pounds per day gain.

Further increases in heifer prices produced no change in the optimal farm plan until heifer price-weight intercepts had risen $10 per hundredweight above the base solution level. At this point, three more heifers were produced in the October-December period, and five heifers produced in the March-June period were carried over to the next period for sale at a heavier weight of 750 pounds. The likelihood that heifers will be carried to a heavier weight is reinforced by the fact that cattle weight has a lower negative (or higher positive) impact on per hundredweight heifer prices than on per hundredweight steer prices.

In the Appalachian base solution, the October 1 purchase price for 500 pound steers is $53.95 per hundredweight and the January 1 sale price for 700 pound steers is $53.44 per hundredweight. The base solution's October 1 purchase price for 450 pound heifers is $43.33 per hundredweight and its January 1 sale price for 600 pound heifers is $46.15 per hundredweight. Although for heifers there is an increase in per hundredweight price from purchase to sale date, it is more profitable to produce steers in the October-December period at the base level prices. It is instructive to observe that, when heifer prices (for both purchase and sale) increase $4 per hundredweight, heifer production replaces steers in this period even though the price differential between January 1 sale and October 1 purchase remains constant. This indicates that the increased desirability of heifer production is due to the increase in marginal net revenue of weight gain that is caused by overall increases in per hundredweight prices, and is not due to a relative change between steers and heifers in the difference between sale and purchase price.

Changing Steer and Heifer Prices. In a second approach, the intercepts of both steer and heifer price-weight functions were decreased $10 per hundredweight, then increased $8 per hundredweight, in $2 per hundredweight increments. When all cattle price-weight intercepts had been decreased $2 per hundredweight from base solution levels, the number of steers produced during the October-December production period decreased from 583 to 573 head per day. Optimal solutions for the remaining production periods did not deviate from the base model. Indeed, no further changes in the optimal solutions in any quarter were observed as intercepts of price-weight relations were decreased to $10 per hundredweight below base levels. The reason for this insensitivity in the optimal solution is that, although reduction of intercepts of price-weight relations decreases the marginal revenue of weight gain, marginal revenue reductions effected here were roughly the same for steers as for heifers. If price-weight intercepts and marginal revenues of gain had been reduced further, it is likely that cattle numbers and average daily gains would eventually have declined.

Increasing the intercepts of the price-weight relations had the same general effect on the optimal solution as did decreasing corn prices. Decreases in corn prices reduced the marginal cost of gain, whereas increases in intercepts of price-weight relations increased the marginal revenue of gain. Hence, each increased the marginal profit of gain. In the present situation, each $0.10 per bushel decrease in corn prices was equivalent in its effect on cattle numbers to a $1.07 per hundredweight increase in intercepts of the cattle price-weight relations.

Changing the Slope of the Price-Weight Relation for Fall Steers Only

In order to focus attention on slope changes only, the intercept of the January 1 price-weight relation was lowered from that in the base solution to equal the intercept of the October 1 function; all other period's cattle prices were set at zero level. The slopes of the January 1 and October 1 price-weight relations were then decreased algebraically (increasing the negative impact of weight on cattle price) in increments of .1.[1/] This was equivalent to incrementally increasing the rate at which prices decreased with weight by $0.001 per hundredweight per pound weight increase.

Decreasing the slopes of both the October 1 and January 1 functions by .1 produced no change from the base solution's optimal farm plan for the October-December period. When the slopes were decreased by .2, however, cattle production fell and corn silage was substituted for corn grain in the optimal ration (see Table 6.8). At this point, it also became relatively more profitable to sell part of the corn grain production than to feed it. Such a plan remained optimal as the slope was decreased to -2.3067. At slope -2.4067, the number of steers held declined (although maintaining the same rate of gain) and the amount of corn sold increased. The optimal ration under this cattle price-weight relation consisted entirely of corn grain and corn stover.

Only when the slope of the price-weight relation was decreased by 1.0 (to -2.9067) did the optimal rate of gain decline to 1.1 pounds per day. Due to the lower energy requirements to achieve 1.1 pounds per day gain, the optimal ration consisted entirely of corn silage and stover (see Table 6.8). The reason for the decrease in optimal daily gain is that, as the slope of the price-weight function decreases algebraically there is a corresponding decline in the value of heavier cattle relative to lighter weight animals. Thus the marginal value of a unit of weight gain decreases with decreases in the slope of the price-weight relation.

