A LINEAR PROGRAMMING DERIVATION OF OPTIMUM RANGE RATIONS FROM ALTERNATIVE NUTRITIVE SPECIFICATIONS IN A WHOLE BEEF FARM FRAMEWORK

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CHAPTER I

INTRODUCTION

Oklahoma has over 23 million acres of pasture land, comprising 66 percent of the State's total farmland resources. Because of topography, soil characteristics and natural vegetation most of those acres are better adapted to forage production than cash crop production. To utilize these abundant forage resources most Oklahoma farmers raise beef cattle. In many areas supplementary grazing of crops such as small grains and use of improved pastures on cropland complement the pastureland in production of beef. Beef cattle convert the low and high quality forages into a marketable product.

Beef production ranks first as a source of cash farm income in Oklahoma. In 1971 receipts from cattle and calves exceeded 850 million dollars or 57 percent of Oklahoma's cash farm income [22, p. 66]. Since agriculture is the state's most important single industry, forage and beef cattle resources are very important to Oklahoma's economy.

Oklahoma has an important part of the Nation's beef production resources. The State ranks third in the number of beef cows and fifth in the number of all cattle and calves [22, p. 43]. Thus, increases in the economic efficiency of beef production are important to Oklahoma and the Nation.

Aggregate Beef Situation

Tweeten estimated the income elasticity for a weighted aggregate of all farm products domestically consumed to be .15 [29, p. 350]. A one percent increase in consumer disposable income raises the demand for farm products .15 percent. Therefore, other things constant, the farmer's relative share of national income will fall as aggregate income increases. However, growth in national and world population causes aggregate consumption to increase across time.

The outlook for the beef sector is optimistic, providing beef production can be organized profitably. Brandow estimated an income elasticity of .47 for beef [29, p. 350]. The consumers' preference for red meat--primarily beef, along with increasing consumers' disposable income, has resulted in an increase in per capita consumption of beef from 85 pounds per person in 1960 to 109 pounds per person in 1973 [30, p. 4]. Improvements in prices of beef relative to other farm products have allowed increasing competition of the beef enterprise for cultivated acres planted to improved pastures. Analyses are needed of potentials to increase beef production in different production areas of the United States.

Local Beef Situation

Macroeconomic factors have an influence on the general price outlook for beef. However, factors closer to the study area in eastern Oklahoma affect resource use and demand for breeding, stocker and feeder animals. One of the most important factors is the growth of beef feeding in the southwestern United States. There are many reasons for the feeding expansion in the High Plains, but an important one is the abundance of feed grains. The specific study area for this dissertation lacks an abundance of feed grains and only a very few feedlots exist. However, the close proximity to large feedlot capacity directly affects the possible use of resources in the study area. The feedlots demand a large quantity of feeder cattle. The study area is fortunate to have great forage production capabilities and a readily accessible market for feeder cattle going to the feedlots. It is a natural economic activity for this area to convert the forage into a saleable product in the form of feeder cattle.

The Problem

In general terms, the problem concerns resource allocation within a beef-forage production firm. Many alternative combinations of separate but interacting decisions must be considered if the firm is to make optimum beef-forage decisions. The basic questions for determining forage-beef organization in this study are: (1) which classes of beef cattle should be produced and how should production and sale be timed, (2) what forages should be utilized, (3) what quantity of beef and forage optimally utilize the fixed factors of production.

The modern beefman is constantly seeking improved techniques of analysis to aid in the decision making process. It is the primary purpose of this study to develop a technique--linear programming--that can be used by beefmen to answer the preceding questions. Little work has been done to bring the detail of the feedlot-feedmix model to a more general beef-forage farm situation in which land use is important. This study is intended to show the applicability.

Most linear programming studies with land using applications have directly or indirectly employed external stocking rate assumptions. The stocking rate simplification provides less detailed nutritional and yield information to the decision maker for both the forages and beef enterprises. Evaluation of added nutritional and yield precision is a subpurpose of the study. This requires comparing the optimum plans derived with the model to those provided by more conventional model formulations.

Objectives

1. To estimate input-output relationships for forage and beef production, particularly measuring forage-pasture yields and livestock requirements by nutrient content--dry matter, total digestible nutrients and digestible protein.
2. To develop a linear programming model for estimating optimum mixes and levels of forage and beef production for selected resource situations.
3. To determine and evaluate the profit maximizing range rations for alternative nutritional constraints.
4. To compare results of the beef-forage model with previously published research.

Previous Research

Linear programming has been widely utilized in the selection of least-cost feed lot rations for livestock. The research has carried to the apex of application. Most commercial formula feed firms have some means of formulating a least-cost mix for their product. The linear programming process is available to individual farmers through the Oklahoma Extension Service [6]. The feed-mix program can be used by anyone to obtain least cost rations for beef, swine and dairy [21]. The beef solution is very versatile. It uses net energy data to determine least-cost rations for different rates of gain. These programs are strictly designed for feedlot conditions.

Smith and Quance conducted separate projects on obtaining least-cost roughage systems for dairy cattle. Smith used only TDN as a basis for nutrient requirements of the dairy animal [26]. Quance considered digestible protein by seasons as well as the stomach capacity of dairy cows [23].

An Arkansas study determined least-cost methods of producing and utilizing forages under alternative situations [9]. The nutritional requirement of a representative beef cow herd measured in animal unit months was used in selecting the forage crop system that minimized costs. Seasonality of forage production was considered as well as different utilization procedures. The profitability of the beef cow herd was derived by subtracting the costs of the feeding system from the value of production.

Gibson employed a profit maximizing linear programming technique to compare the eight most common beef cow systems in North Louisiana [11]. The monthly nutrient requirements for the system studied were given in pounds of digestible protein and total digestable nutrients. The study considered ten forages, all grazed. The optimum level of beef production for selected typical resource situations and the stability of the solutions for varying price levels were discussed.

Gustafson used linear programming to maximize profits for a fixed feedlot facility [12]. The study derived optimum feeding system including a rate of gain, grade and days in feedlot. The ration was specified by DM (restriction on quantity of feed consumed) DP, NEM, NEP, CAL, PHOS, and Vit. A. Breakeven prices (comparative value) were computed via parametric programming for alternative forages. All feedstuffs were assumed purchased and delivered to the feedlot.

Halbrook studied the minimum resource requirements for livestock producers of the eastern prairies of Oklahoma [13]. Linear programming was used to find the minimum resource situation. Halbrook also evaluated the impact of off farm employment on the minimum amounts of land, capital and labor required for specified levels of income to owned resources. The feed yield and livestock nutrient requirement were stated in AUM's and representative livestock systems were selected as a basis for comparisons.

Many projects developed useful data for this study. Schneeberger [24] and Barr [3] developed cost and return budgets for the study area, particularly activities using improved forage production and management practices. This literature does not include all related studies but is only a sample of previous research.

Area of Study

The Oklahoma counties for which the soil and yield data are developed in the study are Wagoner, Okmulgee, Muskogee, Sequoyah, McIntosh, and Haskell. The land resources in the study area are now primarily in livestock supportive use. The area is climatically suited for the production of a large variety of forages and livestock enterprises. Excellent forage yields are possible because of the abundant rainfall, combined with fertilizer and managerial resources. The average annual rainfall is approximately 40 inches.

CHAPTER II

MODEL CONCEPTION

This study is concerned with simultaneously determining the optimum mix and level of forage production and beef production. The basic units of inquiry are the enterprises comprising a farm firm organization. The general approach is normative, i.e. what should be the organization.

This chapter includes a brief review of the assumptions and nature of a linear programming analysis. Production economics models are discussed in a linear programming context. The ability of a linear programming model to meet the profit maximizing marginal conditions of production economics theory is explained mathematically. Conditions for finding the profit maximizing combinations of primary (e.g., pasture) and secondary (e.g., beef) products are discussed. The capability of linear programming to derive the optimum combinations of primary and secondary products is explained. Finally, the chapter contains an overview of some of the technical relationships involved in the research project.

Linear Programming

Among the operational tools of agricultural economists, linear programming (LP) efficiently approximates optimal organizational decisions of an individual farm firm.

The general linear programming model in matrix notation is"

$$\begin{array}{ll} \text{Maximize} & Z = C'X \\ \text{Subject to} & \mathbf{A}X \leq B \\ \text{and} & X_i \geq 0 \end{array}$$

where:

Z represents the value of the objective function, which is net revenue to operator labor and management for this study;

C is a 1xn vector of costs or returns for each of n activities;

X is a nx1 vector of activity levels (X_i) for each of n activities;

A is a mxn matrix of input-output coefficients; and

B is a mx1 vector of resource restrictions, commonly referred to as the right hand side.

For a discussion of the theory of linear programming, see Dantzig [13], Heady and Candler [14], or other linear programming texts.

The **A** matrix in this study contains pasture yields and resource requirements; livestock feed requirements and resulting beef production; nutritive values of supplemental feed; labor requirements for pasture, livestock and feeding enterprises; annual and total capital requirements; cash flow accounting data; land resource requirements; and transfer, buy and sell coefficients. Details of the matrix are discussed in Chapter III. The C vector, or objective function contains the costs associated with production activities and prices associated with buy-sell activities. The B vector, or right hand side, contains the land and labor resource situation.

Economic Relationships

Production economics theory would employ marginal analysis to determine the optimum mix and level of beef and forage production. Deriving simultaneous optimal relationships between factors and products, factors and factors, and products and products is the task of marginal analysis. For a discussion of the marginal analysis theory for those three problems see Heady and other production economics or theory of the firm texts [15]. With proper model construction the optimum resource allocation from linear programming is the same as derived from marginal analysis. In the following, only necessary conditions are presented because price and technical relationships used in the study require conformance with necessary and sufficient conditions for optimality.

Factor-Product Model

The equilibrium of the factor-product model indicates the profit maximizing level of output and the corresponding level of input used. The optimum level of production for the continuous production (Figure 1) is point C where the $\frac{\delta Y}{\delta X} = \frac{P_x}{P_y}$.

The production function of linear programming is a "discontinuous" type [14, p. 43]. The discontinuous factor-product relationship is illustrated by line abcd in Figure 1. Points a, b, c and d represent different input-output ratios as designated by different activities in the LP model. Each of the activities use factor X to produce output Y but at different levels.

If the points a, b, c, and are associated with activities that apply 0, 50, 100 and 200 pounds of nitrogen per acre, the resulting production function of bermuda grass per acre is also given by the respective points a, b, c and d. By connecting these points from the finite LP activities, the continuous curve can be approximated by using additional discontinuous line segments (adding activities).

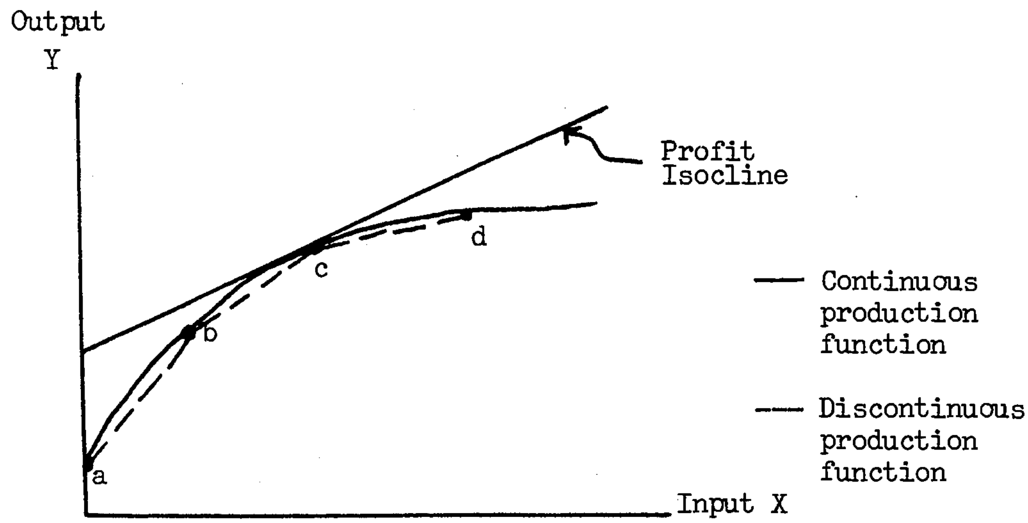


Figure 1. Factor-Product Equilibrium

The equilibrium (optimum) input for the continuous function is at point c where the following condition holds:

$$\frac{\delta Y}{\delta X} = \frac{P_x}{P_y}$$

For the discontinuous function, abcd, optimality at point c is defined by:

$$\frac{\Delta Y}{\Delta X} \geq \frac{P_x}{P_y} \geq \frac{\Delta Y^1}{\Delta X^1}$$

where:

$\frac{\Delta Y}{\Delta X}$ = the change in product per unit change in the factor (marginal product) for segment bc, and;

$\frac{\Delta Y^1}{\Delta X^1}$ = the change in product per unit of change in the factor (marginal product) for the segment cd.

Graphically, the equilibrium reflects the highest profit isocline, $Y = \frac{\Pi}{P_y} + \frac{P_x}{P_y} X$, that can be achieved. The maximum profit point is where the profit isocline is tangent to the continuous production function.

Factor-Factor Model

The factor-factor model equilibrium determines the least-cost combination of two inputs to produce a specified amount of product. The isoproduct is "discontinuous" because of the linearity and finiteness assumptions of linear programming. The discontinuous isoproduct is illustrated in Figure 2 by line segment fghi.

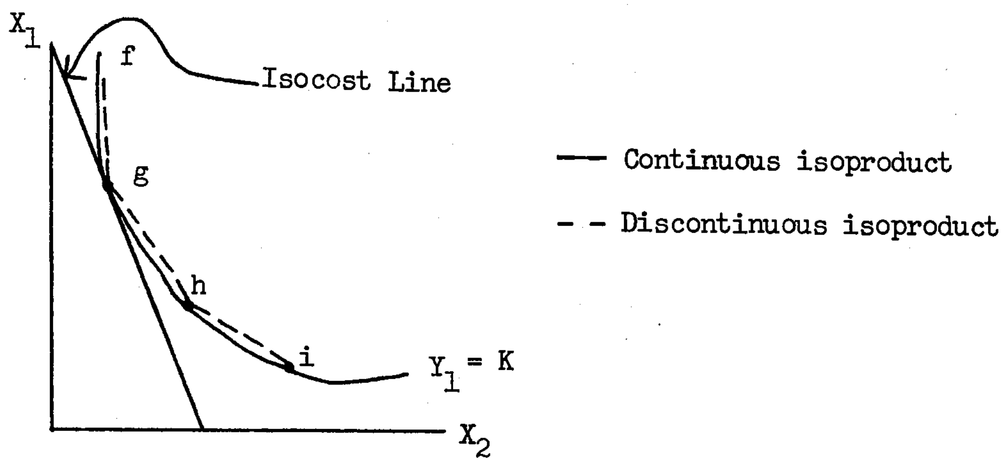


Figure 2. Factor-Factor Equilibrium

For the continuous case, $\frac{dX_1}{dX_2} = \frac{Px_2}{Px_1}$ at point g and is the least cost factor combination. For the discontinuous linear program situation, equilibrium is $\frac{\Delta X_1}{\Delta X_2} \geq \frac{P_{X2}}{P_{X1}} \geq \frac{\Delta X_1^1}{\Delta X_2^1}$.

Each point in Figure 2 (f, g, h and i) is associated with a specific activity in a linear programming model. Each activity requires different ratios of the factors of production to produce the fixed amount of output (Y). The economic problem is to use LP to find which activity is the least cost combination of the factors of production.

Graphically, the optimum mix is at the point of tangency of the least cost isocost, $X_1 = \frac{C}{P_{X1}} - \frac{P_{X2}}{P_{X1}} X_2$, and the isoproduct curve. This is the least cost combination of X_1 and X_2 (for the specified prices) that can produce k amount of product Y_1.

Product-Product Model

The equilibrium of the product-product model is the maximum profit combination of outputs using a specified amount of input or set of inputs. The isoproduct relationship is "discontinuous" because of the linearity and finiteness assumptions of linear programming. A two product linear programming isoinput curve is illustrated by Figure 3.

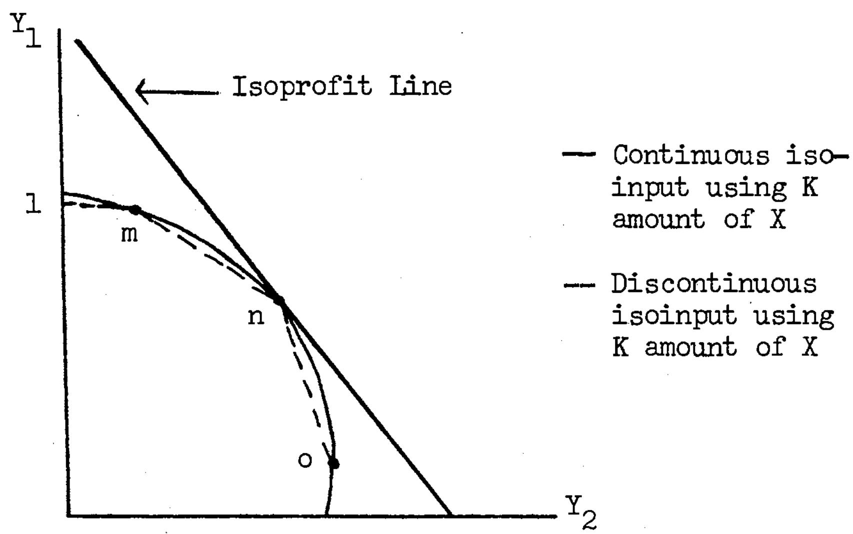


Figure 3. Product-Product Equilibrium

The profit maximizing combination of products on the continuous curve in Figure 3 is point n where $\frac{dY_1}{dY_2} = \frac{P_{Y_1}}{P_{Y_2}}$ for K amount of X. For the discontinuous LP case the equilibrium condition is:

$$\frac{\Delta Y_1}{\Delta Y_2} \geq -\frac{P_{Y_2}}{P_{Y_1}} \geq \frac{\Delta Y_1{}^1}{\Delta Y_2{}^1}$$

where:

$\frac{\Delta Y_1}{\Delta Y_2}$ = the marginal rate of substitution for the segment mn, and;

$\frac{\Delta Y_1^1}{\Delta Y_2^1}$ = the marginal rate of substitution segment mo, of the isoproduct curve.

The line segments lm, mn, and no represent the LP restrictions placed on factors of production and consequently the level of output that is possible. Each line segment is associated with the most limiting LP restriction. The points m, n and o are where two restrictions will enable the same level of output of Y_1 and Y_2.

Graphically, the optimum mix of products is defined by the tangency of the income isocline ($Y_1 = \frac{I}{P_{Y_1}} - \frac{P_{Y_2}}{P_{Y_1}} Y_2$) and the isoinput curve.

<u>Capability of Linear Programming to Satisfy the Equilibrium Conditions of Marginal Analysis</u>

The preceding section illustrated in a very simple way the parallel relationship of linear models, such as linear programming, and the curvilinear, continuous models of the usual textbook marginal analysis. This section further illustrates the conformity of activity analysis to marginal analysis using the notation of linear programming.

The net revenue or objective function in linear programming is $Z = C'X$. As indicated earlier, the vector X is comprised of activities which may include generation and sale of products and purchase (or production) and use of factors, as well as transfer and other accounting transactions in activity form. The criterion guiding the solution of a linear programming problem is that an addition to the set of non-zero values in X does not decrease returns. That is:

$$\sum_{i}^{m} C_i \frac{\Delta X_i}{\Delta X_o} - C_o \leq 0; \tag{1}$$

where:

X_i = activities in the solution before the change and $i = 1 \ldots m$;

C_i = the return (or cost) per unit of X_i;

X_o = the activity entering the solution; and

C_o = the return (or cost) per unit of X_o.

If the amount of income sacrificed as some activities are reduced to increase X_o by one unit ($\Sigma C_i \frac{\Delta X_i}{\Delta X_o}$) is less than the amount of revenue added by a one unit increase of the activity (X_o), profit will be increased by making the change. When the optimal solution is reached, only negative changes in net revenue are possible.

In seeking the optimal solution for a two product case, assume that the maximizing linear programming model's $Z_i - C_i$ row indicates that $C_i \frac{\Delta X_i}{\Delta X_o} - C_o \leq 0$, where X_o is any activity not in the solution. This implies that $\frac{\Delta X_i}{\Delta X_o} \leq \frac{C_o}{C_i}$. Substitution of X_o for X_i would be indicated, and it would stop just short of $C_i \frac{\Delta X_i}{\Delta X_o} \geq C_o$ and so that $\frac{C_o}{C_i} \leq \frac{\Delta X_i^1}{\Delta X_o^1}$. Thus the linear programming algorithm requires that $\frac{\Delta X_i}{\Delta X_o} \leq \frac{C_o}{C_i} \leq \frac{\Delta X_i^1}{\Delta X_o^1}$. The latter identifies an equilibrium condition consistent with marginal analysis relationships described in the preceding section. For example, the equilibrium point could be point n in Figure 3. It would not pay to move to point m or point o. Thus, the linear programming criterion requires that the marginal analysis conditions hold.

Be defining the X_i as factors, factor-factor equilibrium can be derived. At the equilibrium point it would not be profitable to substitute more of an input not in the solution for an input in the solution. Similarly, if X_i is a factor and X_o is a product, use of the factor on a product could not be changed profitably.