[1/] See Chapter IV for the base solution price weight relations.

Table 6.8. Summary of Optimal Farm Plans When Price-Weight Slopes Change for Fall Steers Only

Slope of the price-weight relation[a] (¢ per cwt. per pound cattle weight)	-1.9067[b]	-2.0067	-2.1067	-2.2067	-2.3067	-2.4067	-2.5067	-2.6067	-2.7067	-2.8067	-2.9067	-3.0067
Number steers produced (head)	561	561	465	465	465	308	308	308	308	308	183	170
Gain (pounds per head per day)	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	1.1	1.1
Ration (dry matter basis per head per day)												
Corn silage (lbs)	4.7	4.7	5.7	5.7	5.7	--	--	--	--	--	2.5	--
Corn grain (lbs)	5.8	5.8	4.7	4.7	4.7	6.6	6.6	6.6	6.6	6.6	--	1.2
Corn stover (lbs)	3.6	3.6	4.3	4.3	4.3	8.2	8.2	8.2	8.2	8.2	11.3	12.6
Corn sold (bu)	--	--	1891	1891	1891	4486	4486	4486	4486	4486	7746	7773

[a] The intercept was held constant at $63.49 per hundredweight.

[b] Base solution.

CHAPTER VII

SUMMARY AND CONCLUSIONS

This chapter presents a brief overview of the model, procedures employed in the study, and conclusions reached. Reservations about the results are also discussed, and suggestions for further research presented.

Summary

The purpose of this study was to develop a normative model of a mixed farming operation that included beef cattle production, feed crops, cash grain, and pasture. This involved developing a framework for finding, under specified farm situations, the profit maximizing buying and selling weights of cattle, optimal rations fed, and optimal resource mixes for production of feed inputs. Also to be determined was the response of the optimal farm plan to alternative feed production costs and feed prices, and to alternative feeder cattle prices.

The model employed was a linear program with variable fertilization rates on the crop production activities, alternative cattle purchase and sale weights, and alternative rates of cattle weight gain. Description of ration constituents was made on the basis of protein and energy content. Energy content of feeds was in turn divided into two components: energy for cattle weight maintenance and energy for cattle weight gain.

The model was utilized to find optimal farm plans for typical Virginia beef farms in the Shenandoah and Appalachian areas of Virginia under three price scenarios: 1973-1974 prices, 1976-1977 prices, and

1968-1977 "average year" prices. Results of the analysis indicated, in each of these cases, that profits would be maximized by production of lighter weight cattle at the maximum rate of gain considered (2.2 pounds per day). The optimal ration generally consisted of a mixture of corn grain and stover, corn silage, and pasture. These results substantiate the findings of previous studies of beef cattle in Virginia [Kline and Cameron, Chiang, et. al.] that production of light-weight slaughter or feeder cattle is more profitable than production of heavy-weight cattle.

Various parametric changes were applied to the Appalachian model under the 1968-1977 "average year" price scenario to evaluate the effects of such changes on the optimal farm plan. These changes entailed altering the yields of corn grain, corn silage, and pasture; altering purchase and sale prices of corn; and finally altering parameters of the cattle price-weight relations.

Proportionate increases in corn silage and corn grain yields resulted in increased cattle production in the October-December production period, increases in corn silage acreage, and decreases in corn grain acreage. Increases in pasture yields resulted in substitution of corn grain for corn silage and in slight increases in cattle numbers. In general, however, changes in intercepts of fertilization-yield relations did not significantly alter optimal cattle production patterns. Although cattle numbers tended to respond positively to increases in yields, cattle continued to be produced at maximum daily gains and at lighter weights.

A significant finding was that the proportion of forages in the optimal ration did not change substantially under forage yield alterations.

This failed to substantiate findings by Melton and by Anderson and Walker that conditions may be encountered under which the optimal beef ration consists entirely of forages. One reason for the discrepancy between these studies and the present study is the difference in method by which nutritional data for feeds was evaluated. Anderson and Walker, for example, employed a dry matter quality approach to feed evaluation, whereas the present study employed National Research Council growth equations (see Chapters II and IV).

Essentially the same patterns emerged under parametric alteration of corn prices. When corn prices declined, more cattle were produced but the optimal rate of gain and cattle purchase and sale weights remained the same.

Parametric increases in intercepts of cattle price-weight functions also increased the number of cattle produced, but usually had little effect on the optimal rate of gain. Only when the slope of the price-weight relation was decreased considerably for fall steers did the optimal rate of gain decline. This supports the contention that, under a wide range of feed input costs, the optimal rate of gain is the maximum rate of gain that can be obtained [Wilson, Brokken, et. al.]. But the maximum rate of gain is not always the optimal rate of gain. In general, as the negative impact of cattle weight on per hundredweight price increases, the optimal rate of gain declines.

More specifically the conclusions reached from this study are:

(1) Using this model, and under the three scenarios employed, changes in feed production costs and feed input prices have

little effect on the optimal sex, buying and selling weights, or rates of gain for cattle.

(2) Changes in parameters of the cattle price-weight relations have a greater effect than do changes in feed costs on the rate of gain, sex, or weight range of cattle produced in the optimal plan. Specifically, the change in an animal's market value from one period or weight to the next is the primary determinant of both optimal purchase and sale weight and rate of gain.

(3) The yield-fertilization relations employed encourage maximum application of fertilizer on the crop production activities.

These conclusions provide important management information to Virginia's beef producers. For example, since price variability among weights of cattle is of more importance than feed input price variability in determining the optimal farm plan, the optimal production decisions to be made by a farm operator may be less complex than formerly realized.

Reservations About the Results

Because of the nature of the model and data availability, some reservations about the results should be noted. One such reservation deals with the accuracy of the yield-fertilization relations. There are limited data available for estimating production functions of crops grown under Virginia conditions. In general, these data are developed from research plots rather than from actual or average farm situations. Thus, they tend to overstate yields that could be achieved on most farms, although some effort was made in the present study to compensate for this overstatement.

Estimates employed of a "typical" beef operator's resources may not completely represent current (1979) conditions. Farm resource data employed in this study were based on a survey conducted in 1968, and many changes in the typical beef operation may have occurred since that time.

The reader's attention is also directed to the beef cattle nutritional requirements utilized in the model. The functions used to estimate these requirements do not account for stress from environmental factors such as excessive heat or cold, and do not account for compensatory gains.[1/]

Questions may be raised about the accuracy of the net energy relations themselves under conditions of high roughage intake, since the rations are mainly based on cattle fed high-concentrate diets.

There are some limitations associated with the L-P model construction. The maximum allowable gain for steers was 2.2 pounds per day, although higher rates of gain, up to 3.1 pounds per day, may be achieved. Furthermore, the model assumes constant returns to scale, whereas some economies with respect to cattle production may be encountered in actual farm situations. The model also allows capital to be borrowed in unlimited amounts at a constant rate of interest. This property probably resulted in too many cattle being produced in the fall quarter of the

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[1/] Compensatory gains are additional weight gains encountered when the cattle ration changes suddenly from low to high energy content.

Shenandoah area solutions. Finally, prices and technical production coefficients are treated with certainty, thus ignoring the effects of risk.

Suggestions for Further Research

The present study may provide useful management information for beef operators in Virginia, and for operators in other areas with topography and climate similar to Virginia. The model itself is considerably more flexible than many other beef feeding models, and goes beyond the traditional TDN-based program to include net energy requirements for maintenance and gain. As such it may serve as a guideline for development of future models of beef production. Several issues not addressed in this study may fruitfully be pursued in additional research. They are:

(1) Development of empirical models relating actual farm crop yields to fertilization levels for the various crops produced in the study area;

(2) Maintenance of updated information on economic characteristics of typical beef farms in the study area;

(3) Development of more accurate cattle growth relations that account for climatic conditions and for compensatory gains encountered under study area conditions; and

(4) Model evaluation in the presence of price or yield risk.