Primary-Secondary Product Equilibrium

The primary-secondary problem differs from the product-product model in that, instead of the primary products (Y_1 and Y_2) being sold on the market in order to obtain the highest net revenue, they are "sold" within the firm to produce another product (Y_3). The objective is, for a given resource outlay, to have the combination of initial products which will result in maximum net revenue from the sale of the secondary product in the market place. If all of the primary products are being sold internally (within the firm) the market prices for these products are of no consequence.[1] For example, if all bermuda grass and native hay are fed to beef cows in order to produce calves, the market prices of the primary products are not important. Bermuda grass and native hay are being "sold" to the cows and their effective prices are the value in producing calves.

The choice criterion of the product-product model can be written as:

$$\frac{MVP_{X(Y_1)}}{P_X} = \frac{MVP_{X(Y_2)}}{P_X} \geq 1.$$

The optimum allocation of resource X between two products is such that

[1]It would be well to advise the manager to consider selling if it is a feasible alternative.

the addition to total value product is equal for both products. The optimum combination can be stated:

$$\frac{MPP_{X(Y_1)} \cdot P_{Y_1}}{P_X} = \frac{MPP_{X(Y_2)} \cdot P_{Y_2}}{P_X} \geq 1,$$

because the marginal value product (MVP) equals the marginal physical product (MPP) multiplied by the price of the product (Y_1 and Y_2), respectively. If Y_1 and Y_2 are used to produce Y_3 it is necessary to replace P_{Y_1} and P_{Y2} by value of Y_1 and Y_2 in producing the secondary product Y_3. The value of Y_1 and Y_2 is the marginal value product of Y_1 and Y_2 used to produce Y_3 ($MVPY_1(Y_3)$ and $MVP_{Y_2(Y_3)}$ respectively). The equilibrium conditions for the secondary primary products become:

$$\frac{MPP_{X(Y_1)} \cdot MPP_{Y_1(Y_3)} \cdot P_{Y_3}}{P_Y} = \frac{MPP_{X(Y_2)} \cdot MPP_{Y_2(Y_3)} \cdot P_{Y_3}}{P_X} =$$

$$\frac{MPP_{X(Y_3)} \cdot P_{Y_3}}{P_X} \geq 1.$$

A more complete statement of possible situations would recognize different uses and fixity of resources.

$X_1, X_2, \ldots, X_d$	variable resources that may be used on Y_1, Y_2, and Y_3
$Y_{d+1}, \ldots, X_g$	fixed resources to the firm that may be allocated among Y_1, Y_2, Y_3
$Y_{g+1}, \ldots, Y_n$	fixed resources used only on Y_1
$X_{n+1}, \ldots, X_r$	fixed resources used only on Y_2, and
$X_{r+1}, \ldots, X_t$	fixed resources used only on Y_3.

For optimum allocation it is necessary that:

$$\frac{MPP_{X_i(Y_1)} \cdot MPP_{Y_1(Y_3)} \cdot P_{Y_3}}{P_{X_i}} = \frac{MPP_{X_i(Y_2)} \cdot MPP_{Y_2(Y_3)} \cdot P_{Y_3}}{P_{X_i}} =$$

$$\frac{MPP_{X_i(Y_3)}}{P_{X_i}} \geq 1, \qquad (2)$$

where: $i = 1 \ldots d$.

$$MPP_{X_i(Y_1)} \cdot MPP_{Y_1(Y_3)} \cdot P_{Y_3} = MPP_{X_i(Y_2)} \cdot MPP_{Y_2(Y_3)} = MPP_{X_i(Y_3)} \cdot P_{Y_3} \qquad (3)$$

where: $i = d+1 \ldots g$. Also,

$$P_{X_i \text{ acquisition}} > MVP_{X_i} > P_{X_i \text{ salvage}} \text{ for } i>d. \qquad (4)$$

A summary of effective equilibrium conditions for multiple primary and secondary products is:

1. For given resources, the final (or secondary) products are combined in such a way to yield the highest total value product.
2. The primary products are organized to produce the maximum value of secondary products leading to (1).
3. The variable resources are organized to produce the optimum combination of primary and secondary products.
4. The allocable fixed resources are organized so the marginal value products are equal in all alternative uses.
5. Levels of "fixed" resources are fixed by the economic criterion that a change would not pay.

Capability of Linear Programming to Achieve the Equilibrium Conditions for Primary - Secondary Product Allocation

The linear programming algorithm meets the optimum criteria of marginal analysis for primary and secondary products. In equation (1), the LP criterion equation, evaluation can be made of the profitability of producing more of a primary product (bermuda grazing) as a substitute for another forage. Similarly, more forage might be produced with a "complementary effect" on beef production. All of the marginal criteria are satisfied if the model is properly developed. A careful study of equations (2), (3) and (4) presented in this section will confirm that they are simply factor-factor, factor-product and product-product criteria stated in more complex terms.

Technical Relationships

Units of Measure for Beef-Forage Input-Output Coefficients

Measurement of forage production is difficult because forage is a primary product. Most forage production does not enter the market directly but indirectly as beef. Therefore, a market tested unit of measure for forage is not readily available. Agricultural economists have utilized the animal unit month concept as a unit of measure for most beef related research. Range management researchers have used three different measurements: (1) the pounds of beef per acre; (2) the stocking rate; and, (3) pounds of clipped matter. The alternative measurements and concepts are evaluated in the following sections.

The animal unit (AU) is defined in this study as a mature cow and her calf kept to normal weaning (e.g. seven months). The animal unit month (AUM) measurement for pasture indicates how many months one cow unit under normal calf production could be sustained on one acre of forage. The forage requirement for one cow is 12 AUM's and one cow unit with replacements requires approximately 13.5 AUM's. The data necessary to calculate the AUM yield are the stocking rate and the length of grazing time. Thus, the AUM measurement is essentially a time dimensioned stocking rate. An AUM is calculated by multiplying the cows (animal units) per acre times the number of months the forage is grazed. If a farmer grazes one cow to three acres for six months the pasture is producing $1/3 \times 6 = 2$ AUM. The AUM serves as a common denominator of pasture production or pasture requirements. For example, yields of different pasture stated in AUM's can be added together.

Stocking rate is the number of animals grazed per acre. Although the stocking rate provides valuable managerial information, it is inadequate as a measure of forage production. There is no dimension of time included to indicate how long the beef enterprise can graze at the given stocking rate. Stocking rates do not facilitate a comparison of different types of livestock activities or aggregation of production from separate fields.

The major disadvantage of pounds of beef produced as a measure of forage production is lack of comparability of data because of different stocking rates used and the possibility of operating at different points on the beef or forage production function. Grazing produced is not independent of the stocking rate. The stocking rate may be variable when the unit of measure is the pounds of beef produced per acre.

Variation exists from one experiment to another because of different environmental conditions and different genetic characteristics of animals used. The added variation may not be inherent in the forage enterprise, thus a biased evaluation of the forage yield may occur. To quantify the pounds of beef per acre, the grazing experiment must be set up to test all possible forages and all possible types of beef enterprises. Research to quantify all needed data is not available and is expensive to obtain. In addition, the results may be highly variable.

Clipping as a means of measuring forage yields requires gathering samples of forage growth, oven drying the samples and weighing. If clipping is done on an assigned schedule the growth curve for the forage can be estimated. Researchers can compare pounds of dry matter per acre for different forages. However, the pounds of dry matter give only a measure of the absolute physical amount of the forage produced. Dry matter is not a common denominator. Even though bermuda grass might produce twice as much dry matter as native grass it is not necessarily twice as productive when converted to the secondary product, beef. However, if a nutritive analysis is obtained on the oven dry forage samples to determine the amount of energy (total digestible nutrients) and protein in each of the samples, a common denominator for conversion to beef requirements is approximated. The latter is the procedure used in this study.

Two major advantages of the clipping procedure are of economic importance. The first advantage is that a predetermined stocking rate is not externally imposed. Determining the optimum level of livestock consuming the forage activities is important to accurately estimate the returns to the enterprises as well as the returns to the whole farm.

The second advantage of the clipping procedure is that it enables adding nutritional precision by measuring the forage production in units that are nutritional requirements of beef cattle. Flexible rations are possible within the economic model without developing separate beef enterprises for each forage as has been done in previous research.

However, three problems in converting forage clipping data to beef data remain. The problems are:

(1) Selectivity. Grazing animals' preferences for succulant plants, more palatable plants and portions of plants are not measured in clipping procedures.

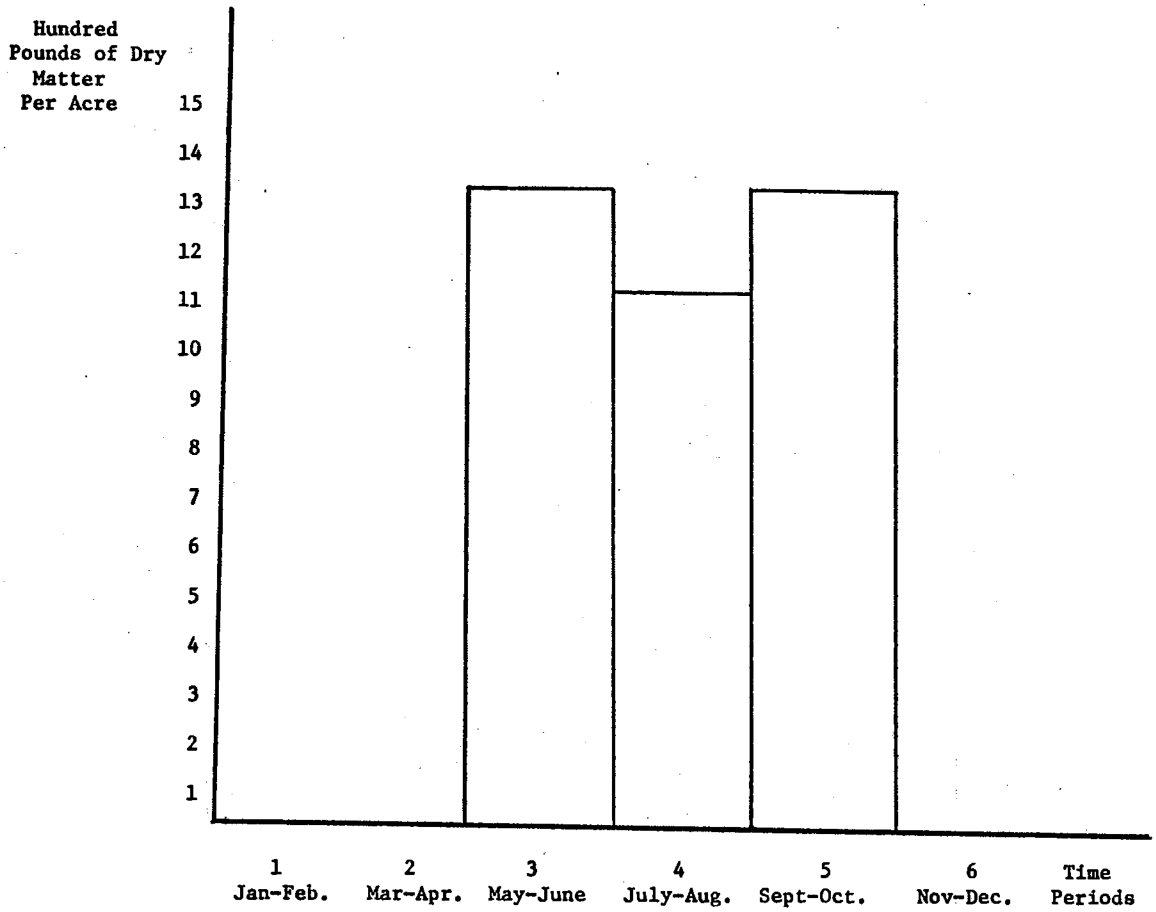
(2) Waste. Grazing animals waste available forage production by trampling during the grazing process.

(3) Nutrient Composition Data. The environmental conditions of the geographic region should influence the nutritional composition of forages, however, very little data for the study area exist.

Adjustment factors that estimated the waste and selectivity problem of clipping were used in this study to convert clipping data to approximate grazing consumption. However, no other consumption problems were considered in this study. Although the aforementioned clipping problems are important, additional research could eliminate the problems.

Timing of Forage Production

A growth curve shows the amount of production related to the timing of production. A typical growth pattern for bermuda is illustrated graphically in Figure 4 for high fertility and multiple applications of fertilizer. The distribution of forage growth throughout the year is



Source: Average Clipping Date From Eastern Oklahoma Experiment Station, Muskogee, Oklahoma [10].

Figure 4. Representative Bermuda Growth Pattern for Eastern Oklahoma

shown graphically. Bermuda is a warm season grass, therefore most of the production occurs from May through October. The quality of the forage is greater during the growing season. Native grass can be represented by a similar graph but with different dry matter yields.

If the beef enterprise is regulated to consume all the bermuda and native grass as it is produced then only short-term or seasonal beef activities are possible unless other feed stuff possibilities exists. Fortunately, forage is partly a stock resource because if it is not utilized in the growing season it can be grazed in the off season. However, the storage process is not perfect. Native or bermuda grass grazed in the winter has a lower quality because of leaching and frost which cause a loss of available nutrients. To have year round grazing as required by a cow-calf enterprise implies a combination of warm and cool season grasses or the feeding of hay or concentrates to supplement low quality, off-season forages.

The mix of warm and cool season growth periods is affected by the timing of nutrient requirements of alternative beef enterprises. A cow-calf enterprise requires an increasing amount of nutrients during the lactation period and the corresponding growth of the calf. A meshing of the forage production timing and the forage consumption timing is necessary.

Beef Nutrition

Snapp and Newman [27] indicate that the nutritional requirements of beef cattle closely parallel those of the micro-organisms found in the rumen. The cattle ration must simultaneously supply the requirements of both the beef cattle and the micro-organisms. The nutritional requirements for the rumen micro-organisms have not been completely determined. However, the science of beef cattle nutrition is well advanced.

The measuring of forage output and beef input requirements in nutritional components enables this study to use some applied nutrition concepts on range situations. Essential nutrient requirements for beef cattle are broadly divided into six categories:

1. Feed Capacity and Bulk
2. Energy
3. Protein
4. Minerals
5. Vitamins
6. Water

Feed Capacity and Bulk. The intake of feed is largely dependent upon the palatability of the feedstuffs. The physical ability of the animal to digest the volume of feed also limits the intake of many forages. The stomach capacity differs for each weight class of beef cattle. Intake limitation can be measured by the proportion of fiber in the ration, however, this study utilizes the pounds of dry matter the animal is able to consume per day. The quality of some forages is so low that if they are used exclusively, the dry matter limitation may result in insufficient levels of the other nutrients.

Energy. According to Snapp and Newman the production of energy to enable the body processes is the prime purpose of feed. The body processes include growth of tissues, maintenance of the body, functioning of all organs and digestion of food. All organic nutrients can be utilized as energy. Thus, energy value can be used as a common basis for expressing the nutritive value. The fact that the organic nutrients, notably protein, may have specific and unique functions does not alter their usefulness as sources of energy.

A shortage of energy is the most common deficiency in beef cattle rations. The results of low energy intake are slow growth or even loss of weight, stunting, failure to conceive, and increased disease and mortality. An energy deficiency is usually accompanied by deficiencies in all other nutrients but especially protein. Overstocking of pastures and ranges is the principle cause of energy deficiency in grazing enterprises. Cattle may eat rations adequate in volume to meet appetite needs but still not perform up to their capabilities because of a lack of sufficient energy in the ration.

The total digestible nutrients (TDN) are the sum of all digestible organic nutrients: protein, fiber, nitrogen-free extract, and fat. This study uses the amount of total digestible nutrients (TDN) as a measure of energy in the beef ration.

Protein. Proteins are of importance in livestock feeding because they are essential for life. Animals build the proteins of their tissues primarily from the amino acids which result from the digestion of protein in their food. Ruminants are able to make all of the amino acids from other nitrogenous compounds. This study uses digestible protein (DP) as a measure of the amount of protein.

Minerals. The requirements of calcium and phosphorus are quite well established. Salt is essential to the growth and health of all kinds of livestock. A mineral and salt mix is fed free choice in the beef-forage model. The cost of providing minerals and salt is accounted for in the enterprise budgets of the beef enterprises.

Water. Water is seldom regarded as a feed, and yet, it is one of the most essential nutrients for all animal life. The cost of providing free access to water is included in the overhead cost in the beef-forage model.

Summary

The economic and technical relationships used in determining the profit maximizing mix and level of forage and beef production are discussed in this chapter. Linear programming fulfills economic conditions for finding the profit maximizing combinations of primary (e.g., forage) and secondary (e.g., beef) products involved in the beef-forage firm. Empirical estimates of the units of measure needed to use the physical production of forage and beef are a concern throughout the study. A major question concerns whether alternative technical units of forage measurement give different organizations.

CHAPTER III

THE BEEF-FORAGE LINEAR PROGRAMMING MODEL

The five basic research steps in this study are: (1) delineation of variables needed in a comprehensive linear programming model for managerial decisions in a beef-forage firm; (2) determination of input-output coefficients applicable for the study area; (3) selection of the optimum organization for specified management situations; (4) comparison of optimum whole farm organizations obtained from alternative nutrient specifications; and (5) determination of profit maximizing rations from the alternative nutrient solutions. This chapter concentrates on the first two steps. Later chapters detail the application of the model and the remaining research steps.

The Beef-Forage Model

A profit maximizing linear programming model is developed as an aid to management of a beef-forage production firm (Table I). Given the size (acres) of the farm, the model is designed to select resource and input combinations to be incorporated in the organization. A multi-period concept is used to enable meshing of the timing of nutrient production and nutrient requirements. Six two-month time periods are used. January-February, March-April, May-June, July-August, September-October, and November-December are periods one through six, respectively.

TABLE I

SUMMARY OF THE COMPONENTS OF THE BEEF-FORAGE LP TABLEAU FOR EASTERN OKLAHOMA

	Pasture Production	Beef Production	Buy Beef	Sell Beef	Purchased Feedstuffs	Equipment & Fencing	Hired Labor	Capital	Land	RHS
Net Revenue	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Nutritive	-A[1]	A[2]			-A[1]					
Soils	B[3]								-B[4]	
Total acre limit									C[5]	H[5]
Labor	D[6]	D[6]				D[6]	-D[7]			I[8]
Capital	E[9]	E[9]	E[9]		E[9]	E[9]	E[9]	-E[10]		
Transfer & Accounting		±F[11]	±F[11]	±F[11]						
Equipment and Fencing Capacity	G[12]	G[12]				-G[13]				

[1] The matrices includes the TDN, DP, DM and AUM nutrient coefficients of raised and purchased feeds for all six time periods [32].

[2] The matrix of beef activities that require nutrients.

[3] The matrix of fourteen productivity soil groups includes separate rows for cropland and native grass, for the land using activities.

[4] The land activity provides the fixed combination of the soil productivity groups.

[5] A coefficient used to limit the size of farm to 1280 acres.

[6] The matrices include the coefficients of the labor required for each activity.

[7] The matrix that makes hiring labor in each time period possible.

[8] The hours of operator labor assumed for the beef-forage model.

[9] The matrices that includes the capital requirements of the respective activities.

[10] The matrix that includes coefficients for borrowing capital.

[11] The matrices of coefficients that enable buying and selling stocker or using steers from the cow-calf activities as stockers or selling as calves.

[12] The matrices of coefficients that require rotational or regular grazing schemes and livestock equipment.

[13] The matrix of activities that provide the grazing system and livestock equipment.

Objective Function

The net revenue row of the model is the objective function (shown in Table I) and is composed of estimated costs and returns of the various inputs and outputs of the beef-forage firm. The net returns definition used in constructing the objective function is the residual to operator labor and management and overhead after all other costs are paid. Overhead for the farm is $1,215 (see Appendix Table XLIV).

Constraints

The other rows in the linear programming model, are restrictions. Nutritive, soil, size, labor and capital restrictions are placed on the optimal solution to develop a realistic and feasible model that fits into the beef-forage firm framework.

Nutritive Constraints

The model has a row for each of the three nutrients (total digestible nutrients, digestible protein and dry matter) in each of the six production periods. The dry matter rows form a maximum restriction limiting the total quantity of feed consumed for each time period to the animal's capacity. The protein and energy rows are minimum restrictions to insure that the nutrients provided are equal to or greater than the protein and energy required for each time period. All nutritive rows except TDN are made neutral for runs in which TDN is used as the only measure of forage yield and livestock requirement.

Six animal unit month (AUM) rows are included in the model as alternative nutritional constraints. The AUM rows can be used in place of the 18 nutritional rows to connect the supply of the forages and the requirement of the livestock activities. The AUM rows are left neutral until changed to minimum restrictions for solutions using AUM as the measure of forage yield and requirement.

Labor Constraints

The labor rows are minimum restrictions to insure that labor hired plus the operator's labor is equal to or greater than the labor needed for each of the various activities. Labor is also divided into the six time periods. The hiring of additional labor is available directly from the computer output for each time period.

Capital Constraints

The capital rows are minimum restrictions. All of the capital needed by the optimum enterprises must be borrowed. The procedure assures that an opportunity cost is charged on owned capital. The annual operating capital row contains all of the variable and cash costs adjusted to an annual basis for computing the interest charge at seven percent per annum. Another row is included for other non-land capital. The non-land capital row enables charging interest on long term investments at seven percent. The land capital row enables charging an opportunity cost (or market cost) on the value of the capital invested in land at six percent per annum.