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APPENDICES

APPENDIX A

Fertilizer recommendations, adjusted long term average yields, and intercepts for yield-fertilizer response functions are here provided for each of the crops specified in the study's LP models.

Appendix Table A.1. Corn Grain: Fertilizer Recommendations, Adjusted Long Term Average Yields, and Intercepts for Corn Grain-Nitrogen Response Functions, by Soil Class

Soil Class	Fertilizer Recommendation N (lbs/acre)	P_2O_5 (lbs/acre)	K_2O (lbs/acre)	Adjusted Long Term Average Yield (bu/acre)	Revised Intercept
Class I	162.5	60	60	110	53.86
Class II	137.5	50	50	100	52.50
Class III	112.5	40	40	82	43.14
Class IV	87.5	40	40	63	32.77

Source: Epperson and Hawkins; and Epperson, Hawkins, and McCart.

Appendix Table A.2. Corn Silage: Fertilizer Recommendations, Adjusted Long Term Average Yields, and Intercepts for Corn Silage-Nitrogen Response Functions, by Soil Class

Soil Class	Fertilizer Recommendations N (lbs/acre)	P_2O_5 (lbs/acre)	K_2O (lbs/acre)	Adjusted Long Term Average Yield (tons/acre)	Revised Intercept
Class I	162.5	80	125	20	13.22
Class II	137.5	65	100	18	12.26
Class III	112.5	50	60	14	9.30
Class IV	87.5	50	60	11	7.35

Source: Epperson and Hawkins; and Epperson, Hawkins, and McCart.

Appendix Table A.3. Alfalfa Hay: Fertilizer Recommendations, Adjusted Long Term Average Yields, and Intercepts for Alfalfa Hay-Fertilizer Response Functions, by Soil Class

Soil Class	Fertilizer Recommendations N (lbs/acre)	P_2O_5 (lbs/acre)	K_2O (lbs/acre)	Adjusted Long Term Average Yield (lbs/acre)	Revised Intercept
Class I	0	70	200	6801	5962
Class II	0	65	162.5	6234	5469
Class III	0	50	142.5	5100	4501
Class IV	0	40	112.5	3967	3488

Source: Epperson and Hawkins; and Epperson, Hawkins, and McCart.

Appendix Table A.4. Fescue: Fertilizer Recommendations, Long Term Average Yields, and Intercepts for Fescue-Nitrogen Response Functions, by Soil Class

Soil Class	Fertilizer Recommendations N (lbs/acre)	P_2O_5 (lbs/acre)	K_2O (lbs/acre)	Long Term Average Yield (tons/acre)	Revised Intercept
Class I	180	60	100	4.0	2.92
Class II	140	55	65	3.75	2.91
Class III	100	40	40	3.25	2.65
Class IV	60	40	40	2.625	2.265

Source: Epperson and Hawkins; and Epperson, Hawkins, and McCart.

Appendix Table 4.5. Orchardgrass-Clover Pasture: Fertilizer Recommendations, Long Term Average Yields, and Intercepts for Pasture-Fertilizer Response Functions, by Soil Class

Soil Class	Fertilizer Recommendations N (lbs/acre)	P_2O_5 (lbs/acre)	K_2O (lbs/acre)	Long Term Average Yield (lbs/acre)	Revised Intercept
Class I	0	55	75	4741	3807.26
Class II	0	35	45	4042	3481.75
Class III	0	30	30	3147	2773.50
Class IV	0	25	25	2574	2262.75
Class V	0	25	25	1830	1518.75

Source: Epperson and Hawkins; and Epperson, Hawkins, and McCart.

APPENDIX B

This Appendix contains budgets utilized in developing costs and input requirements for each of the crops specified in the study's LP models.

Appendix Table B.1. Corn Grain: Operating Costs Per Acre[a/]

Operating Inputs	Units	Price ($)	Quantity	Value ($)
Corn seed	bu	40.00	.25	10.00
Lime	ton	14.00	.5	7.00
Herbicides	acre	8.00	1	8.00
Insecticides	acre	8.00	1	8.00
Tractor fuel cost	acre	3.23	1	3.23
Tractor repair cost	acre	3.61	1	3.61
Tractor lube cost	acre	.48	1	.48
Equipment fuel cost	acre	11.36	1	11.36
Equipment lube cost	acre	1.70	1	1.70
Equipment repair cost	acre	18.23	1	18.23
Total operating cost per acre				71.61

[a/]These exclude costs of land, labor, capital, and fertilizer.

Source: Moore, Brant, and Folmar.

Appendix Table B.2. Corn Silage: Operating Costs Per Acre[a/]

Operating Inputs	Units	Price ($)	Quantity	Value ($)
Corn seed	bu	40.00	.25	10.00
Lime	tons	14.00	.5	7.00
Herbicide	acre	8.00	1	8.00
Insecticide	acre	8.00	1	8.00
Silo[b/]				
Tractor fuel cost[c/]	acre	3.66	1	3.66
Tractor repair cost[c/]	acre	4.30	1	4.30
Tractor lube cost[c/]	acre	.55	1	.55
Equipment lube cost	acre	.33	1	.33
Equipment fuel cost	acre	.05	1	.05
Equipment repair cost[c/]	acre	9.61	1	9.61
Total operating cost per acre				51.50

[a/]These exclude costs of land, labor, capital, and fertilizer.

[b/]Silo cost is estimated to be $4.50 per ton silage harvested.

[c/]Costs reported here do not include the variable costs associated with changes in yields that were also included in the model. Such costs amount to $1.73 per ton silage harvested.

Source: Moore, Brant, and Folmar.

Appendix Table B.3. Alfalfa Hay: Operating Costs Per Acre[a/]

Operating Inputs	Units	Price ($)	Quantity	Value ($)
Establishment cost	acre	22.00	1	22.00
Boron	lbs	.20	20	4.00
Elevator[b/]				
Lime	ton	14.00	.5	7.00
Herbicide	acre	4.25	1	4.25
Insecticide	acre	3.00	1	3.00
Twine[c/]				
Tractor fuel cost[d/]	acre	2.27	1	2.27
Tractor repair cost[d/]	acre	2.70	1	2.70
Tractor lube cost[d/]	acre	.34	1	.34
Equipment lube cost	acre	6.55	1	6.55
Equipment fuel cost	acre	.98	1	.98
Equipment repair cost[d/]	acre	16.31	1	16.31
Total operating cost per acre				69.40

[a/] These exclude costs of land, labor, capital, and fertilizer.

[b/] Elevator cost is estimated to be $2 per ton of hay harvested.

[c/] Twine cost is estimated to be $3 per ton of hay harvested.

[d/] Costs reported here do not include the variable costs associated with changes in yield that were also included in the model. Such costs amount to $1.41 per ton hay harvested.

Source: Moore, Brant, and Folmar.

Appendix Table B.4. Fescue Hay: Operating Costs Per Acre[a/]

Operating Inputs	Units	Price ($)	Quantity	Value ($)
Establishment costs	acre	17.00	1	17.00
Lime	ton	14.00	.5	7.00
Twine[b/]				
Tractor fuel costs	acre	3.53	1	3.53
Tractor repair costs	acre	4.49	1	4.49
Tractor lube costs	acre	.53	1	.53
Equipment repair costs	acre	13.32	1	13.32
Total operating cost per acre				45.87

[a/]Exclusive of land, labor, capital, and fertilizer.

[b/]Twine cost is estimated to be $3.00 per ton hay harvested.

Source: Moore, Brant, and Folmar.

Appendix Table B.5. Improved Pasture: Operating Costs Per Acre[a]

Operating Inputs	Units	Price ($)	Quantity	Value ($)
Clover seed	lbs	1.90	.33	.63
Fertilizer spreader	acre	2.50	1.00	2.50
Sprayer	acre	3.00	1.00	3.00
Herbicide	acre	4.00	1.00	4.00
Lime	tons	14.00	.50	7.00
Tractor fuel cost				.05
Tractor repair cost				.06
Tractor lube				.01
Total operating costs per acre				17.25

[a] These exclude costs of labor, capital, and fertilizer.

Source: Moore, Brant, and Folmar.

APPENDIX C

Nutritional data are here summarized for each of the feeds available for utilization by the study's LP models.