Soil Constraints

The soils of the study area are divided into fourteen productivity levels. The soil constraints approximate the mix of soil qualities in the region [17]. The model has a separate inventory of soils in native grasses. The separation of native grass soils is needed because native grass is either available or not. It cannot be established in the model. The model allows the transfer of open cropland that is severely sloping and shallow to activities that approximate native grass. If the low productivity soil had been cropped a good substitute to native grass is planting a grass mixture.

Size Constraint

The preceding sections indicate the comprehensiveness of the general beef-forage model. The resources (i.e. labor and capital) can be purchased with no upper limit. However, to have a feasible and bounded linear programming solution, it is necessary to have at least one limited resource. The total acreage of the farm is an equality row that limits the size of the beef-forage firm. The row also facilitates adjusting the linear programming solution for different sizes of farms. The total acreage used for this study is 1,280 acres [2].

Transfer and Accounting Constraints

In addition to those used for soil transfer, there are other accounting rows and transfer columns. The model contains rows that enable transferring of steer and heifer calves to selling activities or to stocker enterprises. Other rows contain hay from the forage production enterprises or purchasing activities which can be transferred to the nutrient rows. Additional rows allow for the purchase and sale of stocker calves and the sale of cull heifers and cows from the cow-calf enterprises.

The total capital requirement is computed in accounting rows. The total capital row gives the sum of the annual operating capital and the fixed capital for the firm. Total capital is a measure of the size of total investment.

Equipment and Fencing

The multi-time period beef-forage model solves the problem (without double charging) of undertaking a specific activity in one time period which might generate the capacity to undertake a similar activity in another period with no additional capital investment. An example is the equipment utilized by stocker enterprises. If a firm has stocker steers on small grain pasture in period one the same equipment would be available to another stocker activity in another time period. To keep from overcharging the fixed cost, capacity rows are created to enable the use of the fixed asset over the entire year if it comes into the optimal solution. The cow-calf equipment is no problem because it is for a year-round enterprise. Other rows of a fixed cost nature for a year include facilities for regular grazing, rotational grazing, hay feeding, and protein and concentrate feeding. Each of these have some associated equipment or assumed labor requirement that, if brought into the solution, is paid for in all time periods.

Column Vectors

The beef-forage model developed in this study is comprised of eight major column vector sections: (1) pasture production; (2) beef production; (3) buying and selling beef cattle; (4) purchased feedstuffs; (5) equipment and fencing facilities; (6) hired labor; (7) capital; and

(8) land. Each of the sets of column vector and input-output coefficients is discussed in turn.

Pasture Production Section

The comprehensive beef-forage model considers four possible forage production systems: (1) the seasonal system assumes grazing of the forage during the growing season; (2) the hay and grazing system involves harvesting hay and grazing the aftermath; (3) the hay system harvests all of the forage and provides no grazing; and (4) the year-round system distributes the dry matter yield across the year. For detailed information on which systems are used with different pasture species, see Table II.

Eight species of grasses are included in the pasture production section: (1) bermuda; (2) bermuda-fescue; (3) fescue; (4) native; (5) sorghum-sudan; (6) small grain; (7) rye-vetch; and (8) weeping love. Three levels of nitrogen fertilizer are applied to bermuda grass. Other practices are summarized in Table II.

The distribution of nutrients for a forage activity depends upon the particular grazing system, as well as the physiological growth curve of the particular grass. The level of the nutrients produced per acre is a function of the fertility level of the soil, the physical yield characteristics of the specific variety of forage and the grazing system.

Survey data, experiment station results and information from agricultural scientists were used to develop nutrient input-output coefficients for grazing. The dry matter yields of the forage producing enterprises were obtained from clipping experiments at the Muskogee Experiment Station [10]. The station is located in the study area.

TABLE II

SUMMARY OF LAND USING FORAGE ACTIVITIES FOR EASTERN OKLAHOMA

Kind	Activities	Fertilizer Levels	Soils	Management Systems[11]
		(Number of Alternatives)		
A. Pasture-Cropland				
(1) Bermuda	85	3[1]	14[2]	1,2,4
(2) Bermuda-Fescue	14	1[3]	14	1
(3) Fescue	11	1[4]	11[5]	1,2,3
(4) Sorghum-Sudan	33	1[6]	11[5]	1,2,3
(5) Small Grain	11	1[7]	11[5]	1
(6) Rye-Vetch	3	1[8]	3[9]	1
(7) Weeping-Love	6	1[10]	3[9]	1,4
B. Native	25		14[2]	1,2

[1]0,100, and 200 lbs. of N with base of 0-40-40 (per year).

[2]System 2 (hay and grazing) is not used on the D soils.

[3]210-40-40 fertilizer.

[4]120-40-40 fertilizer.

[5]Annuals and fescue are not planted on D soils.

[6]40-10-0 fertilizer.

[7]60-30-15 fertilizer.

[8]60-30-15 fertilizer.

[9]SA, SB and SC soils.

[10]80-80-0 fertilizer.

[11]Management System 1 is seasonal grazing.
Management System 2 is haying and grazing aftermath.
Management System 3 is haying only.
Management System 4 is year-round deferred grazing.

Therefore, extrapolation to another environmental area was not needed. The clipping experiments were not conducted on all soil productivity levels of interest in the study. A soil productivity index was used to estimate dry matter yields on all of the soils [17].

The yields from the agronomic clipping experiments cannot be used directly. The amount of forage clipped is not the same as the amount that can be "harvested" by the beef animals. The clipping data must be corrected for tramping of the forage and other wastes by the consuming livestock enterprises. The percentages of utilization were estimated by reviewing appropriate journal articles and publications and in consultation with professional agricultural scientists [7]. The utilization coefficients used are presented in Table III.

TABLE III

ESTIMATED FORAGE UTILIZATION COEFFICIENTS TO CONVERT CLIPPING DATA TO GRAZING DATA FOR EASTERN OKLAHOMA

Forage	Percent of Production Available for Grazing
Bermuda	75
Fescue	75
Small Grains	80
Rye Vetch	80
Sorghum-Sudan	70
Weeping Love	85
Native Succulant[a]	50
Native Dry	75

[a]Required for longevity of the native grass.

Multiplying the utilization coefficient by the average dry matter yield from the clipping experiments gives the adjusted dry matter yield available for consumption by the livestock activity. The available adjusted dry matter yields are given in Table III and are hereafter referred to as the dry matter (DM) production per acre, because the wasted forage is of no economic importance.

Some clipping experiments for bermuda grass and other forages included a digestible protein analysis in conjunction with the measurement of dry matter production. Thus, the protein data were available from the bermuda grass experiments. Nutrient composition tables were utilized to estimate the total digestible nutrients and remaining protein percentages of other forages [19].

The nutrient percentages used are listed by periods in Table IV. The TDN and digestible protein supplied by an acre of forage is estimated by multiplying the percentage times the net dry matter yield of the respective forages. The calculated values of TDN, digestible protein and dry matter are used in the model to balance the ration of the beef enterprises.

The forage production activities require that one of the grazing facility activities be utilized to connect the forage production section to the beef production section. The grazing activity includes appropriate "<u>harvesting</u>" inputs discussed later.

An acre of the appropriate quality of cropland is required as an input for a particular forage activity. However, because native grass cannot be established, native grass requires native soil and not cropland.

TABLE IV

YIELDS AND NUTRIENT PERCENTAGES FOR A BEEF-FORAGE FARM IN EASTERN OKLAHOMA

Dry Matter Yields for CB & SC Soils	Bermuda No Fert.	Bermuda 100# N	Bermuda 200# N	Bermuda Fescue	Fescue	Native	SOS[1]	Small Grain	Rye-Vetch	Weeping Love
System	1,4	1,2,4	1,2,4	1	1	1,2	1,2,3	1	1	1,4
Period										
1 DM					609.6	174.6		293.9	306.0	214.0
2 DM				806.3	806.3			1705.9	2537.0	214.0
3 DM	816.2	1346.5	2014.6	3441.1	806.3	558.5	1128.2	89.8	255.0	2295.0
4 DM	340.1	1079.3	1615.8	1303.3	322.5	93.1	2035.8			765.0
5 DM	204.0	1289.1	1929.1	1303.3		46.5	1348.8	137.2	142.0	214.0
6 DM					1567.5	174.6		750.4	779.0	214.0
Total	1360.3	3714.9	5559.5	6854.4	4112.2	1047.3	4512.8	2977.2	4019.0	5716.0
Nutrient (% of Dry Matter)										
Period Nutrient										
1 TDN	44.0	45.0	45.0		57.0	44.0		75.6	75.6	56.4
2 TDN				57.0	57.0			75.6	73.2	56.4
3 TDN	67.6	62.3	62.3	55.0	53.0	67.6	55.0	75.6	70.5	63.0
4 TDN	64.3	54.8	54.8	53.0	48.0	64.3	55.0			56.4
5 TDN	64.3	54.1	54.1	49.0		64.3	55.0	75.6	75.6	56.4
6 TDN	54.0	48.4	48.4		57.0	54.0		75.6	75.6	56.4
1 DP	1.79	3.72	4.65		9.4	1.79		14.0	14.0	1.9
2 DP				9.4	9.4			14.0	16.1	1.9
3 DP	4.09	13.69	16.93	6.6	5.0	14.7	11.09	14.0	17.0	6.89
4 DP	2.30	7.59	9.25	6.2	4.1	12.9	11.09			3.35
5 DP	2.05	7.86	9.58	5.9		12.9	11.09	14.0	14.4	1.9
6 DP	1.79	4.07	5.07		9.4	3.2		14.0	14.4	1.9

[1]This is the abbreviation used for Sorghum Sudangrass hybrids.

The cost of producing the forage activities was estimated by a synthesized budget approach. The cost includes an annual charge for establishing perennial grasses, fertilizer, weed control and machinery operation necessary for the forage activity.

The operating capital required by each forage activity is stated in terms of an annual equivalent. An annual charge for the cost of establishing perennials is included in the capital section (except for non-fertilized bermuda).

The thumb rule of 1600 pounds of oven dry forage [18] to feed one cow and calf for one month is used to convert clipping to AUM measuring unit. Basing the AUM estimate on native grass which has a utilization coefficient of 50 percent means the rule of themb is equal to 800 pounds of adjusted dry matter per month. The AUM coefficients were calculated by dividing the dry matter for each period by 800.

Beef Production Section

The beef cattle alternatives are: (1) cow-calf production; (2) stocker production. Four cow-calf enterprises are considered in the beef-forage model: (1) fall calving; (2) spring calving; (3) late spring calving; (4) fall calving with weaning delayed one time period. The fourth cow activity results in a heavier calf at weaning. For the stocker enterprises two activities are possible: (1) a fall purchased stocker, and (2) a spring purchased stocker.

The nutritional requirements for the beef enterprises were estimated from the work on the Nutritional Research Council of the National Academy of Sciences [20]. The level of nutrients depends on the body weight of the animal, the rate of gain and the stage of lactation or gestation, if applicable. The initial weight of the stocker activities assumed is 460 pounds. The fall stocker purchased in November and sold in April has a rate of gain of 1.1 pounds per day for period six, 1.65 pounds per day for period one and 2.2 pounds per day for period two, an average of 1.65 over the three periods. The spring stocker purchased in May and sold in November has a rate of gain of 1.65 pounds per day for periods three and four but only 1.1 pounds per day for period five for an average of 1.46. For the different rates of gain, animal weights were interpolated to estimate the nutrients required for each time period. The amount of nutrients required increases as the weight of the animal and the rate of gain increase.

The nutrients for a cow-calf enterprise were approached in the same way as the stocker. However, feed for a cow unit must include nutrients for the replacement heifers and the bull. The nutrients required vary by time periods because of the reproduction cycle. During lactation a large increase in nutrients is necessary. Nutrients for the weaning calves were included in the activity when weaning was delayed one time period.

The labor coefficients were estimated from survey data and in consultation with agricultural scientists [27]. The capital input includes fixed livestock capital and annual operating capital for the cow-calf activity but no fixed livestock investment is directly assigned to the stocker production activities. Both require livestock equipment capital.

The cost of producing beef for each enterprise was estimated by a synthesized budget approach. Survey data and actual farm records was used in the estimation procedure. Items other than feed include the cost of minerals, a charge for death loss (two percent), cost of transportation and marketing, supplies and miscellaneous expenditures [28].

Beef Buy-Sell Column Vectors

The buy-sell activities facilitate the inclusion of seasonal beef price variation in the beef-forage model. Two stocker steer buy, two stocker steer sell and four calf sell activities are available in the model. The buy activities have costs in the objective function equal to the price paid per hundredweight for the particular time period. The sell activities have returns in the objective function. The unit of measure is hundredweight of beef. Sell activities are also available for stocker heifers, cull replacement heifers and cull cows.

Feedstuff Activities

The beef-forage model contains feedstuffs to supplement or substitute for pasture. The roughage activities include alfalfa hay, bermuda hay, native hay, and sorghum-sudan hay. The grains available for feeding are barley, grain sorghum, and oats. Available protein concentrates include cottonseed meal, soybean meal, cottonseed cake, 20 percent protein cubes and 40 percent protein cubes. All of the feedstuffs are available in every time period. Except for the farm produced roughages—bermuda hay, native hay and sorghum-sudan hay—the feedstuffs are purchased inputs.

The estimated variable cost of feeding the feedstuffs (e.g. labor and equipment operating costs) is included in the objective function, the cash flow and the labor rows. The variable cost of feeding depends on the form of the roughage, e.g. hay, ground grain, meal or pellets. Fixed cost capacity (e.g., equipment ownership costs) for feeding is required and an activity supplying that capacity must be in the solution to allow feeding as described in the next section.

Equipment and Fencing

The equipment and fencing activities are designed to link the nutrient producing activities to the nutrient using activities without double counting costs. To "harvest" the pasture producing enterprises, management must provide labor for checking the rate of grazing, condition of the cattle, the availability of water and minerals, the condition of fences, and for moving and handling cattle. The cost of those operations make up the variable cost of grazing. The overhead costs are those items that cannot be allocated to a specific time period. Depreciation of fences and water facilities is an example of an overhead cost of a grazing activity. The fixed cost is the depreciation on equipment and fencing needed for the activity. For the grazing activities, the fixed cost vectors assume a fixed labor requirement for keeping fences in good repair.

The level of utilization of the equipment and facilities affects overhead costs per unit of grazing. The beef-forage model contains regular and rotational grazing systems that have different variable and fixed equipment cost elements. For high yielding pasture enterprises (all except nonfertilized bermuda and native grass) a rotational grazing system is employed that requires more labor and a larger investment in fences.

TABLE V

ESTIMATED NUTRIENT REQUIREMENTS OF THE LIVESTOCK ACTIVITIES INCLUDED IN THE BEEF-FORAGE MODEL FOR EASTERN OKLAHOMA

	SPST	FLST	COW1	COW2	COW3	COW4
			(pounds)			
1TDN		580.2	703.69	547.52	856.25	856.25
1DP		64.2	59.07	35.40	79.77	79.77
1DM		894.0	1295.44	1046.07	1506.58	1506.58
2TDN		717.0	882.67	732.63	881.16	940.80
2DP		76.8	84.79	61.85	79.91	85.33
2DM		964.2	1557.94	1346.52	1557.33	1654.31
3TDN	526.2		885.37	882.67	566.08	1151.90
3DP	56.4		82.39	84.79	36.60	97.73
3DM	786.		1557.64	1557.94	1081.53	2151.13
4TDN	616.2		902.72	899.93	575.36	575.30
4DP	69.		81.22	83.70	37.20	37.20
4DM	966.		1582.86	1583.17	1099.26	1099.26
5TDN	480.		566.08	888.16	737.47	737.47
5DP	43.2		36.60	79.91	62.59	62.59
5DM	833.4		1081.53	1557.33	1353.34	1353.34
6TDN		369.	566.08	566.08	882.67	882.67
6DP		37.2	36.60	36.60	84.79	84.79
6DM		641.4	1081.53	1081.53	1557.94	1557.94
			(AUMS)			
1AUM		1.14	2.24	2.24	2.24	2.24
2AUM		1.38	2.24	2.24	2.24	2.24
3AUM	1.01		2.24	2.24	2.24	2.24
4AUM	1.21		2.24	2.24	2.24	2.24
5AUM	1.41		2.24	2.24	2.24	2.24
6AUM		.99	2.24	2.24	2.24	2.24

Variable costs for supplemental feeding differ for each form of feedstuff (i.e. hay, pellets or grain). The fixed cost of feeding includes the ownership equipment costs. The variable costs of feeding and grazing were synthesized with the aid of professional agricultural workers [27]. Above average management is assumed in estimating the time required to perform certain operations needed by the activity. The labor required was estimated directly, and an indirect calculation of fuel and other variable cost was made based on labor.

The initial cost and maintenance cost of equipment for the stocker steer enterprises is allocated over all time periods. If the stocker equipment is used in one period, it is available in all other periods at no additional cost.

Labor Activities

The labor activities in the model provide hired labor for each of the six periods of the year. An unlimited supply of labor in each time period is assumed available. The cost ($1.75 per hour) of hiring labor is included in the objective function.

Capital Activities

The capital activities are similar to the hired labor activities in form. In the beef-forage model, capital is assumed to be unlimited at six percent for land and seven percent for operating and nonland capital (see Table VI). The interest charge can be viewed as an opportunity cost for owned capital if the beef-forage firm need not borrow all of the required capital.

TABLE VI

ASSUMED BASE PRICES FOR ITEMS SOLD OR PURCHASED IN THE BEEF-FORAGE MODEL OF EASTERN OKLAHOMA

Item		Price
Cow-Calf Enterprise (cwt.)		
Steer calf sold in April	(460 pounds)	33.34
Steer calf sold in June	(580 pounds)	31.82
Steer calf sold in August	(460 pounds)	32.95
Steer calf sold in October	(460 pounds)	32.09
Heifer calf sold in April	(440 pounds)	28.73
Heifer calf sold in June	(554 pounds)	28.27
Heifer calf sold in August	(440 pounds)	27.70
Heifer calf sold in October	(440 pounds)	28.27
Cull cows		19.57
Cull heifers sold in April		25.52
Cull heifers sold in August		25.65
Cull heifers sold in October		24.70
Stocker Enterprise (cwt.)		
Purchase steer November	(460 pounds)	32.09
Sell steer April	(750 pounds)	29.87
Purchase steer May	(460 pounds)	33.34
Sell steer October	(720 pounds)	28.49
Alfalfa Hay (Ton)		30.28
Grains (cwt.)		
Barley		2.63
Corn		3.13
Grain Sorghum		2.53
Oats		3.23
Protein Supplements (cwt.)		
Soybean meal		5.10
Cottonseed meal		4.57
Cottonseed cake		4.67
20% range cubes		2.89
40% range cubes		4.00
Land Per Acre		200.00
Operating Capital (dol.)		.07
Land Capital (dol.)		.06
Labor (hr.)		1.75

[a]Feedstuff base prices are a four year average ending November, 1970; Source of livestock base price and labor and capital is Southern Regional Project S-67.

Land Activity

A column vector in the beef forage model supplies the land required by the forage enterprises. The direct cost of an acre of land is the tax on a unit of real estate. The activity provides soil classes according to the proportion of the soils in the study area. The activity requires land capital based on the price of land in the study area.

Prices

The price levels used in this beef-forage model approximate 1975 prices as estimated by the Southern Regional Project S-67. All prices are listed in Table VI. The planning horizon of one year allows the inclusion of seasonal price variation of both inputs and outputs. The seasonal price patterns are estimated using a monthly moving average to calculate seasonal price indices. The seasonal beef price pattern for Oklahoma is from Hummer and Campbell [16]. The seasonal price indices for inputs were calculated for the beef-forage model [17].

Summary

This chapter describes the comprehensive beef-forage linear programming model. The objective function is to maximize net returns for a representative beef-forage firm subject to the constraints of the model. The constraining variables are broadly classified as nutrients, soils, acres, labor, capital, equipment and fencing, and transfer and accounting. Each variable is further delineated by its impact on the beef-forage linear programming model.

The column vectors (activities) are grouped into eight major sections. The activities are broadly grouped as: (1) pasture forage production; (2) beef cattle production; (3) buying and selling beef cattle; (4) purchased feedstuffs; (5) equipment and fencing costs; (6) hired labor; (7) capital; and (8) land.

CHAPTER IV

RESULTS AND ANALYSIS OF THE BEEF-FORAGE LINEAR PROGRAMMING MODEL

Optimum whole farm organizations for the profit maximizing beef-forage firm are presented and discussed in this chapter. The objective of the chapter is to provide sufficient data to answer two questions: first, does the model appropriately solve the important economic problems of beef-forage farm managers; second, what is the effect of alternative nutrient measurement approaches on the solutions obtained to the economic problems. It is important for research personnel as well as farm managers to know if the means of specifying a ration (units of measure) alters the optimum forage or beef organization. Results in this chapter reflect the profit maximizing beef and forage organization for three measures: (1) the TDN, digestable protein and dry matter (referred to as the Balanced Ration); (2) total digestable nutrient as the only unit of measure for the ration (TDN Ration); (3) animal unit month as the only unit for measuring the ration (AUM Ration). The chapter concludes with an analysis of a problem inherent in the beef-forage model itself.

The data from the linear programming solutions are presented and compared in three broad categories. The beef system (secondary product) and organization is the first consideration. The forage (primary product) and feeding system organization is the second item. Finally, the economic characteristics of each solution are examined and then compared with other results.

In the following sections, optimum organizations are first found using the three alternative ration specifications with all livestock activities included. Secondly, the cow-calf organizations are computed by eliminating the stocker enterprises. Thirdly, the cows are eliminated to give an optimum stocker organization for each of the alternative nutritional specifications.

Profit Maximizing Whole Farm Organization -- All Activities -- Balanced Ration

The beef-forage model used to obtain the profit maximizing whole farm organization is essentially the model described in Chapter III. The TDN and DP nutritional rows for each time period are lower limits, meaning the quantity needed by the optimum beef activity must be supplied by a forage or supplemental feeding activity. The dry matter rows are upper limits; thus, the pounds of dry matter supplied by the forages in producing the nutrients cannot exceed the stomach capacity of the beef enterprise. The AUM rows are neutral, thus, not binding on the solution. All of the beef activities and forage activities detailed in Chapter III are in the LP model. The solution of the LP algorithm yields the profit maximizing organization of the beef-forage farm with a balanced ration.

Optimum Livestock Systems

The profit maximizing mix of beef enterprises (Table VII) consists of an integrated cow-calf and stocker organization. The optimum stocker

TABLE VII

SUMMARY OF PROFIT MAXIMIZING BEEF-FORAGE ORGANIZATION FROM ALTERNATIVE NUTRITIONAL CONSTRAINTS OF THE BEEF-FORAGE MODEL FOR EASTERN OKLAHOMA

		Balanced Ration	Per Animal Unit		TDN	Per Animal Unit			AUM	Per Animal Unit
Return to Land, Labor, and Risk		$ 31,687.96	58.46		34,578.26	63.80			41,674.14	67.11
Cost		242,134.46	(446.74)		232,542.76	456.86			426,459.54	686.73
Fixed Capital		113,797.09	(209.95)		108,111.90	212.40			70,236.86	113.10
Operating Capital		84,046.73	(155.06)		78,324.15	153.88			150,860.59	242.93
Total Labor		6,293.5	(11.61)		5,999.5	11.79			5,625.5	9.06
Total Acres		1,188			1,188				1,188	
Percent Rotational		66			66				69	
Animal unit equivalents		542			509				621	
Acres/A.U.E.		2.18			2.34				2.14	
Livestock System	Cow 4	Fall Stockers		Cow 4	Fall Stockers				Stockers	
Period 1	217	986		191	964				1,286	
Period 2	217	986		191	964				1,286	
Period 3	217			191	12				786	
Period 4	217			191	12				786	
Period 5	217			191	12				786	
Period 6	217	986		191	964				1,286	
Feeding System										
Perennial Grasses (acres)										
Bermuda		271			86				860	
Bermuda Fescue					124					
Fescue		82			125					
Native		302			302				302	
Annual Grasses (acres)										
Sorghum-Sudan									26	
Small Grain		443			396					
Rye-Vetch		58			58					
Hay (cwt.)	Native	SOS		Native	SOS		Native	Bermuda	SOS	
Period 1	3,663	1,763		4,000	5,888		3,602			
Period 2							915	5,221	372	
Period 6	298						1,503			
Grain (cwt.)										
Period 1										
Period 6	2,877									

activity includes 986 head of the fall stockers. The stockers are purchased in November and sold in April. The 217 cow unit produces calves in the fall and has an extended weaning period with calves weaned and sold in June.

Optimum Feeding Systems

The content timing of the forage system is depicted in Figure 5. The optimum forage organization has more than one-third of the total acres planted to small grain winter grazing for the fall stockers and fall calving cows. The native grass is second in acreage and is at the upper limit imposed by the beef-forage model. The acres of bermuda grass follows native in importance for year round and warm season grazing. Additional cool season grazing is provided by 82 acres of fescue and 58 acres of rye-vetch grazing. Ninety-two acres are idle.

To fulfill the nutrient requirements, supplemental feeding is required in addition to the grazing activities. Native hay and sorghum hay is utilized in the January and February time period. Grain sorghum is also needed in the first time period to balance the ration. Small amounts of native hay in the sixth period and grain sorghum in the fourth period are needed to complete the ration.

Economic Characteristics of the Plan

The profit maximizing beef-forage farm is a very intensive unit with only 2.18 acres per animal unit equivalent and 66 percent of the acres requiring rotational grazing. The return to land and operator labor is $31,657.96. The land charge was added to the value of the objective function to remove revenue differences from solutions that

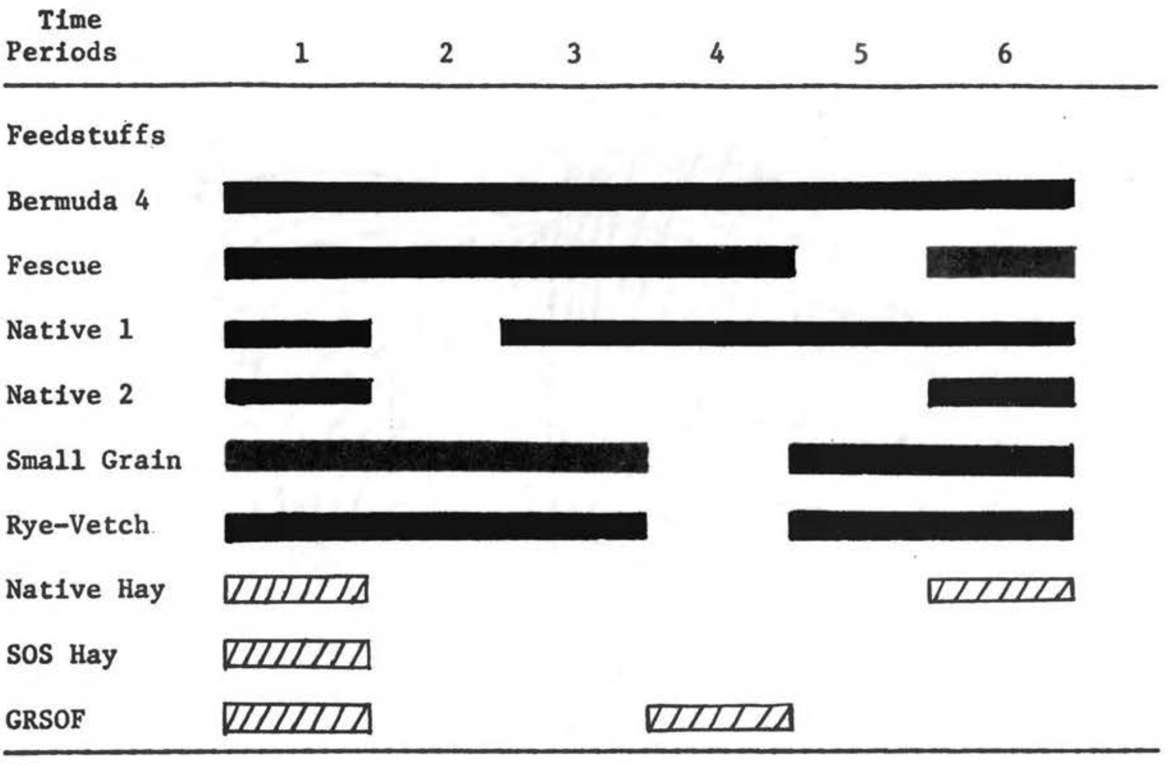


Figure 5. The Time Period Distribution of the Grazing and Feeding Activities From the Profit Maximizing Balanced Ration Forage Land Use Plan for Eastern Oklahoma

included idle land. The farm needs a total labor force of 6,293.5 hours in the appropriate seasonal distribution. The non land capital is $113,797.09, annual operating capital is $84,046.73, and total capital excluding land capital is $197,843.82.

Profit Maximizing Whole Farm Organization -- TDN Approach

A ration based only on TDN requirement does not consider the level of protein nor the volume of dry matter. The lower limit of TDN requirement must be supplied by the forage or feeding activity. To obtain the TDN ration presented in this section the DP and DM rows were neutralized in the balanced ration model for each time period.

Optimum Livestock System

The profit maximizing beef enterprises for the TDN ration are shown in Table VII. The livestock system is an integrated cow-calf and stocker organization. The stocker enterprise consists of 964 fall stockers and only 12 head of spring stockers. The livestock system also contains 191 head of the extended weaning, cow-calf enterprise.

Both the TDN and balanced ration organizations have an integrated cow-calf and stocker operation. Measured in animal unit equivalents the balanced ration approach has more cows and more fall stockers than the TDN approach. However, the TDN specification includes spring stocker steers not included in the balanced ration. The model specification critique section of this chapter includes a discussion of the reasons for fewer animal units in the TDN solution.

Optimum Feeding System

The timing of the forage system is illustrated in Figure 6. The TDN approach relies heavily upon small grain and rye-vetch annual pastures. The acres of native grass is of secondary importance in the optimum TDN land use plan. Approximately equal acres of bermuda-fescue and fescue are included.

To supplement the grazing activities in period one a significant amount of hay is required to meet the TDN nutrition requirement. Both native hay and sorghum-sudan hay are fed in the first time period.

The TDN feeding system is similar to the balanced ration but shifts away from bermuda and small grain acres to include more bermuda overseeded with fescue and more fescue acres. The TDN specification requires no grain while the balanced ration does.

Economic Characteristics

Direct comparison of the economic information from the optimum whole-farm organizations for the alternative ration approaches is not possible. To compare the available economic data it is beneficial to remove the differences because of the stocking rate or number of livestock selected. The adjustment for number of livestock is accomplished by dividing the total values by the number of animal unit equivalents for the optimum beef organization.

The stocking rate for the TDN specification is 2.34 animal unit equivalents per acre. The return to the operator labor and land is \$63.80 per animal unit.

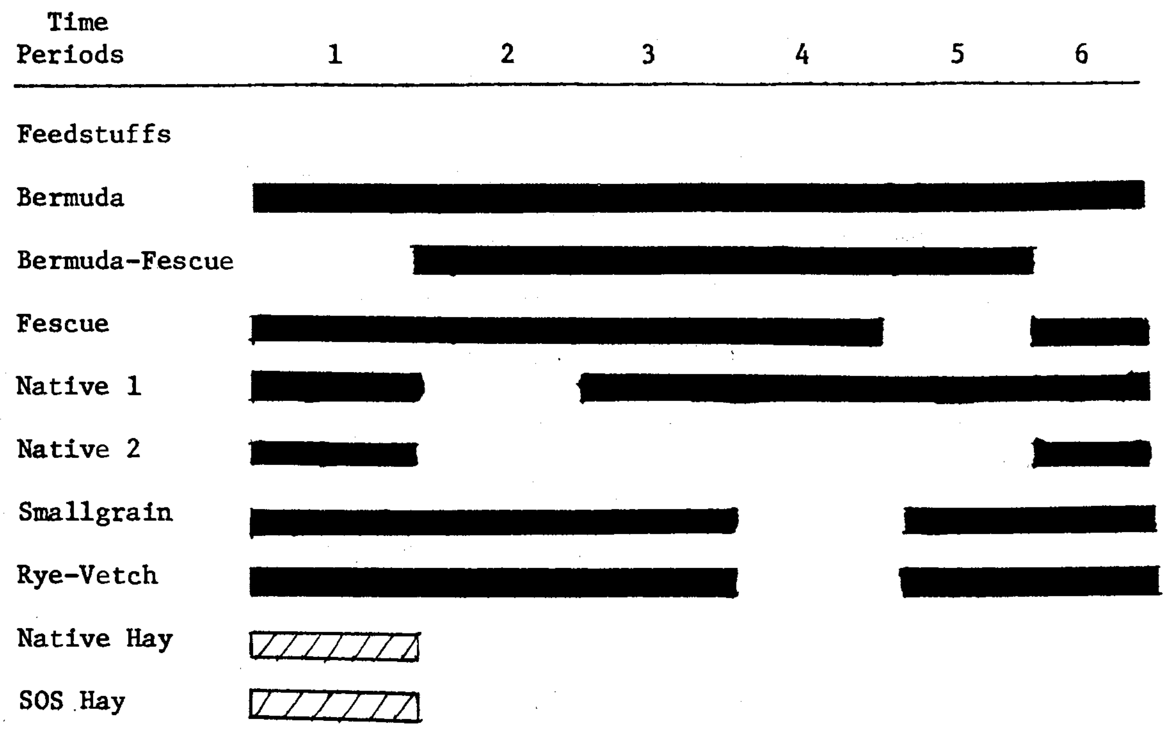


Figure 6. The Time Period Distribution of the Grazing and Feeding Activities From the Profit Maximizing TDN Ration Forage Land Use Plan for Eastern Oklahoma

The net return is greater for the TDN ration than for the balanced ration. The lower quality forage system allowable in the TDN approach accounts for the lower cost and, hence, higher profit.

Profit Maximizing Whole Farm Organizations -- AUM Ration Specification

The AUM profit maximizing solution entails neutralizing the nutritional rows for dry matter, TDN and digestable protein and activating the AUM rows by establishing lower bounds as described in Chapter III. The lower bound insures that at least the required level of forage, measured in AUM's is produced.

Optimum Beef Systems

The profit maximizing beef enterprise selected in the AUM solution is a stocker operation (Table VII). The other nutritional approaches yielded an integrated cow-calf system combined with stocker enterprises (Table VII.) The AUM specification not only selects stockers as the most profitable beef mix but also contains a higher level of fall stockers and spring stockers than either of the other nutritional approaches.

Previous research by Barr [4], Schneeberger [25], and Halbrook [13] utilizing the AUM specification also indicated that stocker organizations maximized profits. In Barr's study of cattle systems in Northeastern Oklahoma, a static LP model selected steers purchased in October that grazed native range with cake and hay supplement and were sold in August. These were combined with steers utilizing oat-vetch grazing and hay purchased in October and sold in May. Schneeberger's study excluded crop alternatives for Eastern Oklahoma. His AUM model selected stocker steers using cottonseed cake, hay and pasture (bermuda + native) for winter and summer pasture, plus 5 pounds of grain sorghum per day for 90 days in the late summer and fall. Halbrook's AUM model selected the same steer activity as Schneeberger's as well as stockers purchased in October and sold in May and using small grain-vetch pasture.

Assuming that other aspects (i.e., price, technology, etc.) of this study and those cited are about the same, the nutritional specifications must be concluded to influence the optimum mix of beef enterprises selected for the optimum farm organization. The ration specification used in whole farm analysis may affect the mix of beef enterprises for beef-forage farm organization.

Optimum Feeding System

The profit maximizing grazing system for the AUM specification is comprised primarily of bermuda pasture augmented with native grass and a limited amount of sorghum-sudan. The feeding of hay is required in January-February, March-April and November-December. The grazing pattern is depicted by Figure 7.

The AUM approach leads to a very different feeding system than the other nutritional specifications. The balanced ration and TDN approaches determine forage systems with a heavy reliance on the cool season annuals. The different forage systems will be discussed in more detail in the following chapter.

Economic Characteristics

The estimated net return to fixed resources per animal unit equivalent is least for the balanced ration and greatest for the AUM ration

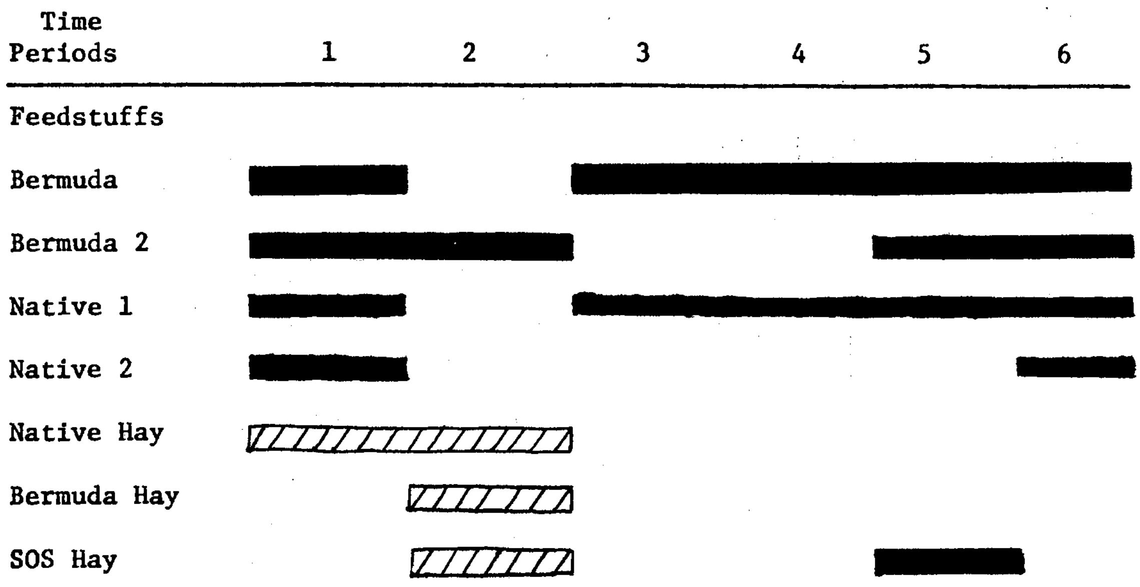


Figure 7. The Time Period Distribution of the Grazing and Feeding Activities From the Profit Maximizing AUM Ration Forage Land Use Plan for Eastern Oklahoma

specification. As might be anticipated, fullfilling the energy and protein requirements of the balanced ration reduces the net revenue compared to the TDN specification, which insured only that the energy level is fulfilled. Similarly, the AUM approach which only requires a volume of forage with no guarantee of quality was "more profitable" than either of the other nutrient specifications. Whole farm research that has used either AUM's or TDN approaches may have risked overestimating the level of net returns to resources because the ration may not be balanced.

The differences in the cost, fixed capital and operating capital per animal unit for the AUM specification (compared to the other approaches) can be attributed to the fact that an all stocker beef system was selected. Stocker enterprises increase the annual cost because of the purchase of steer calves. Similarly, the fixed capital is less and operating capital is more in the optimum AUM organization because of the steer calf purchases and no investment in cows.

Optimum Cow-Calf Organizations for Three Alternative Ration Specifications

The beef firm decision unit may place limitations on the possible mix of beef enterprises. Beef firms already in the cow-calf business may not want to liquidate the cow-calf inventory and the cow-calf manager might want information on how to optimally allocate resources to various cow-calf enterprises. The optimum organizations of a cow-calf system for the alternative nutritional constraints are presented in Table VIII and discussed in the following section. The stocker activities were deleted from the LP models to obtain the cow-calf solutions.

TABLE VIII

SUMMARY OF COW-CALF OPTIMUM FORAGE ORGANIZATIONS FROM ALTERNATIVE NUTRITIONAL CONSTRAINTS OF THE BEEF-FORAGE MODEL OF EASTERN OKLAHOMA

		Balanced Nutrients	Per Animal Unit		TDN	Per Animal Unit	AUM	Per Animal Unit
Return to Land, Labor								
and Risk		26,428.61	(44.42)		27,559.34	(44.52	23,323.08	39.20
Cost		75,802.22	(127.39)		78,101.90	(126.17)	78,966.18	(132.71
Fixed Capital		192,472.00	(323.48)		201,425.53	(325.40)	199,612.77	(335.49
Operating Capital		26,024.42	(43.73)		27,481.26	(44.39)	29,175.63	(49.03
Total Labor		5,685.5	(9.55)		5,931.5	(9.58)	6,733.5	(11.31
Total Acres		1,188			1,188		1,188	
Percent Rotational		65			64		65	
Animal Unit Equivalents		595			619		595	
Acres/A.U.E.		1.99			1.91		1.97	
Livestock Systems		Cow 4			Cow 4		Cow 4	
Period 1		531			553		531	
Period 2		531			553		531	
Period 3		531			553		531	
Period 4		531			553		531	
Period 5		531			553		531	
Period 6		531			553		531	
Feeding System								
Perennial Grasses (acres)								
Bermuda		314			378		847	
Bermuda-Fescue		33			124			
Fescue		308			163			
Native		302			302		288	
Annual Grasses (acres)								
Sorghum-Sudan		25			47		39	
Small Grain		148			115			
Rye Vetch		58			58			
Hay (cwt.)	Native	SOS		Native	SOS		Native	
Period 1	4,098	717		3,283	990		960.4	
Period 2							1,217	
Period 3								
Period 4							1,363	
Period 5							461	
Period 6	240			1,125				
Grain (cwt.)								
Period 1		383						
Period 2								
Period 3								
Period 4								
Period 5								
Period 6								

Cow-Calf System

All three nutritional approaches selected the extended weaning period for the fall calving cows as the most profitable cow-calf organization. The only difference is the TDN solution has 22 more cows at the optimum level. The results of this study indicate that with cow-calf activities considered the method of specifying the ration has little effect on the optimum cow-calf enterprise.

Optimum Feeding System for the Balanced Ration

Cow-Calf Activity

The forage system or land use plan for the balanced ration specification (Table VIII) has approximately equal acres of bermuda, fescue and native grass. Small grain and rye-vetch acreages are also important. The forage system is completed with a small amount of land used for bermuda overseeded with fescue and a limited amount of sorghum-sudan production.