Appendix Table C.1. Dry Matter Content, Net Energy for Maintenance, Net Energy for Gain, and Crude Protein Content, by Feed

Feed	Dry Matter (percent)	Net Energy for Maintenance (Mcal/kg dry matter)	Net Energy for Gain (Mcal/kg dry matter)	Crude Protein (percent)
Corn grain	84.5	2.28	1.48	10.0
Corn silage	27.9	1.56	.99	8.1
Corn stover	87.2	1.21	.55	5.9
Alfalfa hay	91.2	1.07	.28	13.6
Fescue hay	88.5	1.15	.44	11.1
Ladino clover pasture	18.0	1.69	1.11	24.7
Orchardgrass pasture	23.8	1.41	.82	18.4

Source: National Academy of Sciences [1976].

APPENDIX D

This Appendix contains crop price and cattle price data utilized in the study's 1973-74, 1976-77, and 1968-76 "average year" models.

Appendix Table D.1. Corn and Alfalfa Prices Paid and Received By Farmers Seasonal Averages, Virginia, 1973-74

Date	Corn Grain Received ($ per bu)	Alfalfa Hay Received ($ per ton)	Corn Meal Paid ($ per cwt)	Alfalfa Hay Paid ($ per ton)
October 15, 1973	2.26	49.50	6.30	63.00
January 15, 1974	2.69	47.50	6.60	65.00
April 15, 1974	2.62	51.50	6.80	68.00
July 15, 1974	2.94	48.00	7.10	55.00
October 15, 1974	3.46	53.00	8.60	58.00

Source: Virginia Agricultural Statistics, July, 1975.

Appendix Table D.2. Corn and Alfalfa Prices Paid and Received By Farmers, Seasonal Averages, Virginia, 1976-77

Date	Corn Grain Received ($ per bu)	Alfalfa Hay Received ($ per ton)	Corn Meal Paid ($ per cwt)	Alfalfa Hay Paid ($ per ton)	Wages Paid to Hired Labor ($ per hour)
October 15, 1976	2.52	66.00	6.90	101.00	2.55
January 15, 1977	2.54	69.50	6.70	108.00	2.65
April 15, 1977	2.60	79.00	6.60	112.00	2.63
July 15, 1977	2.21	64.00	6.30	90.00	2.08
October 15, 1977	1.88	80.50	5.60	113.00	2.72

Source: Virginia Agricultural Statistics, 1978.

Appendix Table D.3. Corn and Alfalfa Prices Paid and Received by Farmers Seasonal Averages, Virginia, 1968-1977, in 1977 Dollars

Season	Corn Grain Received ($ per bu)	Alfalfa Hay Received ($ per ton)	Corn Meal Paid ($ per cwt)	Alfalfa Hay Paid ($ per ton)
Fall	2.57	70.59	7.46	86.00
Winter	2.57	63.97	6.85	93.00
Spring	2.54	65.85	7.67	86.00
Summer	2.69	62.72	7.46	81.00

Sources: Virginia Agricultural Statistics, 1974, 1975, 1978; and Agricultural Prices, Annual Summary, 1969.

Appendix Table D.4. Feeder Steer and Heifer Prices by Weight Class, Fall 1973[a/]

Steers		Heifers	
Weight (pounds)	Price ($ per cwt)	Weight (pounds)	Price ($ per cwt)
500	60.72	450	49.84
600	57.53	525	48.97
700	54.45	600	47.95
800	51.48	675	46.78
900	48.61	750	45.47
1000	45.84	825	44.00
1100	43.18	900	42.35
		975	40.63

[a/]Generated from equations (4-20) and (4-21).

Appendix Table D.5. Feeder Steer and Heifer Prices by Weight Class, Fall 1976[a]

Steers		Heifers	
Weight (pounds)	Price ($ per cwt)	Weight (pounds)	Price ($ per cwt)
500	39.30	450	27.80
600	38.54	525	28.33
700	37.64	600	28.67
800	36.60	675	28.82
900	35.42	750	28.78
1000	34.10	825	28.56
1100	32.65	900	28.14
		975	27.53

[a] Generated from equations (4-14) and (4-15).