The cow-calf balanced ration approach land use plan relied heavily on the high quality small grain pasture as did the integrated cow-calf and stocker balanced ration solution (Table VII). The acres of bermuda and fescue increased when the balanced solution was limited to cow-calf activities. The adjustment in land use for a separate cow-calf operation (deleting stockers) results from lowering the quality demanded by the livestock activity as well as altering the seasonal distribution of nutrient needs.

Optimum Feeding System for the TDN Ration

Cow-Calf Activity

The TDN approach yields a diversified grazing system (Table VIII) similar to the cow-calf balanced ration. The relative importance of the forages differs. The TDN specification increased the acres of bermuda and bermuda-fescue and decreased the fescue and small grain compared to the balanced ration cow-calf feeding system. Both nutritional approaches require hay in the January-February and November-December time periods, but the TDN approach requires no grain.

Optimum Feeding System for the AUM Ration

Cow-Calf Activity

The AUM land use solution consists entirely of bermuda, native grass and a small amount of sorghum-sudan. The optimum land use is significantly different from the other approaches. The major component of the cow-calf AUM ration specification is bermuda. Bermuda is required on more than two-thirds of the total acres, whereas, it did not exceed one-third for the other nutritional approaches.

Hay feeding was required not only in the same time periods, as both the balanced and TDN specifications, but also in March-April and September-October time periods. The AUM approach required no grain for the cow-calf enterprise.

The measuring unit for specifying the ration does significantly alter the optimum combination of the alternative forages. Research of a whole-farm cow-calf nature must take account of the differences that might arise in the optimum forage system because of the use of one of the nutritional approaches.

Economic Characteristics

The net return per animal unit equivalent is similar in all three nutritional systems but is highest on the balanced ration and lowest on the AUM approach. The reversal from the previous solution is explained by the construction of the beef-forage model. The balanced ration model limits the maximum pounds of feed that can be consumed but has no minimum except to provide adequate energy and protein. The AUM approach sets a minimum volume that must be consumed. The limit required is closely related to the upper restriction on the stomach capacity of the balanced ration. The result is the balanced ration may meet the energy and protein requirements and have stomach capacity remaining. But the AUM system conceptually fills the stomach, regardless of the chemical composition of feeds consumed. It may require too many nutrients in this case.

The cost per animal unit is least for the TDN approach and most for the AUM system. The preceding paragraph implies a lower cost when using only energy with no restriction on volume compared to having a minimum volume required for AUM. The result is a higher cost for the AUM formulation. Economies for higher quality are not provided for in the AUM model.

The three nutritional alternatives reflect small differences in the percentage of land using rotation grazing or acres per animal unit equivalent. Thus, the intensities are not significantly different.

Optimum Stocker Organizations for Three Alternative Ration Specifications

Some beef-forage units may decide to undertake a specialized stocker operation. A comparison of the effects of three nutritional approaches on the optimum stocker organization is presented in Table IX.

Livestock System

Both fall and spring stockers are in all solutions; only the levels of the stocker organizations are different. The TDN approach has fewer spring stockers and more fall stockers than the balanced ration solution. The AUM approach has a greater number of both fall and spring stockers than either of the other two methods of specifying the ration. The larger number of spring stockers selected by the AUM formulation results from ignoring quality of the forage system. This insufficiency receives further consideration in the following chapter.

Optimum Feeding System for the Balanced Ration Stocker

The balanced ration specification depends heavily upon small grains and rye-vetch grazing, augmented with native grass and bermuda (Table IX). Over fifty percent of the land is in annual cool season grasses and 374 acres (twenty-nine percent) are idle.

Compared to the integrated cow-stocker organization approach from the balanced ration model (Table VII), the separate balanced ration stocker activity has fewer acres of bermuda and native grasses but more acres of small grains grazing.

TABLE IX

SUMMARY OF STOCKER OPTIMUM FORAGE ORGANIZATIONS FROM ALTERNATIVE NUTRITIONAL CONSTRAINTS OF THE BEEF-FORAGE MODEL OF EASTERN OKLAHOMA

		Balanced Nutrients	Per Animal Unit		TDN	Per Animal Unit			AUM	Per Animal Unit
Return to Land, Labor and Risk		28,356,81	(65.49)		34,010.67	(78.36)			41,674.14	(67.11)
Cost		308,130.04	(711.61)		303,502.20	(699.31)			426,459.54	686.73
Fixed Capital		46,563.58	(107.53)		56,569.69	(130.34)			70,236.86	113.10
Operating Capital		105,850.85	(244.45)		102,393.61	(235.92)			150,860.59	242.93
Total Labor		4,605.5	(10.65)		3,698.5	(8.52)			5,625.55	9.06
Total Acres		906			1,188				1,188	
Percent Rotation		66			60				69	
Animal Unit Equivalents		433			434				621	
Acres/A.V.E.		2.34			2.73				1.91	
Livestock System (hd.)										
Period 1		1,245			1,266				1,286	
Period 2		1,245			1,266				1,286	
Period 3		190			171				786	
Period 4		190			171				786	
Period 5		190			171				786	
Period 6		1,245			1,266				1,286	
Feeding System										
Perennial Grases (acres)										
Bermuda		113			271				860	
Bermuda-Fescue										
Fescue										
Native		181			302				302	
Annual Grasses (acres)										
Sorghum-Sudan		2							26	
Small Grain		490			445					
Rye Vetch		58			58					
Hay (cwt.)	Native	SOS		Native	SOS		Native	Bermuda	SOS	
Period 1	2,991	3,613		3,937	6,285		3,602			
Period 2					226		915	6,221	372	
Period 6	904									
Grain (cwt.)							1,503			
Period 1		2,820								
Period 4		1,128								

Optimum Feeding System for the TDN Ration

Stocker Activity

The optimum TDN approach has about the same feeding system components as the balanced ration (Table IX). However, the acres of the forages are adjusted. An increase is reflected in bermuda acres and native grass. Fewer acres of small grain grazing are needed in the TDN ration. The TDN specification has only 72 acres of idle land.

The feeding of hay is required in only two time periods. A large amount is fed in January-February, but only a small quantity is needed in March and April compared with balanced ration.

Optimum Feeding System for the AUM Ration

Stocker Activity

The solution is the same as the AUM profit maximizing organization discussed in Table VII. The same comparisons are valid. Most of the land is used for bermuda followed by native and some sorghum-sudan. The latter two pastures provide hay that is fed in the January-February time period.

Economic Characteristics

The net returns per animal unit equivalent are least for the balanced ration and highest for the TDN situation. The level of net return is clearly influenced by the nutrient measure specified for the stocker enterprises. The balanced stocker ration combining energy, protein, and stomach capacity rules out many of the low quality forages from which it is not feasible to obtain nutrients for stocker activities. The balanced ration stocker organization relied heavily upon the high quality forages which are more costly to produce than most of the low quality forages.

The quality concept is not utilized in the TDN or AUM situations. For the TDN approach, the requirement is to meet the energy level without considering the feasibility of consumption. The relaxing of a quality constraint (TDN/DM) accounts for the higher net returns per animal unit for the TDN approach. The AUM situation requires a specified volume with no consideration of the chemical composition. The result of the optimum AUM stocker solution is a lower net return per animal unit equivalent than for the TDN model and higher than the balanced ration model.

As will be developed in the next chapter, the AUM approach may provide more feed than the stomach capacity of the stocker is capable of holding. Requiring excess forage production is the cause for the lower net return per animal unit compared with TDN model. Because AUM contains no quality measurement, the lower quality and less expensive forage per pound of dry matter raises the net return per animal unit above that for the balanced ration.

The net returns per animal unit is greater for the stockers than for cows for all three nutritional approaches. However, the cost is much greater for the stockers because of the cash outlay needed to purchase the calves. Because of the long term investment in cows, the stocker solutions have considerably lower fixed capital requirements but higher operating capital requirements. The stocker AUM organization yields the highest total net returns to land, labor and management of all other ration approaches. Using AUM's in whole farm research might lead to overestimating possible returns if care is not taken to insure feasibility of the stocker rations. This may be one reason why previous research has consistently selected stocker operations for the optimum livestock organization.

Summary of Ration Specification Results

Researchers conducting whole farm studies or area studies based on representative whole farms should be cognizant that inconsistencies may result from the unit of measure used to specify the ration. When comparing cow-calf versus stockers, the AUM approach can yield stockers, while the other approaches give a combination of cow-calf and stockers.

For land use studies the method of specifying the ration can significantly alter the optimum forage organization. As will be demonstrated in more detail in the next chapter, both the TDN and AUM approaches can yield forage organizations that are not physically feasible, given the stomach limitation. This is especially important for stocker activities which in fact require high ratios of digestible protein and TDN to DM. Ignoring the quality constraint can also alter the level of returns as well as the physical organization. Studies not recognizing the quality concept may result in inefficient recommendations for resource utilization.

Critique of Model Specification

After considerable research effort and computer fund expenditures, two model configuration problems evolved. The first problem is in model specification, whereby inefficient recommendations might result. The second problem resulted from trying to find the exact ration of each optimum livestock enterprise from multiple livestock solutions. The latter problem is discussed in Chapter V.

The specification problem arose from two characteristics of the basic balanced ration beef forage linear programming model. The first is fixed timing of nutrient availability and use. The second is the upper bound on DM rows. The forage producing activities cannot transfer or defer grazing to a later time period. To offset the rigidity, alternative forage strategies were built into the model by adding activities that had different distributions of nutrient availability. Therefore, the flexibility problem by itself is no major obstacle. However, fixed timing of nutrient production combined with upper bound row restriction on dry matter may provide a less than optimum forage and or livestock organization.

The possible problem can be visualized by following through a logical iteration. If small grains are grazed by a fall stocker activity, the small grains activity of the basic beef-forage model also provides nutrients not utilized by the fall stocker in time periods three and five. Therefore, the dry matter bounds in these respective periods are exceeded. The LP routine must force in a beef activity to allow the net dry matter to be ≥ 0 or use another feed that does not provide nutrients in time periods three and five. The dry matter restrictions may push the level of the beef enterprises beyond the profit maximizing point by forcing in a livestock activity to provide stomach capacity. Or it may use a more costly nutrient source.

Evidence that this configuration problem alters the level of livestock is shown in the solutions presented in the preceding sections. An example evolved in the optimum beef and forage organization (Table VII) where the balanced ration approach had more Cow four and fall stockers than did the TDN approach. Because the TDN approach can yield the same solution as the balanced ration formulation, the same or greater level of livestock is expected. Instead the TDN approach had maximum net income at a lower level of the livestock activities for the highest profit TDN ration compared to the balanced ration.

Forage Transfer Model

Testing for further influence of the model configuration involved modifying the beef-forage LP model. Activities were developed that did not fix the production of the forage activities directly into the nutritional rows. Instead the forage production goes into a row that either transfers the nutrients to the nutrient rows or transfers the dry matter production to the next time period of the crop year. The result was a model that allowed either utilization of forage in an appropriate period or deferring grazing to a later time period. The modified LP solution gives the optimum time to utilize the forage as well as removing the configuration problem. The optimum grazing pattern and pounds of dry matter are given in Table X.

Beef Organization - Forage Transfer Model. The forage transfer model results in the optimum beef and forage organization summarized in Table XI. The forage transfer model determined a stocker operation (fall and spring) as the most profitable livestock enterprises; whereas, the basic balanced ration model (Table VII) had a mix of fall stocker and extended weaning cow-calf enterprises. Both models selected year round livestock systems to utilize the available forages.

TABLE X

OPTIMUM GRAZING PATTERN AND DISTRIBUTION FROM THE FORAGE TRANSFER MODEL FOR EASTERN OKLAHOMA

TIME PERIODS

	1	2	3	4	5	6
	HUNDRED WEIGHT OF DRY MATTER (cwt.)					
Bermuda No Fertilizer				587.6	519.2	
Bermuda 200 N.	3662.0	357.	90.4	60.3	411.8	4901.9
Native	554.8			472.3		1907.6
Small Grains	7712.6	11,203.5	592.0			46.2
Rye-Vetch	181.0	1,500.9	150.9			544.8
Grain Sorghum						1447.3

TABLE XI

OPTIMUM WHOLE FARM ORGANIZATION
FOR THE FORAGE TRANSFER MODEL
FOR EASTERN OKLAHOMA

	TOTALS		PER ANIMAL UNIT EQUIVALENT
Return to land, labor and risk	$ 39,131.19		88.13
Cost	306,879.26		691.17
Fixed Capital	50,909.11		114.66
Operating Capital	105,604.91		237.85
Total Labor	4,998.40		11.3
Total Acres	1,188.00		
Percent Rotation	68.3		
Animal Unit Equivalent	444.0		
Acres/A.U.E.	2.67		
Livestock System (hd.)	FLST	SPST	
Period 1	1,355		
Period 2	1,355		
Period 3		116	
Period 4		116	
Period 5		116	
Period 6	1,355		
Feeding System			
Perennial Grasses (A.)			
Bermuda	271		
Bermuda-Fescue			
Fescue			
Native	302		
Annual Grasses (A)			
Sorghum-Sudan			
Small Grain	555		
Rye-Vetch	58		
Grain (cwt.)	Grain Sorghum		
Period 1			
Period 2			
Period 3			
Period 4			
Period 5			
Period 6	1,447.3		

<u>Feeding System - Forage Transfer Model</u>. The land use organization of the forage transfer model is similar to the basic balanced ration. The transfer model had more acres of small grain grazing and no fescue pasture. However, fescue and small grains are close substitutes. Both are cool season grasses, but the small grain is of higher quality. The land use systems are very similar.

The basic difference is the time period the forages are utilized. The forage transfer model defers most of the small grain grazing to the first and second time periods to be consumed by the fall stockers. However, in period six the fall stockers also consume a large amount of deferred bermuda supplemented with feeding grain sorghum. A large proportion of the deferred bermuda is also grazed in period one. The aforementioned grazing (of deferred bermuda) and feeding grain is probably not a realistic grazing pattern. The fixed balanced ration model would have utilized bermuda as hay in periods six and one rather than grazing.

<u>Economic Considerations - Forage Transfer Model</u>. The important economic consideration derived from the forage transfer model is in deciding if it is superior to the basic balanced ration model. The possibility of obtaining realistic forage utilization systems was judged to be a more important drawback to the forage transfer model than the combined inflexibility and dry matter configuration of the balanced ration model.

The remaining chapter delineates exact rations for each livestock enterprise from the balanced ration model. Because a feasible allocation is possible from all of the Balanced Ration solutions it is used for the reminder of this study. More research is needed to use the forage transfer model.

Relationship of Cow Activities to Stocker Activities in the AUM Ration Specification

A stocker was converted to animal units by dividing the average weight of the stocker by 1,000, representing a 1,000 pound cow (which is assumed to be one animal unit), and multiplying the result by the fraction of the year the stocker activity is on the farm. The fall stocker (flst) has an average weight of 605 and the enterprise takes 6 months or 1/2 a year. The animal unit equivalent becomes $(\frac{605}{1000} \times \frac{1}{2})$ or .3025. For the spring stocker activity the calculation is $(\frac{509}{1000} \times \frac{1}{2})$ or .295 animal unit equivalents. Theoretically this calculation enables comparing a stocker activity to a cow activity. In Table XII, TDN is used as a measure of energy needs to calculate the relationship of the fall and spring stockers to the Cow two activity. The cow equivalents are .369 and .359 for the fall and spring stocker respectively. Assuming the TDN relationships are accurate, the rule of thumb method understates the stocker by .0665 units for the fall stocker enterprise and .064 units for the spring stocker enterprises.

Approaches utilizing the AUM ration (from the rule of thumb) approach appear to give an advantage to the stocker enterprise when comparing cows to stockers. The error can also cause an over estimation of net returns to stockers in whole farm analysis. This overestimation of returns appears in the AUM stocker solution. A large difference exists in the net returns ($41,674.14 vs. $23,323.08) for the AUM ration specification for stockers when compared to the cow AUM solution.

TABLE XII

ESTIMATES OF ANIMAL UNIT EQUIVALENTS FOR STEERS, BASED ON TDN REQUIREMENTS AND A RULE OF THUMB

	Fall Stocker	Spring Stocker	Spring Cow-Calf Unit
Total TDN Required (lbs.)	1666.2	1622.4	4517.0
Relation to Cow Unit per Pound of TDN	.369	.359	1.0
Rule of Thumb[1] Animal Unit	.3025	.2950	1.0
Difference (under-estimate)	.0665	.064	

[1]An AUM is the proportion of average live weight to a 1,000 pound cow unit is the rule of thumb.

The differences in the other ration approaches are not nearly as large between stockers and cows. Therefore, as used in past research a stocker animal unit is not equal to a cow animal unit.

Summary

The chapter provided data pertinent to the economic decisions facing beef farm managers. The profit maximizing beef cattle organization provides decision guides for the mix and level of the secondary product. Adjustments in the ration specifications enabled comparing alternative units for measuring the technical coefficients of the forage-beef relationship. The alternative nutritional approaches (e.g. balanced ration, TDN ration, AUM's) yield different optimum beef and feeding systems.

The balanced ration comprehensive beef-forage LP model selected an integrated cow and stocker as the profit maximizing beef organization. The optimum land use organization relied heavily upon small grain and bermuda supplemented with feeding grain and hay. Neutralizing the protein and dry matter rows resulted in a TDN ration specification for the LP model. The TDN ration also selected an integrated cow and stocker beef system. The TDN forage system contained fewer acres of small grain and more bermuda-fescue and fescue than the balanced ration. The AUM ration approach selected a stocker beef system. The AUM forage land use organization had most of the land producing bermuda grass with no small grain grazing.

The unit used in measuring forage production and beef ration did have an effect on the optimum whole farm organization selected as optimal. As discussed in the previous paragraph, the three alternative nutritional approaches yielded different optimum beef and feeding organizations. The separate cows and stocker forage organizations were different for each of the three nutritional specification approaches. Generally as the nutritional specification was relaxed the optimum land use contained more acres of lower quality forages.

The chapter demonstrates that the specification of the beef-forage model can also be responsible for different beef and forage solutions. Finally, the rule of thumb commonly used was explored as a factor influencing the optimum beef-forage farm organization in linear programming studies.

CHAPTER V

PROFIT MAXIMIZING RATIONS AND ACTIVITY BUDGETS

The beef-forage firm decision maker requires more information than the description of the optimum beef and forage production system provided by the model. As described in Chapter IV, the optimum whole farm organizations presented in the preceding chapter involve complex sets of livestock and forage enterprises. This chapter develops a profit maximizing ration that gives a detailed plan for how and when to utilize the forage mix. Finally, the chapter incorporates the LP model's profit maximizing balanced ration into beef enterprise cost and return budgets.

A least cost ration assures that a known and exogenously specified level of required nutrients is provided (e.g. for a given number and class of livestock, say, 100 cows). The profit maximizing ration terminology is used here to emphasize that the optimum level and class of livestock is determined endogenously to the linear programming model. The profit maximizing ration minimizes the cost of producing the optimum level of beef production. The least cost ration as defined above is not necessarily associated with the optimum beef enterprise or level.

The distinction between a profit maximizing and a least cost ration is important to the farm manager, as well as the researcher. Utilizing a least cost ration approach, the beef activity and level of nutrients are determined before solution. If an incorrect beef activity or level of the activity is used, the manager's resources are not yielding their full income potential. To an economic researcher, the least cost ration may not allocate the scarce resources in the most economically efficient manner. Therefore, to both the manager and researchers, the profit maximizing model is superior to the least cost ration.

Delineating the Profit Maximizing Ration

The comprehensive beef-forage linear programming model does not indicate which beef enterprise consumes which nutrient source. For example in cases of multiple livestock activities occurring during the same time period, the model does not directly give the ration for each beef enterprise. The optimum whole farm forage system is determined but a feeding plan is not provided, although a knowledgeable farmer could probably devise one from the information provided. This section discusses alternative procedures to define the exact feeding plan.

Separate Solutions

The simplest approach to find a ration is to obtain separate solutions for each livestock activity. However, the complementary relationships discussed below preclude using separate solutions to accurately reflect exact balanced rations. To obtain separate optimum organizations for each stocker activity, the beef-forage balanced ration model was solved individually for the spring stockers and the fall stockers. The dry matter constraints were released in periods 1, 2 and 6 for the spring stockers. The releasing of off-season dry matter constraints enables a forage not exactly timed with the stocker enterprise in question to be feasible.

Land use organizations are used to show that separate solutions cannot be aggregated to obtain the multiple organization. For the constructed organization to be nutritionally feasible (not necessarily land use feasibility), the organization has to provide sufficient nutrients in all time periods. But if the constructed organization has more acres than the multiple solution (which is feasible), a feasible allocation of nutrients could be constructed for the separate solution.

A combined stocker organization is constructed from the separate solutions discussed in the previous paragraph. A summary of the solutions from the separate stocker activities is presented in Table XIII. To construct a combined stocker organization from the separate solutions the largest value in each row is used. For example, the 1,245 head of separate fall stockers require 271 acres of bermuda, while the 190 head of separate spring stockers uses only 96.3 acres. The constructed stocker combinations requirement for bermuda is 271 acres because this meets the required acres for the 190 head of spring stockers and equals the amount required by the fall stockers. The largest value in each row is valid because there is no direct competition for nutrients within a time period.

For the combined cow-calf and stocker organization, an additive model is utilized because of direct competition for nutrients in periods 1, 2 and 6. For example, the 986 head of separate fall stockers require 216.9 acres of bermuda, while the 217 separate cow-calf units require only 141 acres of bermuda but because both require nutrients in periods 1, 2 and 6 the combined separate organization must have the total needed from the separate solution to make feeding the respective numbers feasible. (Note the constructed solution procedure only assures feasibility

TABLE XIII

SUMMARY OF SEPARATE AND MULTIPLE STOCKER LAND USE AND FEEDING ORGANIZATIONS FROM THE BEEF-FORAGE MODEL FOR EASTERN OKLAHOMA

	Separate Fall Stocker Organization[a] (1)	Separate Spring Stocker Organization[b] (2)	Constructed Stocker Combination[c] (3)	Multiple Solution (4)	Complementary Savings[d] (5)
<u>Forages</u>					
Bermuda (acres)	271	96.3	271	113	158
Fescue (acres)	20		20		20
Native (acres)	181		181	181	0
Sorghum-Sudan (acres)		32.7	33		33
Small Grains (acres)	497		497	490	7
Rye-Vetch (acres)	58		58	58	0
Supplemental Feeds					
Nat Hay Fed - Period 1 (cwt.)	3820.		3,820	2,991	829
Nat Hay Fed - Period 6 (cwt.)	72		72	904	-832
SOS Hay Fed - Period 1 (cwt.)	2247		2,247	3,613	-1366
SOS Hay Fed - Period 5 (cwt.)		249.9	249.9	0	249.9
Grain Sorghum Fed - Period 1 (cwt.)	2927		2,927	2,820	127
Grain Sorghum Fed - Period 3 (cwt.)		265	265		265
Grain Sorghum Fed - Period 4 (cwt.)		675	615	1,128	-513
Grain Sorghum Fed - Period 5 (cwt.)		79	79		79

[a]Separate fall stockers were fixed at 1,245 head.

[b]Separate spring stockers were fixed at 190 head.

[c]The combination is the largest value of the separate solutions.

[d]The complementary savings is the difference between the multiple livestock solution and the constructed stocker combination (col. 3-4).

providing sufficient nutrients not that fixed resources such as land acreage are not exceeded.)

The optimum acres of bermuda are 86.9 acres less in the optimum multiple stocker organization than in the separate constructed organization (Table XIV). The decline in acreage is possible because 100 pounds of nitrogen are applied to bermuda in the optimum multiple stocker organization, and no fertilizer is used on the 271 acres in the separate stocker solution. Thus, one element of complementary is that when a livestock activity consumes the bermuda during the growing season, fertilizer can profitably be applied.

The 20 acres of fescue from the separate solution is more closely tied to the fall stocker utilization than the heavily fertilized bermuda in the multiple livestock organization. The complementary influence (measured by column 5) is considerable for the multiple stocker forage system as well as for the integrated cow-calf and fall stocker.

Accounting Rows

Another approach to obtain a ration is to build into the LP model enough accounting rows to find the ration from the optimum multiple livestock situation. However given the size of model as presently constructed, adding rows or columns to identify feed for each livestock activity is not very practical. Care would be needed to show effects of multiple livestock solutions and assure that the ration is identical to the profit maximizing multiple beef activity ration.

TABLE XIV

SUMMARY OF SEPARATE AND INTEGRATED STOCKER AND LAND USE AND COW-CALF LAND USE AND FEEDING ORGANIZATIONS FROM THE BEEF-FORAGE MODEL OF EASTERN OKLAHOMA

	Separate Fall Stocker Organization[a] (1)	Separate Cow-Calf Organization[b] (2)	Constructed Stocker and Cow-Calf Combination[c] (3)	Integrated[d] Organization (4)	Complementary[e] Savings (5)
Forages					
Bermuda (acres)	216.9	141	357.9	271	86.9
Fescue (acres)	19.7	126	145.7	82	63.7
Native (acres)	147.9	124	271.9	302	-30.1
Sorghum (acres		11	11		11
Small Grain (acres)	394.4	60.8	455.2	443	12.2
Rye Vetch (acres)	49.3	23.8	73.10	58	15.1
Supplemental Feeds					
Nat Hay Fed - Period 1 (cwt.)	3,027	1,675	4,702	3,663	1039
SOS Hay Fed - Period 1 (cwt.)	1,784	293	2,077	1,763	314
Nat Hay Fed - Period 6 (cwt.)	57	95	152	298	-146
Grain Sorghum - Period 1 (cwt.)	2,317	156	2,473	2,877	-404
Grain Sorghum - Period 5 (cwt.)				58	-58

[a]The separate fall stockers were fixed at 986 head.

[b]The separate cow-calf activity was fixed at 217 head.

[c]The combination is total acreages from the separate solutions.

[d]Table VII explains this solution.

[e]The complementary savings is the difference between the multiple livestock solution and the constructed combination.

Empirical Procedure

The empirical procedure utilized a fortran computer program. The computer program required card input containing the optimum level of the activity from the linear programming solution. This solution vector was multiplied times the nutrient elements of the tableau (-A and A matrices of Table I). The total nutrients supplied and subtotal for each forage was found by the computer program as was the total nutrients required. Table XV is a summary of the totals and subtotals of the nutrients from the program for each forage.

The procedure selected to delineate a feasible balanced ration is a repetitive procedure. In the time periods where the livestock activities compete for nutrients, the forages in the ration are allocated among each of the livestock activities and the nutrients supplied by the forages are summed. If the TDN or protein is insufficient or if the dry matter allowable is exceeded for any enterprise, a different allocation of optimum forages among the beef enterprises is required to maintain nutrition feasibility.

The reallocation and summing procedure is continued until the nutrients supplied to each livestock activity equals the nutrients required. A feasible balanced ration is reached when all nutritional constraints are satisfied for the optimum mix of beef enterprises, enterprise by enterprise. A starting criterion of feeding low quality forages to cow-calf and high quality to stocker enterprises was used in the allocation procedure.

Profit Maximizing Balanced Ration

The optimum organization for the balanced ration when all activities were allowed included an integrated fall stocker and extended weaning fall calving cow-calf livestock system (Table VII). For time periods 6, 2, and 1, it is impossible from the linear programming results to determine which livestock enterprise consumes the optimum feed ingredients for the specified time periods (Table XV). To find a feasible allocation of the feedstuffs to give a balanced ration for each livestock enterprise, the procedure outlined in the pervious section was utilized.

The importance of each kind of forage is evident in Table XV. For example, in period two over 75 percent of the pounds of TDN are supplied by grazing small grain. The importance of hay and grain to the optimum whole farm organization is also demonstrated in Table XV. In the first time period, over 50 percent of the nutrients supplied are from native and sorghum-sudan hay and grain sorghum.

The feasible profit maximizing rations are outlined in Table XVI for the cow-calf enterprise and in Table XX for the fall stocker enterprise. In addition to the pounds of nutrients, the tables also indicate the percentages of nutrients produced by the forage activity that are utilized by the beef enterprise for each time period. For example, in Table XVI the ration for the cow-calf enterprise includes 100 percent of nutrients provided by bermuda and fescue for period 1 but only 2 percent of the total nutrients provided by the optimum hay feeding activity (the other 98 percent is fed to the stocker enterprise. See Table XVI).

TABLE XV

TOTAL NUTRIENTS FOR THE PROFIT MAXIMIZING INTEGRATED COW-CALF AND STOCKER SOLUTIONS FROM THE BALANCED RATION SPECIFICATION OF THE BEEF-FORAGE MODEL OF EASTERN OKLAHOMA

Nutrients	Bermuda	Fescue	Native	Sorghum Sudan	Small Grain	Rye Vetch	Weeping Love	Hay	Concentrates	Total lbs. Supplied	Total Required by All Livestock[2]
				(lbs. supplied)							
1TDN	84,802	33,530	16,012	0	118,494	13,681		263,346	228,418	758,282	757,883
1DP	8,336	5,534	660	0	22,540	2,608		22,600	24,453	86,730	80,611
1DM	188,765	58,828	36,408	0	156,736	18,099		494,258	256,092	1,209,185	1,208,411
2TDN	70,081	44,352	0	0	687,282	109,828		0	0	911,543	911,115
2DP	8,245	7,316	0	0	130,905	24,193		0	0	170,659	94,241
2DM	173,478	77,816	0	0	909,108	150,067		0	0	1,310,470	1,309,686
3TDN	141,148	41,246	25,332	0	36,299	10,641		0	0	254,666	249,962
3DP	31,375	3,891	1,538	0	6,923	2,568		0	0	46,295	21,207
3DM	222,403	77,816	41,762	0	48,046	15,084		0	0	405,111	466,795
4TDN	101,157	14,942	4,478	0	0	0		0	4,575	125,152	124,840
4DP	16,275	1,275	130	0	0	0		0	490	18,170	8,072
4DM	183,020	31,127	6,003	0	0	0		0	5,128	225,277	238,539
5TDN	96,930	0	2,005	0	55,150	6,347		0	0	160,431	160,031
5DP	16,716	0	64	0	10,513	1,207		0	0	28,499	13,582
5DM	178,252	0	3,123	0	72,946	8,399		0	0	262,720	293,675
6TDN	93,622	86,228	19,653	0	307,023	34,835		14,449	0	555,809	555,373
6DP	9,109	14,215	660	0	57,357	6,637		1,221	0	89,198	55,079
6DM	191,363	151,276	36,385	0	399,876	46,079		27,379	0	852,358	970,493

[1]Solution of beef-forage model with all livestock activities allowed (217 cow 4 and 986 fall stockers).

[2]The minor violation of nutritional feasibility was attributed to rounding error.

TABLE XVI

PROFIT MAXIMIZING INTEGRATED COW-CALF BALANCED RATION FOR A BEEF-FORAGE FARM IN EASTERN OKLAHOMA

	Bermuda	Fescue	Native	Small Grain	Rye-Vetch	Hay	Grain	Total Supplied	Total Required[2]
% of Total[1]	100	100				2	27		
1 TDN	84,802	33,530				5,266	61,954	185,532	185,806
1 DP	8,336	5,534				452	6,625	20,947	17,310
1 DM	188,765	58,828				9,886	69,448	326,927	326,927
% of Total	100	10		2.94	100				
2 TDN	70,081	4,435		20,238	109,828			204,582	204,153
2 DP	8,245	731		3,848	24,193			37,017	18,516
2 DM	173,478	7,782		26,728	150,067			358,055	358,985
% of Total	100	100	100	100	100				
3 TDN	141,148	41,246	25,332	36,299	10,641			254,666	249,962
3 DP	31,375	3,891	1,538	6,923	2,568			46,295	21,207
3 DM	222,403	77,816	41,762	48,046	15,084			405,111	466,795
% of Total	100	100	100				100		
4 TDN	101,157	14,942	4,478				4,575	125,152	124,840
4 DP	16,275	1,275	130				490	18,170	8,072
4 DM	183,020	31,127	6,003				5,128	225,277	238,539
% of Total	100		100	100	100				
5 TDN	96,930		2,005	55,150	6,347			160,431	160,031
5 DP	16,716		64	10,513	1,207			28,499	13,582
5 DM	178,252		3,123	72,946	8,399			262,720	293,675
% of Total	100		100	14.14	100				
6 TDN	93,622		19,653	43,429	34,835			191,556	191,539
6 DP	9,109		660	8,110	6,637			24,516	18,399
6 DM	191,363		36,385	56,542	46,079			330,369	338.072

[1]The proportion of total forage production of each forage that was used by the cow-calf activity, for each time period.

[2]The minor violation of nutritional feasibility was attributed to rounding error.

Analysis of the Profit Maximizing Balanced Cow-Calf Ration by Time Periods

Bermuda provides more nutrients to the cow-calf enterprise in the first period than any other feedstuff. However, use of 5.33 pounds of grain sorghum per cow per day indicates that a significant level of grain supplement is required. All of the fescue produced in the first period is grazed by the cow activity. Only a few nutrients are provided by feeding hay in the first period.

In the second time period, all the bermuda is again grazed by cows. However, rye-vetch pasture produces the largest amount of nutrients, yielding over one-half of the total digestible nutrients. The fescue and small grain pastures are shared with the stocker enterprise. The change in ration from the first to the second period is allowed by the increased seasonal production of the cool season annuals and accentuated by increasing nutrient requirements for the cow and calf.

In periods 3, 4 and 5 no steers are on the farm and the cow-calf herd consumes all of the production of the optimum forage system. Time period three includes the calf weaning period of the optimum cow-calf enterprise and the nutrients required reflect the growth of the calf. The timing of the high quality small grain and rye-vetch forages is advantageous to the extended weaning fall calving cow enterprise compared to alternative cow-calf activities. The third time period is also the period of highest production and quality of the warm season perrenials, bermuda and native grasses. The decline in growth of bermuda and native grasses in period four results in supplemental feeding of 1.14 pounds of grain per cow per day. In period five the bermuda and native activities are augmented by some early grazing of rye-vetch and small grains.

The cow ration for period six is estimated by the procedure used in periods one and two. The cow enterprise uses all of the bermuda, native and rye-vetch forage activities. In addition small grain grazing produces a significant proportion of the cow ration in period six.

Cow-Calf Enterprise Cost and Return Budget

Table XVII is a cow-calf budget from Schneeberger, et. al. [24] used to compare traditional budget formats with a revised format. The first item in the inputs (Section 3) is pasture measured in AUM. The budget makes no reference to the kind of pasture (except in title) or makes no charge for the pasture, although cake and hay cost are specified.

Table XVIII converts the optimum cow-calf ration obtained in this study to a 100 cow unit. The ration per 100 cows enhances the ability to appreciate the importance of each nutrient source. The 100 cow breeding unit basis also assists in deriving the ration per breeding unit later used in the beef enterprise budgets (Table XIX).

The major problem of using the ration from the balanced nutrient situation (TDN, DP, and DM) in an enterprise budget is finding a common meaningful unit of measure to replace the AUM measure. Indicating acres required of each forage is a possibility. However, the ration formulated in the LP routine is dependent upon the estimated yields of each forage and the soil quality mix. The yield differs so greatly from one quality of soil to another that measuring the pasture input in terms of acres provides very little information to the beef-forage decision maker.

TABLE XVII

EXAMPLE OF THE FORMAT FROM A PUBLISHED COW-CALF COST AND RETURN ENTERPRISE BUDGET

Estimated Production Requirements and Income for Beef Cow Herd (25 Cow Unit); Calves Born November 1; Not Creep Fed; Graze out small grain or Vetch Pasture with Cottonseed Cake, Hay, and Pasture in Bad Weather; Selling Good-Choice Feeder Calves May 20.

(1) Livestock Investment

Item	Head	Animal Units	Value Per Head	Total Value
Brood Cows	25	25	160.00	4,000.00
Bulls	1	1	300.00	300.00
Heifers over one year	4	2	125.00	500.00
Calves weaned	22	-	-	
Total				4,800.00

(2) Production

Item	Head (no.)	Wt. (lbs)	Price (dol/cwt)	Value Per Head (dol.)	Total Value (dol.)
Steer Calves	11	460	24.97	114.86	1,263.46
Heifer Calves	7	430	22.97	98.77	691.39
Cull Cows	3	987	14.94	147.46	442.38
Cull Heifer over 1 yr.	1	900	15.94	143.46	143.46
Death Loss[1]					-114.43
Total					2,426.26

(3) Inputs

	Item	Unit	Rate	Number	Total	Price	Total Cost
	Pasture	AUM	7.5	28.0	210.0		
	Small Grain Pasture	AUM	4.5	28.0	126.0	3.67[5]	462.42
	Hay Cost	ton	.26	28.0	7.28	8.40[6]	61.15
	CSC	cwt.	.73	28.0	20.44	3.80	77.67
	Minerals	lb.	30.0	28.0	840.0	.03	25.20
	Vet. and Med.	dol.	3.0	28.0	84.0		84.00
	Bull Depreciation	dol.	35.00	1.0	35.00		35.00
	Hauling & Marketing	cwt.			119.31	.50	59.66
	Taxes[2]	dol.					63.25
	Miscellaneous Costs[3]	dol.					122.34
	Annual int. on captl.	dol.			5,678.99	.06	340.74
(4)	Total Specified Costs						1,331.33
(5)	Returns to Land, Labor, Management and Risk						1,094.93
(6)	Labor	hr.	13.68	25	342.0	1.00	342.00
(7)	Returns to Land, Management and Risk[4]						752.93

Labor Requirements (Man hr./cow)

Jan-Apr	May-July	Aug-Sept	Oct-Dec	Total
5.36	1.51	1.25	5.56	13.68

Annual Capital Requirements (dol.)

Operating Capital	152.49
Fixed Capital	5,526.50

1,2,3,4,5,6 See page 8

TABLE XVIII

PROFIT MAXIMIZING COW-CALF COST AND RETURN FOR ONE HUNDRED COWS, FOR A BEEF FORAGE FARM IN EASTERN OKLAHOMA

Nutrients	Bermuda	Fescue	Native	Sorghum Sudan	Small Grain	Rye Vetch	Weeping Love	Hay	Concentrates	Total Supplied	Total Required[1]
					(POUNDS OF NUTRIENTS)						
1TDN	39,079	15,451	0	0	0	0	0	2,545	28,550	85,625	85,625
1DP	3,841	2,550	0	0	0	0	0	208	3,053	9,653	7,977
1DM	86,988	27,110	0	0	0	0	0	4,556	32,004	150,658	150,658
2TDN	32,296	2,044	0	0	9,326	50,612	0	0	0	94,277	94,080
2DP	3,800	337	0	0	1,773	11,149	0	0	0	17,058	8,533
2DM	79,944	3,586	0	0	12,317	69,156	0	0	0	165,002	165,431
3TDN	65,045	19,007	11,674	0	16,728	4,904	0	0	0	117,357	115,190
3DP	14,458	1,793	709	0	3,190	1,183	0	0	0	21,334	9,773
3DM	102,490	35,860	19,245	0	22,141	6,951	0	0	0	186,687	215,113
4TDN	46,616	6,886	2,064	0	0	0	0	0	2,108	57,674	57,530
4DP	7,500	588	60	0	0	0	0	0	226	8,373	3,720
4DM	84,341	14,344	2,766	0	0	0	0	0	2,363	103,814	109,926
5TDN	44,668	0	924	0	25,415	2,925	0	0	0	73,931	73,747
5DP	7,703	0	29	0	4,845	556	0	0	0	13,133	6,259
5DM	82,144	0	1,439	0	33,616	3,871	0	0	0	121,069	135,334
6TDN	43,144	0	9,056	0	20,013	16,053	0	0	0	88,275	88,267
6DP	4,198	0	304	0	3,737	3,058	0	0	0	11,298	8,479
6DM	88,186	0	16,767	0	26,056	21,235	0	0	0	152,244	155,794

[1]The minor violation of nutritional feasibility was attributed to rounding error.

TABLE XIX

PROFIT MAXIMIZING COW-CALF COST AND RETURN ENTERPRISE BUDGET FROM THE BEEF-FORAGE MODEL FOR EASTERN OKLAHOMA

Livestock Investment

Item	Head	Value Per Head	Total Value	Value Per Breeding Unit
Brood Cows	25	220	5,500	220
Bull	1	519	519	20.76
Heifers	4	150	600	24.00

Production

Item	Head (No.)	Wt. (Lbs.)	Price (Dol./Cwt.)	Value Per Head (Dol.)	Total Value (Dol.)	Value Per Breeding Unit
Cull Cows	3	980	19.57	191.78	575.36	23.01
Cull Heifer	1	900	25.19	226.71	226.71	9.07
Steer Calves	11	580	31.82	184.55	2030.11	81.20
Heifer Calves	7	554	28.27	156.62	1096.31	43.85
Total Receipts					3298.49	157.14

Inputs

		Unit	Rate	Number	Price	Total Cost	Cost Per Breeding Unit
Feed	Pasture Charge	dol.	936.58	1		936.58	37.46
	Hay	dol.	6.69	1		6.69	.27
	Grain	dol.	276.33	1		276.33	11.05
Other	Mineral	lb.	30.	900	.053	47.75	1.91
	Death Loss	herd	120.10	1		120.10	4.80
	Bull Depreciation	herd	67.50	1		67.50	2.76
	Marketing	head	2.57	22		56.54	2.26
	Vet. Med.	head	2.30	30		69.00	2.71
	Hauling	head	2.00	22		44.00	1.76
	Supplies	head	1.40	30		42.00	1.66
	Misc.	head	2.25	25		56.25	2.23
	Equt. Charge	head	4.36	25		109.00	4.36
	Taxes	herd	1220.00	1	.065	79.30	3.17
						562.52	22.50
Capital Cost							
Feed System							
	Operating Capital[2]	dol.	.07	446.65	.07	31.27	1.25
	Fixed Capital[3]	dol.	.07	1846.05	.07	129.22	5.17
Livestock Investment							
	Operating Capital[4]	dol.	.07	53.75	.07	3.76	.15
	Fixed Capital[5]	dol.	.07	7986.24	.07	559.04	22.36
	Total						28.93
Total Specified Cost							105.32
Returns to Land, Labor, Management and Risk							51.82
Labor	11.30 hours at $1.75/hour						19.78
Returns to Land, Management and Risk							32.04

TABLE XIX (Continued)

RATION (pounds per breeding unit)

	Bermuda	Fescue	Native	Small Grain	Rye-Vetch	Hay	Grain	Total Supplied	Total Required
1 TDN	390.79	154.79				25.45	285.50	856.25	856.25
1 DP	38.41	25.50				2.08	30.53	96.53	79.77
1 DM	869.88	271.10				45.56	320.04	1506.58	1506.58
2 TDN	322.96	20.44		93.26	506.12			942.77	940.08
2 DP	38.00	3.37		17.73	111.49			170.58	85.33
2 DM	799.44	35.86		123.17	691.56			1650.02	1654.31
3 TDN	650.45	190.07	116.74	167.28	49.04			1173.57	1151.90
3 DP	144.58	17.93	7.09	31.90	11.83			213.34	97.73
3 DM	1024.90	358.60	192.45	221.41	69.51			1866.87	2151.13
4 TDN	466.16	68.86	20.64					576.74	575.30
4 DP	75.00	5.88	.60					83.74	37.20
4 DM	843.41	143.44	27.66					1038.14	1099.26
5 TDN	446.68		9.24	254.15	29.25			739.31	737.47
5 DP	77.03		.29	48.45	5.56			131.33	62.59
5 DM	821.44		14.39	336.16	38.71			1210.69	1353.34
6 TDN	431.44		90.56	200.13	160.53			882.75	882.67
6 DP	44.48		3.04	37.37	30.58			112.98	84.79
6 DM	88.186		167.67	260.56	212.35			1522.44	1557.94

TIME PERIOD DISTRIBUTION OF LABOR

		Jan-Feb	Mar-Apr	May-June	July-Aug	Sept-Oct	Nov-Dec	Total
Care Labor	Hrs.	.94	.94	.94	.56	2.48	1.00	
Feed Labor[6]	Hrs.	.22	.35	1.00	1.34	.34	.14	
Total Labor	Hrs.	1.16	1.29	2.99	1.90	2.82	1.14	11.30

[1]Profit maximizing cow-calf ration for east central Oklahoma. From the integrated beef organization of 217 cows and 986 stockers. Yield data from Oklahoma State Experiment Station, Muskogee, Oklahoma.