Appendix Table D.6. Average Steer and Heifer Prices by Weight Class, Virginia State-Graded Feeder Cattle Sales, Summer 1977

Steers		Heifers	
Weight (pounds)	Price ($ per cwt)	Weight (pounds)	Price ($ per cwt)
450-550	40.77	425-500	32.73
550-650	40.33	500-550	32.41
650-750	39.42	550-650	32.74
750-850	38.43	650-700	32.43
850-950	37.58	700-750	32.32
950-1000	36.52	750-850	31.20
1000+	35.80	850-900	30.80
		900+	30.97

Source: Cooperative Extension Service, Dept. of Animal Science, Virginia Polytechnic Institute and State University, Blacksburg.

Appendix Table D.7. Feeder Steer and Heifer Prices by Weight Class, Fall Quarter, 1968-1977 "Average Year" Scenario[a]

Steers		Heifers	
Weight (pounds)	Price ($ per cwt)	Weight (pounds)	Price ($ per cwt)
500	56.21	450	46.83
600	54.18	525	45.87
700	52.15	600	44.91
800	50.12	675	43.94
900	48.10	750	42.98
1000	46.07	825	42.02
1100	44.04	900	41.06
		975	40.10

[a]Generated from equations (4-26) and (4-27).

Appendix Table D.8. Average Seasonal Price Differentials for Feeder Steers and Heifers, Virginia Weekly Sales: Periods 1973-74, 1976-77, and 1968-77

Model	Steers		Heifers	
	Summer-Spring[a/] ($ per cwt)	Winter-Fall[b/] ($ per cwt)	Summer-Spring[a/] ($ per cwt)	Winter-Fall[b/] ($ per cwt)
1976-77	-0.57	2.64	0.22	3.14
1973-74	-4.01	-1.36	-6.73	-0.85
1968-77[c/]	-3.65	3.30	-1.58	3.77

[a/]Average summer price minus average spring price.

[b/]Average winter price minus average fall price.

[c/]Expressed in 1977 dollars.

Appendix Table D.9. Costs of a Corn Storage-Drying System With Capacity of 13,440 Bushels

	Total $	Per Bu ¢
Variable Costs[a]		
Energy for drying	1,269	9.44
Electricity	269	2.00
Insurance[b]		
Repairs	340	2.53
Total Variable	1,878	13.97
Fixed Costs		
Depreciation	774	5.76
Interest	567	4.22
Taxes	26	.19
Insurance	81	.60
Total Fixed	1,448	10.77
Total Cost	3,326	24.74

[a] Excludes labor and capital costs.

[b] Insurance costs amount to $88 per 3-month period, or 0.65¢ per bushel per quarter.

Source: Bauer, Donald, and Smith.

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A MODEL FOR OPTIMAL MANAGEMENT DECISIONS
IN INTEGRATED BEEF STOCKING-FINISHING OPERATIONS

by

Warren B. Jessee, Jr.

(ABSTRACT)

The objective of this study was to develop a normative model of a mixed farming operation that included production of beef cattle, feed crops, cash grain, and pasture. A linear program was designed to determine profit maximizing cattle purchase and sale weights, optimal rations, and optimal resource mixes for production of feed inputs. Included were variable fertilization rates on crop production activities, alternative cattle purchase and sale weights, and alternative rates of cattle weight gain, each expressed on quarterly bases over a two-year decision horizon.

The model was utilized to find optimal farm plans for typical Virginia beef farms in the Shenandoah and Appalachian areas under three price scenarios: 1973-1974 prices, 1976-1977 prices, and 1968-1977 "average year" prices. Results of the analysis indicated, in each of these cases, that profits would be maximized by production of lighter weight cattle at maximum rates of gain.

Various parametric changes were applied to the Appalachian model under the 1968-1977 "average year" price scenario to evaluate the effects of such changes on the optimal farm plan. For the most part, changes in crop yields and corn prices did not significantly alter optimal production patterns for cattle. Although cattle numbers tended

to respond positively to increases in yields and decreases in corn prices, cattle continued to be produced at maximum daily gains and at lighter weights. Only when the negative impact of cattle weight on price per hundredweight was increased substantially did the optimal rate of weight gain decline.