[2]Annual charge for variable expenses of providing pasture and feed (includes fertilizer, fuel, repairs, etc.)

[3]Annual charge for long term investments associated with the grazing and feeding system (includes fencing investment, investment in establishing improved forages, feeding facilities).

[4]Annual charge for non feed operating expenses (i.e., minerals, vet medicine, stocker, supplies and miscellaneous).

[5]Long term livestock investment (includes cattle handling equipment).

[6]Varies with feeding system.

A suitable unit of measure for the balanced ration enterprise budget was not found. The cost of providing the optimum ration to the beef activity is included in the annual input cost section. Then to illustrate and define the ration used to estimate the cost of the ration, a section is added to the budget containing the balanced ration, as developed in preceding sections, on a per head basis (Table XIX). The ration gives information concerning the timing of production and importance of each forage in supplying the nutrients for each time period applicable to that particular budget.

The ration section could be used by farm managers to find the required nutrients. The acres required would depend on the quality of soils and yields for the farm situation in question.

The new enterprise budget format alters the labor and capital sections compared to the Schneeberger format. The labor section is enlarged to distinguish the distribution of labor required to perform different tasks. The labor section is divided into livestock care labor and the labor requirement for the optimum feed system as determined by the computer program. The annual capital section is enlarged to include not only operating and fixed capital for the livestock enterprise, but also for the optimum forage system. Table XIX gives a breakdown of capital requirements for the feeding system.

Analysis of the Fall Stocker Profit Maximizing Balanced Ration by Time Periods

January-February is a slack one for production of the cool season annuals, small grain and rye-vetch. Most of the nutrients of the stocker

TABLE XX

PROFIT MAXIMIZING INTEGRATED FALL STOCKER BALANCED RATION
FOR A BEEF-FORAGE FARM IN EASTERN OKLAHOMA

	Fescue	Native	Small Grain	Rye Vetch	Hay	Grain	Total Supplied	Total Required
% of Total[1]		100	100	100	98	72.89		
1 TDN		16,012	118,494	13,681	258,080	166,464	572,731	572,077
1 DP		660	22,540	2,608	22,148	17,828	66,236	63,301
1 DM		36,408	156,736	18,099	484,372	186,644	882,258	881,484
% of Total[1]	90		97.06					
2 TDN	39,917		667,044				706,962	706,962
2 DP	6,584		127,057				133,641	75,724
2 DM	70,037		882,380				935,984	950,701
% of Total[1]	100		85.86		100			
6 TDN	86,228		263,609		14,449		364,286	363,834
6 DP	14,215		49,246		1,221		64,682	36,679
6 DM	151,276		343,333		27,379		527,988	632,420

[1]The proportion of total forage production of each forage that was used by the stocker activity for each time period.

ration in period one are provided by supplemental feeding of hay and grain (Table XX). The steers received 45 percent of the required TDN from 8.18 pounds of (dry matter) hay fed per head per day. Grain provides 29 percent of the TDN requirement through 3.15 pounds fed per head per day. Grazing is available from native grass, small grain and rye-vetch.

Fall stockers are bought in period six. Upon receiving new calves it is a common practice to feed hay. The profit maximizing ration provides .46 pounds of hay per head per day averaged over the 60 days in period six. The steers also graze fescue and small grain with small grain providing the bulk of the required nutrients.

Time period two is a demanding one for the stocker enterprise because the steers are at a heavier weight. The optimum forage system must fulfill these higher requirements. The fall steer balanced ration for the second time period is comprised mostly of small grains augmented with some fescue. The seasonality of small grain yield is matched closely with the requirements of the fall stocker enterprise.

Stocker Enterprise Cost and Return Budget

Table XXI converts the optimum stocker ration to a 100 head ration. Table XXII is a reproduction of a similar stocker budget [24]. The enterprise budget for the stocker portion of the optimum stocker activity is given in Table XXIII.

Aside from the obvious price level changes the format designed for the balanced stocker ration charges 12.60 for the feeding (grazing pasture plus supplemental fees) outlined in the ration where the old budget made charges only for hay and cake and no charge for the small

TABLE XXI

PROFIT MAXIMIZING INTEGRATED STOCKER BALANCED RATION, FOR ONE HUNDRED STOCKERS, BEEF-FORAGE FARM IN EASTERN OKLAHOMA

Nutrients	Fescue	Native	Small Grain	Rye Vetch	Hay	Concentrates	Total Supplied	Total Required
			(POUNDS OF NUTRIENTS)					
1 TDN		1,624	12,018	1,388	26,174	16,883	58,086	58,020
1 DP		67	2,286	265	2,246	1,808	6,718	6,420
1 DM		3,692	15,896	1,836	49,124	18,929	89,478	89,400
2 TDN	4,048		67,651				71,700	71,700
2 DP	668		12,886				13,554	7,680
2 DM	7,103		89,491				94,927	96,420
6 TDN	8,745		26,735		1,465		39,946	36,900
6 DP	1,442		4,994		124		6,560	3,720
6 DM	15,342		34,821		2,777		53,548	64,140

TABLE XXII

EXAMPLE FORMAT OF PUBLISHED STOCKER COST AND RETURN BUDGET

Table 7: Estimated Production Requirements and Income for Winter Pasturing Good Stocker Cattle; Fall Buy October 10; Wintered on Small Grain Pasture with Hay, Cottonseed Cake, and Pasture in Bad Weather; Sell March 1.

Item	Unit	Amount	Price	Total Value
			- Dollars -	
(1) Livestock Investment				
Calf	cwt.	4.50	23.42	105.39
(2) Production				
Feeder	cwt.	6.15	22.12	136.04
Less 1 percent Death Loss				-1.36
Total				134.68
(3) Inputs				
Calf	cwt.	4.50	23.42	105.39
Small Grain Pasture	AUM.	2.2		
Pasture	AUM	.20		
Hay	ton	.15	18.00	2.70
CSC	cwt.	.20	3.80	.76
Vet. and Med.	dol.			1.00
Minerals	lb.	6.0	.03	.18
Hauling and Marketing	cwt.	10.80	.50	5.40
Tax	dol.	20.00	.05	1.00
Miscellaneous Costs	dol.			1.48
Annual Investment on captl.	dol.	63.07	.06	3.78
(4) Total Specified Costs				121.69
(5) Returns to Land, Labor, Management and Risk				12.99
(6) Labor	hr.	1.84	1.00	1.84
(7) Returns to Land, Management and Risk[4]				11.15

Labor Requirements (Man hr/animal)					Annual Capital Requirements (dol.)	
Jan-Apr	May-July	Aug-Sept	Oct-Dec	Total	Operating Capital	56.48
.90	-	-	.94	1.84	Fixed Capital	6.59

4 See page 8

TABLE XXIII

PROFIT MAXIMIZING STOCKER COST AND RETURN ENTERPRISE BUDGET FOR A BEEF-FORAGE FARM IN EASTERN OKLAHOMA

Livestock Investment

	Item	Head	Wt. (Lbs.)	Value Per	Total Value
(1)	Steer	1	460	32.09	147.61

Production

	Item	Head (No.)	Wt. (Lbs.)	Price (Dol./Cwt.)	Value Per Head (Dol.)
(2)	Steer	1	750	29.87	224.02

Inputs

(3)			Unit	Rate	Number	Price	Cost Per Stocker
	Feed	Grazing Cost					8.11
		Hay Cost					3.53
		Grain Cost					6.02
	Other	Minerals	lb.	6.0	1	.053	.32
		Death Loss	hd.	2.57	1		2.57
		Marketing	hd.	2.57	1		2.57
		Calf	cwt.	32.09	1		147.61
		Vet. Med.	hd.	1.75	1		1.75
		Hauling	cwt.	.50	12.10		6.05
		Misc.	hd.	3.50	1		3.50
		Equipment	hd.	2.14	1		2.14
		Taxes	lb.	.04	6.22	.065	1.62
	Capital Cost						
	Feed System						
	Operating Capital[2]		dol.	.07	6.24	.07	.44
	Fixed Capital[3]		dol.	.07	17.21	.07	1.20
	Livestock Investment						
	Operating Capital[4]		dol.	.07	76.90	.07	5.38
	Fixed Capital[5]		dol.	.07	16.07	.07	1.12
	Total Capital						8.14
(4)	Total Specified Costs						193.94
(5)	Returns to Land, Labor, Management and Risk						30.08
(6)	Labor	3.45 hours at $1.75/hour					6.04
(7)	Returns to Land, Management and Risk						24.04

TABLE XXIII (Continued)

(9) RATION (pounds per head)

	Fescue	Native	Small Grain	Rye-Vetch	Hay	Grain	Total Supplied	Total Required
1 TDN		16.24	120.18	13.88	261.74	168.83	580.86	580.20
1 DP		.67	22.86	2.65	22.46	18.08	67.18	64.20
1 DM		36.92	158.96	18.36	491.24	189.29	894.78	894.00
2 TDN	40.48		676.51				717.00	717.00
2 DP	6.68		128.86				135.54	76.80
2 DM	71.03		894.91				949.27	964.20
3								
3								
3								
4								
4								
4								
5								
5								
5								
6 TDN	87.45		267.35		14.65		369.46	369.00
6 DP	14.42		49.94		1.24		65.60	37.20
6 DM	153.42		348.21		27.77		535.48	641.40

(10) TIME PERIOD DISTRIBUTION OF LABOR

		Jan-Feb	Mar-Apr	May-June	July-Aug	Sept-Oct	Nov-Dec	Total
Care Labor	Hrs.	.36	.68				.88	1.92
Feed Labor[6]	Hrs.	.41	.09	.54	.37	.05	.07	1.53
Total Labor	Hrs.	.77	.77	.54	.37	.05	.95	3.45

[1]Profit maximizing steers for each central Oklahoma. From the integrated beef organization of 217 cows and 986 stockers. Yield data from Oklahoma State Experiment Station, Muskogee, Oklahoma.

[2]Annual charge for variable expenses of providing pasture and feed (includes fertilizer, fuel, repairs, etc.)

[3]Annual charge for long term investments associated with the grazing and feeding system (includes fencing investment, investment in establishing improved forages, feeding facilities)

[4]Annual charge for non feed operating expenses (i.e., minerals, vet medicine, stocker, supplies and miscellaneous).

[5]Long term livestock investment (includes cattle handling equipment).

[6]Varies with feeding system.

grains pasture. Similarly, the capital requirement section of the old budget does not charge for the capital on the feeding system. The labor requirement section of the new format is expanded and separated care labor from feeding labor. The labor distinction enables altering the budget for other feeding systems but the same livestock enterprise.

Profit Maximizing Balanced Rations For Separate Livestock Solutions

The allocation problems encountered in the multiple livestock solution do not affect the separate livestock solutions presented earlier in this chapter. The optimum forage system is not shared with any other beef enterprise in any time period. Thus the model output can be summarized directly. However, the total nutrients supplied by each forage must be computed to measure the significance for the separate balanced rations.

The Profit Maximizing Separate Cow-Calf Balanced Ration

The total nutrients supplied by each of the forages in the ration mix are presented in Table XXIV. Table XXV converts the forage mix per 100 cow basis for convenience in discussion.

The profit maximizing ration in the first time period consists mostly of hay with fescue providing the second largest amount of TDN. In period two, the small grain and rye-vetch enterprises and fescue provide significant nutrients. Bermuda and fescue provide the bulk of the ration in the third time period. Bermuda is most important in period four. In period five, bermuda grass is augmented with a signifi-

TABLE XXIV

TOTAL NUTRIENTS FOR THE SEPARATE COW-CALF BALANCED RATION SOLUTION FOR A BEEF-FORAGE FARM IN EASTERN OKLAHOMA

Nutrients	Bermuda	Fescue	Native	Sorghum Sudan	Small Grain	Rye Vetch	Weeping Love	Hay	Concentrates	Total Supplied	Total Required[1]
					(POUNDS OF NUTRIENTS)						
1TDN	9,217	113,473	16,012	0	38,208	13,684	0	233,576	30,417	454,586	454,669
1DP	379	18,721	660	0	7,266	2,609	0	19,883	3,256	52,773	42,358
1DM	20,941	199,104	36,409	0	50,533	18,103	0	440,664	34,095	799,848	799,994
2TDN	17,987	150,111	0	0	221,543	109,850	0	0	0	499,491	499,565
2DP	2,967	24,759	0	0	42,197	24,198	0	0	0	94,121	45,310
2DM	31,559	263,358	0	0	293,040	150,099	0	0	0	738,056	878,439
3TDN	424,210	139,596	25,332	0	11,749	10,643	0	0	0	611,531	611,658
3DP	78,671	13,164	1,538	0	2,233	2,568	0	0	0	98,174	51,895
3DM	690,984	262,358	41,762	0	15,566	15,087	0	0	0	1,026,757	1,142,248
4TDN	250,379	50,564	4,478	0	0	0	0	0	0	305,421	305,484
4DP	33,289	4,313	130	0	0	0	0	0	0	37,732	19,753
4DM	456,434	105,340	6,003	0	0	0	0	0	0	567,777	583,706
5TDN	282,607	0	2,005	82,802	17,763	6,348	0	0	0	391,525	391,597
5DP	40,149	0	64	16,712	3,396	1,207	0	0	0	61,527	33,235
5DM	525,949	0	3,123	150,552	23,507	8,401	0	0	0	711,531	718,623
6TDN	13,232	291,833	19,653	0	97,433	34,842	0	11,625	0	468,617	468,698
6DP	438	48,110	660	0	18,559	6,638	0	983	0	75,387	45,023
6DM	24,502	511,979	36,386	0	128,877	46,089	0	22,028	0	769,861	827,265

[1]The minor violation of nutritional feasibility was attributed to rounding error.

TABLE XXV

SEPARATE COW-CALF BALANCED RATION FOR ONE HUNDRED COWS FROM A BEEF-FORAGE FARM IN EASTERN OKLAHOMA

Nutrients	Bermuda	Fescue	Native	Sorghum Sudan	Small Grain	Rye Vetch	Weeping Love	Hay	Concentrates	Total Supplied	Total Required[1]
					(POUNDS OF NUTRIENTS)						
1TDN	1,736	21,370	3,016	0	7,195	2,577	0	43,988	5,728	85,610	85,625
1DP	71	3,526	124	0	1,368	491	0	3,744	613	9,938	7,977
1DM	3,944	37,496	6,857	0	9,517	3,409	0	82,987	6,421	150,631	150,658
2TDN	3,387	28,270	0	0	41,722	20,687	0	0	0	94,066	94,080
2DP	559	4,663	0	0	7,947	4,557	0	0	0	17,725	8,533
2DM	5,943	49,597	0	0	55,186	28,267	0	0	0	138,993	165,431
3TDN	79,889	26,289	4,771	0	2,213	2,004	0	0	0	115,165	115,190
3DP	14,816	2,479	290	0	421	484	0	0	0	18,489	9,773
3DM	130,129	49,597	7,865	0	2,931	2,841	0	0	0	193,362	215,113
4TDN	47,152	9,522	843	0	0	0	0	0	0	57,518	57,530
4DP	6,269	812	25	0	0	0	0	0	0	7,106	3,720
4DM	85,957	19,838	1,130	0	0	0	0	0	0	106,926	109,926
5TDN	53,222	0	378	15,594	3,345	1,195	0	0	0	73,733	73,747
5DP	7,561	0	12	3,147	640	227	0	0	0	11,587	6,259
5DM	99,049	0	588	28,352	4,427	1,582	0	0	0	133,998	135,334
6TDN	2,492	54,959	3,701	0	18,349	6,561	0	2,189	0	88,252	88,267
6DP	82	9,060	124	0	3,495	1,250	0	185	0	14,197	8,479
6DM	4,614	96,418	6,852	0	24,271	8,680	0	4,148	0	144,983	155,794

[1]The minor violation of nutritional feasibility was attributed to rounding error.

cant level of the summer annual sorghum-sudan. In the final period, most of the nutrients are provided by fescue followed by bermuda, and small grain and rye-vetch. The profit maximizing cow ration illustrates the use of a year-round grazing system to meet the changing requirements of the cow-calf enterprise and the environmental seasons of the year.

The Profit Maximizing, Separate Stocker Balanced Ration

The total nutrients supplied by the optimum stocker organization are given in Table XXVI. The optimum stocker organization consists of two stocker activities, but no competition for forages within time periods exists. The ration is determined without the procedure utilized by the multiple livestock solution. The ration on a per hundred head basis is presented in Table XXVII.

The fall stocker enterprise uses nutrients in periods 1, 2 and 6. Therefore, the ration for the fall stockers is found in the corresponding time periods in the table. In period one, 3.37 pounds of grain dry matter and 8.0 pounds of hay dry matter per head per day provide most of the nutrients, supplemented with small grain and rye-vetch grazing. Small grain and rye-vetch produce most of the nutrients in the second time period and in the sixth period. Supplemental feeding of 1.11 pounds of dry matter per stocker per day from hay is required in the period the steers are purchased.

The profit maximizing spring stocker ration is given in time periods three through five. The major ingredient of the ration is bermuda. However, the clean-up of the small grain and rye-vetch (used mostly by the fall stockers) provides a significant quantity of energy

TABLE XXVI

SUMMARY OF THE TOTAL NUTRIENTS FOR THE STOCKER SOLUTION OF THE PROFIT MAXIMIZING BALANCED NUTRITION FROM THE BEEF-FORAGE MODEL FOR EASTERN OKLAHOMA

Nutrients	Bermuda	Fescue	Native	Sorghum Sudan	Small Grain	Rye Vetch	Weeping Love	Hay	Concentrates	Total Supplied	Total Required[1]
					(POUNDS OF NUTRIENTS)						
1TDN	20,391	0	10,862	0	132,696	13,681	0	320,655	223,879	722,163	722,163
1DP	1,436	0	449	0	25,242	2,608	0	27,799	23,967	81,500	79,908
1DM	45,616	0	24,684	0	175,526	18,099	0	597,873	252,073	1,113,871	1,112,743
2TDN	12,883	0	0	0	769,719	109,828	0	0	0	892,430	892,435
2DP	1,216	0	0	0	146,607	24,193	0	0	0	172,016	95,591
2DM	31,892	0	0	0	1,018,152	150,067	0	0	0	1,200,111	1,200,120
3TDN	49,562	0	0	2,416	40,622	10,641	0	0	0	103,241	99,978
3DP	6,163	0	0	488	7,750	2,568	0	0	0	16,969	10,716
3DM	75,816	0	0	4,392	53,754	15,084	0	0	0	149,046	149,340
4TDN	22,944	0	0	4,359	0	0	0	0	89,547	116,851	117,078
4DP	2,619	0	0	880	0	0	0	0	9,586	13,085	13,110
4DM	40,458	0	0	7,926	0	0	0	0	100,374	148,759	183,540
5TDN	20,012	0	0	2,888	61,775	6,347	0	0	0	91,022	91,200
5DP	2,595	0	0	583	11,771	1,207	0	0	0	16,155	8,208
5DM	36,178	0	0	5,251	81,705	8,399	0	0	0	131,534	158,346
6TDN	24,107	0	13,327	0	343,186	34,835	0	43,833	0	459,288	459,287
6DP	1,583	0	449	0	64,190	6,637	0	3,705	0	76,564	46,302
6DM	47,949	0	24,684	0	447,855	46,079	0	83,056	0	649,624	798,337

[1]The minor violation of nutritional feasibility was attributed to rounding error.

TABLE XXVII

NUTRIENT SUMMARY OF THE PROFIT MAXIMIZING BALANCED RATION FOR THE ONE HUNDRED STOCKERS FROM THE SEPARATE STOCKER BEEF-FORAGE MODEL, FOR EASTERN OKLAHOMA

Nutrients	Bermuda	Fescue	Native	Sorghum Sudan	Small Grain	Rye Vetch	Weeping Love	Hay	Concentrates	Total Supplied	Total Required[1]
					(POUNDS OF NUTRIENTS)						
1TDN	1,638	0	872	0	10,658	1,099	0	25,755	17,982	58,005	58,005
1DP	115	0	36	0	2,027	209	0	2,233	1,925	6,546	6,418
1DM	3,664	0	1,983	0	14,098	1,454	0	48,022	20,247	89,468	89,377
2TDN	1,035	0	0	0	61,825	8,821	0	0	0	71,681	71,682
2DP	98	0	0	0	11,776	1,943	0	0	0	13,817	7,678
2DM	2,562	0	0	0	81,779	12,054	0	0	0	96,394	96,395
3TDN	26,085	0	0	1,271	21,380	5,601	0	0	0	54,337	52,620
3DP	3,244	0	0	257	4,079	1,351	0	0	0	8,931	5,640
3DM	39,903	0	0	2,312	28,292	7,939	0	0	0	78,445	78,600
4TDN	12,076	0	0	2,294	0	0	0	0	47,130	61,500	61,620
4DP	1,379	0	0	463	0	0	0	0	5,045	6,887	6,900
4DM	21,294	0	0	4,172	0	0	0	0	52,829	78,294	96,600
5TDN	10,533	0	0	1,520	32,513	3,340	0	0	0	47,906	48,000
5DP	1,366	0	0	307	6,195	635	0	0	0	8,503	4,320
5DM	19,041	0	0	2,764	43,003	4,421	0	0	0	69,228	83,340
6TDN	1,936	0	1,070	0	27,565	2,798	0	3,521	0	36,891	36,890
6DP	127	0	36	0	5,156	533	0	298	0	6,150	3,719
6DM	3,851	0	1,983	0	35,972	3,701	0	6,671	0	52,179	64,123

[1]The minor violation of nutritional feasibility was attributed to rounding error.

to the spring stockers. During the summer slump of bermuda (period four) the ration is mostly grain with some bermuda grazing. The 4.63 pounds of grain dry matter are fed per steer per day in period four. The small grain and rye-vetch enterprises begin to provide nutrients in the fifth time period. The cool season annuals augmented by some bermuda grazing provide most of the nutrients in period five.

In summary, although the spring stockers utilize bermuda grass primarily, they also depend on the beginning and ending of the seasonal growth of small grains and rye-vetch. Large amounts of grain are needed when high quality grazing is not available. The required relationship of TDN to dry matter (quality relationship) eliminates the use of many other forages for the spring stocker activity. The ratio of TDN to DM (quality) required by the fall stocker enterprise (Table XXVIII) for period one is 65. Otherwise the stomach capacity is not sufficient to provide enough energy for the assumed rate of gain. According to Table III, the only alternatives with adequate quality are small grains or rye-vetch grazing which provide 75.6 percent energy on a dry weight basis. Many of the perennial grasses are not feasible. The energy required by the animal exceeds the dry matter capacity. For example, in period one, none of the perennial grasses are feasible. Low rates of gain are required if stockers are to utilize the low quality forages.

Profit Maximizing TDN Ration

The optimum livestock system using TDN as the only nutritional constraint includes the extended weaning, fall calving cow-calf enterprise and the fall stocker enterprise. A procedure similar to that used to estimate balanced rations from the multiple livestock solution is needed

TABLE XXVIII

ESTIMATED REQUIRED PROPORTIONS OF TDN AND DP TO DRY MATTER BY THE FALL AND SPRING STOCKER ACTIVITIES AND COW 4 FOR A BEEF-FORAGE FARM, EASTERN OKLAHOMA

		FLST	SPST	COW 4
	Period			
TDN/DM	1	64.9		56.8
	2	74.4		56.4
	3		66.9	53.5
	4		63.8	52.3
	5		57.6	54.5
	6	57.5		56.7
DP/DM	1	7.2		5.3
	2	8.0		5.2
	3		7.2	4.5
	4		7.1	3.4
	5		5.2	4.6
	6	5.8		5.4

to analyze the ration for the profit maximizing TDN solution. The goal is to allocate the TDN supplied by the optimum forage system between the two competing beef enterprises, but without considering protein or dry matter limitations.

A feasible ration (per 100 head) for the cow-calf enterprise of the optimum multiple livestock organization is summarized in Table XXIX. The cow activity relies upon bermuda and fescue for most of the required energy. In the winter time periods, supplemental hay is needed in period one and some rye-vetch pasture in period two. The cows utilize the small grain and rye-vetch pasture that is available before the stockers are purchased and clean up small grain and rye-vetch pastures after the fall stockers are sold in the spring. Native grass supplies a small amount of the energy required by the cow-calf enterprise.

The stocker TDN ration (Table XXX) includes small grains and rye-vetch in all three time periods. Most of the energy in period one comes from the hay activity. Fescue provides the necessary energy to balance the TDN in period six.

To check the feasibility of the TDN ration (assuming that the balanced nutrient model is the correct one), the total protein and dry matter required and supplied by the optimum solution are calculated and presented in Table XXXI. The TDN rations meet all of the protein requirements. However, the dry matter constraint is violated in periods 1, 2, 4 and 6. The excess amount of dry matter forced by the TDN solution is summarized in Table XXXII. The TDN nutritional approach results in a least cost ration per unit of TDN ignoring the stomach capacity or forage quality relationship. The optimum TDN forage organization is based on the cost of producing the most pounds of energy

TABLE XXIX

NUTRIENT SUMMARY OF THE INTEGRATED COW-CALF PROFIT MAXIMIZING TDN RATION FOR ONE HUNDRED COWS FROM A BEEF-FORAGE FARM IN EASTERN OKLAHOMA

	Bermuda	Fescue	Native	Small Grain	Rye-Vetch	Weeping Love	Hay	Total Supplied	Total Required
				(POUNDS OF NUTRIENTS)					
1 TDN	40,876	20,440	8,383				15,789	85,488	85,624
1 DP	4,455	3,375	345				8,311	9,311	7,977
1 DM	90,826	35,863	19,062				175,173	175,173	150,658
2 TDN	36,692	27,039			30,205			93,936	94,080
2 DP	4,317	4,460			6,654			15,430	8,533
2 DM	90,826	47,436			41,273			179,535	165,431
3 TDN	56,584	25,142	13,262	17,667	5,572			118,228	115,190
3 DP	15,378	2,372	805	3,369	1,344			23,269	9,773
3 DM	90,826	47,436	21,864	23,377	7,899			191,404	215,113
4 TDN	49,774	9,109	2,344					61,228	57,530
4 DP	8,405	776	68					9,250	8,955
4 DM	90,826	18,975	3,142					112,944	109,926
5 TDN	49,140		1,050	26,840	3,324			80,353	73,747
5 DP	8,701		34	5,116	632			14,481	6,259
5 DM	90,826		1,635	35,500	4,398			132,360	135,334
6 TDN	43,960	33,872	10,290					88,122	88,266
6 DP	4,602	5,584	345					10,531	8,479
6 DM	90,826	59,416	19,050					169,293	155,794

TABLE XXX

NUTRIENT SUMMARY OF THE INTEGRATED STOCKER
PROFIT MAXIMIZING TDN RATION FOR 100
STEERS FROM A BEEF-FORAGE FARM,
EASTERN OKLAHOMA

	Bermuda	Fescue	Native	Small Grain	Rye Vetch	Hay	Total Supplied	Total Required
				(POUNDS OF NUTRIENTS)				
1 TDN				11,429	1,420	45,171	58,020	58,020
1 DP				2,174	271	3,922	6,367	6,419
1 DM				15,118	1,878	84,131	101,127	89,400
2 TDN				66,289	5,411		71,700	71,700
2 DP				12,626	1,185		13,811	7,680
2 DM				87,685	7,393		95,078	96,420
6 TDN		3,704		29,582	3,614		36,900	36,900
6 DP		611		5,531	689		6,841	3,720
6 DM		6,463		38,569	4,781		49,813	64,140

TABLE XXXI

SUMMARY OF THE TOTAL NUTRIENTS REQUIRED AND SUPPLIED BY THE TDN RATION SPECIFICATION FOR A BEEF-FORAGE IN EASTERN OKLAHOMA

Nutrients	Bermuda	Fescue	Native	Sorghum Sudan	Small Grain	Rye Vetch	Weeping Love	Hay	Concentrates	Total Supplied	Total Required	Infeasibility
						(POUNDS OF NUTRIENTS)						
1TDN	78,074	39,040	16,012	0	110,179	13,684	0	465,607	0	722,596	722,856	
1DP	8,059	6,446	660	0	20,957	2,609	0	40,431	0	79,162	77,125	
1DM	173,478	68,498	36,409	0	145,739	18,103	0	867,223	0	1,309,405	1,149,572	159,878
2TDN	70,081	51,644	0	0	639,029	109,850	0	0	0	870,605	870,880	
2DP	8,245	8,518	0	0	121,716	24,198	0	0	0	162,676	90,333	
2DM	173,478	90,603	0	0	845,282	150,098	0	0	0	1,259,461	1,245,461	14,000
3TDN	108,075	48,021	25,332	0	33,744	10,643	0	0	0	225,815	220,013	
3DP	29,372	4,531	1,538	0	6,435	2,568	0	0	0	44,444	18,666	
3DM	173,478	90,603	41,762	0	44,651	15,087	0	0	0	365,581	410,886	
4TDN	95,068	17,398	4,478	0	0	0	0	0	0	116,945	109,882	
4DP	16,054	1,483	130	0	0	0	0	0	0	17,667	7,105	
4DM	173,478	36,242	6,003	0	0	0	0	0	0	215,724	209,959	5,765
5TDN	93,858	0	2,005	0	51,264	6,348	0	0	0	153,474	140,857	
5DP	16,618	0	64	0	9,771	1,207	0	0	0	27,659	11,955	
5DM	173,478	0	3,123	0	67,806	8,401	0	0	0	252,808	258,488	
6TDN	83,963	100,398	19,653	0	285,171	34,842	0	0	0	524,027	524,306	
6DP	8,789	16,553	660	0	53,319	6,638	0	0	0	85,960	52,056	
6DM	173,478	176,137	36,386	0	371,809	46,089	0	0	0	803,898	915,875	

TABLE XXXII

ESTIMATED EXCESSIVE DRY MATTER GENERATED BY THE TDN RATION SPECIFICATION OF THE BEEF-FORAGE LP MODEL FOR EASTERN OKLAHOMA

Period	Activity	Excess Dry Matter[1] pounds/day/hd
1	Cow 4	4.08
	Stockers	1.95
2	Cow 4	2.35
4	Cow 4	.50
6	Cow 4	2.24

[1]Excessive compared to stomach capacity limits used in the balanced ration approach.

without concern for the percentage of TDN to dry matter. The TDN solution, therefore, ignores the stomach capacity (D.M.) aluded to in the balanced ration. As a result of this alteration, livestock activity is not capable of consuming the level of dry matter as suggested by the TDN model. Table XXXII shows the pounds of excess dry matter the TDN ration formulation assumes is feasible. The optimum TDN ration exceeds the stomach capacity of Cow 4 in the first period by 4.08 pounds per cow per day and the fall stocker by 1.95 pounds per head per day. Compared to the balanced rations, the TDN rations are infeasible for both the stocker and cow-calf enterprises.

Profit Maximizing AUM Ration

The optimum mix of beef enterprises determined by the AUM nutritional approach is a stocker operation. The profit maximizing AUM ration is available from the computer solution without the allocation problems of the profit maximizing nutritional approach. The ration stated in AUM's is given in Table XXXIII. The optimum AUM ration is mostly bermuda grass. Bermuda provides as much as 99 percent of the required AUM's in period four and as little as 56 percent in period two. Hay provides the remaining 44 percent in period two. Native grass provides as much as 6 percent in time period three and none of the AUM's in period two.

The feasibility of the profit maximizing AUM ration was checked by calculating the pounds of TDN, protein and dry matter supplied by the ingredients of the AUM ration compared to the nutrients required and stomach capacity of the stocker activities. Table XXXIV summarizes the nutrients supplied and required from the profit maximizing AUM solution. The infeasibility column indicates the amount of TDN or protein not

TABLE XXXIII

SUMMARY OF THE PROFIT MAXIMIZING AUM RATION[1/] FOR A BEEF-FORAGE FARM IN EASTERN OKLAHOMA

AUM	Bermuda	Native	Sorghum-Sudan	Hay	Supplied	Required
1	78.29	3.5		31.7	113.5	114
2	78.29	0		60.3	138.6	138
3	120.0	6.6			126.6	101
4	120.0	1			121.0	121
5	128.1	.5	12.4		141	141
6	78.29	3.5		17.2	99.0	99

[1/]The ration is stated in total animal unit months per period.

TABLE XXXIV

SUMMARY OF THE TOTAL NUTRIENTS OF THE AUM RATION FOR ONE HUNDRED HEAD OF CATTLE FOR A BEEF-FORAGE FARM IN EASTERN OKLAHOMA

Nutrients	Bermuda	Fescue	Native	Sorghum Sudan	Small Grain	Rye Vetch	Weeping Love	Hay	Concentrates	Total Supplied	Total Required	Degree of Infeasibility[1]
						(POUNDS OF NUTRIENTS)						
1TDN	28,187	0	1,245	0	0	0	0	14,230	0	43,663	58,020	14,357
1DP	2,922	0	51	0	0	0	0	1,765	0	4,739	6,420	1,681
1DM	62,635	0	2,831	0	0	0	0	25,351	0	90,818	89,400	1,481
2TDN	25,305	0	0	0	0	0	0	25,477	0	50,782	71,700	20,918
2DP	2,985	0	0	0	0	0	0	2,973	0	8,920	7,680	
2DM	62,635	0	0	0	0	0	0	45,860	0	108,495	96,420	12,075
3TDN	59,817	0	3,223	0	0	0	0	0	0	63,040	52,620	
3DP	16,246	0	196	0	0	0	0	0	0	16,441	5,640	
3DM	96,013	0	5,313	0	0	0	0	0	0	101,326	78,600	22,726
4TDN	52,615	0	570	0	0	0	0	0	0	53,185	61,620	8,435
4DP	10,546	0	17	0	0	0	0	0	0	10,563	6,900	
4DM	96,013	0	764	0	0	0	0	0	0	96,777	96,600	177
5TDN	55,443	0	255	5,465	0	0	0	0	0	61,163	48,000	
5DP	9,825	0	8	1,103	0	0	0	0	0	10,936	4,320	
5DM	102,479	0	397	9,936	0	0	0	0	0	112,813	83,340	29,473
6TDN	30,316	0	1,528	0	0	0	0	5,938	0	37,783	36,900	
6DP	3,171	0	51	0	0	0	0	736	0	3,958	3,720	
6DM	62,635	0	2,829	0	0	0	0	10,579	0	76,044	64,140	11,904

[1]The AUM ration is checked against the balanced ration to estimate the nutritional feasibility.

supplied or pounds of dry matter exceeding the stomach capacity. Energy (TDN) is inadequate in periods 1, 2, and 4. Protein is insufficient in period one. The stomach capacity is exceeded in all periods. The pounds of dry matter per head per day by which the AUM solution exceeds the stomach capacity is given in Table XXXV. The AUM solution forces a stocker to consume 4.91 pounds per day more than capacity in period five and as little as .03 pounds in excess in period four.

The AUM nutritional approach may lead to rations that are not physically feasible. However, most uses of the AUM concept in agricultural economics have differed from the comprehensive beef-forage model. Researchers have generally been careful to force some additional protein supplement in the winter periods. The latter is not done in the profit maximizing AUM solution. Similarly, researchers have constructed different beef enterprises for different forage types to take account of quality. This exogenous AUM approach assures neither an optimum ration nor a feasible ration.

The balanced ration beef-forage LP model assures a feasible ration and, given the inclusion of all appropriate activities, also insures a profit maximizing ration. Compared to the traditional AUM procedure this study employs a reverse process. Only after solving the beef-forage LP model can the traditional livestock cost and return activity budget be completed. The profit maximizing ration gives additional information to the farm manager as well as indicating efficient allocation of resources.

TABLE XXXV

ESTIMATED EXCESSIVE DRY MATTER GENERATED BY THE AUM RATION SPECIFICATION OF THE BEEF-FORAGE LP MODEL FOR EASTERN OKLAHOMA

Time Period	Pounds of Excess[1] Dry Matter Per Head Per Day
1	.24
2	2.01
3	3.79
4	.03
5	4.91
6	1.98

[1]Excessive compared to stomach capacity limit used in the balanced ration approach.

Summary

This chapter discusses the problems of determining the ration from the beef-forage model. A trial and error procedure was used to determine the ration for the cow-calf and fall stocker enterprises from the beef-forage model. The livestock enterprise cost and return budget format was revised so the profit maximizing ration can be included. The process of solving the beef-forage model to obtain the ration or amount of feed needed in the enterprise budget is the reverse of normal activity budget building. Usually the process is to state the ration requirements in AUMs, build the activity budgets and use the budget data in linear programming studies. The procedure of this study eliminates the exogenous development of budgets for each feed source for each livestock. The study calculates the optimum ration and livestock within the linear programming model. Determining the rations for the TDN and AUM approaches concludes the chapter. By calculating the DP and DM supplied and required for the TDN and AUM rations a check for feasibility compared to a balanced ration is possible. TDN and AUM do not guarantee a feasible ration. If the coefficients of the balanced ration approach are correct it will always be a feasible ration.

CHAPTER VI

SUMMARY AND IMPLICATIONS FOR FURTHER STUDY

Increases in income to beef production relative to that from other farm products are a signal from the marketing price system. The signal is to adjust resources to expand beef production to meet consumer tastes for red meat. Adjustments in resource use draw heavily upon beef forage farm management decisions. The input data and the results of this study provide management information that is helpful in achieving a profit maximizing beef forage farm organization.

Economic models which provide the logic for production decisions were discussed in a linear programming context. The theoretical conditions for finding the profit maximizing combinations or primary and secondary products, such as pasture and beef, were descirbed. A brief review of beef cattle nutrition and the technical requirement of the model was provided to give insight to the research task.

The Model

A linear programming model constructed within the framework of the Mathematical Programming System (IBM, MPS) can be versatile, adapted to unique situations, and easily modified. The model, as constructed for this study and described in Chapter III, has many uses as well as some limitations.

The model provides answers to questions concerning optimum beef-forage farm organizations in eastern Oklahoma. The land using activities provide nutrients through grazing. The model balances a range ration for the beef systems included in the optimum farm organization. Pasture, hay, and concentrates are used to the best economic advantage for the total farm organization. Cash crops are not considered in this model.

The ration is specified by three alternative methods. The balanced ration approach balances the range ration for the total digestible nutrients, disgetible protein, and dry matter requirements specified within the model. Dry matter is a maximum constraint and total digestible nutrients and digestible protein are minimum requirements. The TDN ration approach specified only that the pounds of TDN required are fulfilled with no consideration of protein or dry matter volume. The AUM ration approach requires feed and grazing to satisfy the animal unit requirements, based on 800 pounds of dry matter per month.

The distribution of resources through a year is accomplished by using six two-month time periods. Nutrient production and consumption are specified for each period. If adequate pasture nutrients are not available in a period, supplemental hay or concentrates can be fed if it is profitable. Analysis by periods allows the model to schedule resource use to meet seasonal requirements.

A land activity allocates one acre of land to fourteen soil productivity levels. Thus, land use reflects soil capabilities in the area. The capital section of the model offers information for planning and evaluating the capital structure of optimum beef farms. Total capital is broken into annual operating capital, nonland capital, and land capital. Capital charges required by the optimum beef-forage organization are calculated for each category of capital.

The grazing and feeding systems used in the optimum farm organization reflect different intensities of land use and management requirements. Capacities (e.g. fencing and facilities) for different types of grazing are generated internally in the model according to the type of system that is optimum for the organization. Annual costs, capital required and labor required are unique to each type of grazing capacity included in the model, either intensive (rotation) or extensive (regular grazing).

Summary and Use of Data and Results

Though forage nutrient yield data are limited, the model shows that such information can be useful to beef-forage farm managers. The use of nutrient data for specifying forage yields enables a range ration to be balanced according to production and use patterns, considering the resource base of the farm. The result is more precise managerial information to beef-forage farm managers.

The research in this study is partly designed to test alternative nutritional measurements. The balanced ration approach includes estimates on the production and consumption of the total digestible nutrients, digestible protein, and dry matter, with dry matter being a maximum (stomach capacity) constraint. The TDN approach uses only the energy row of the balanced nutritional approach, and the other rows are neutralized and have no constraining affect. The nutritional philosophy of the TDN approach is that energy is the most limiting nutrient. Therefore, if the energy level is adequate the animal will make the specified gain. However, the total intake of feed required to provide the energy is not a consideration.

Theoretically, the AUM nutritional approach uses a time dimensioned stocking rate as a nutritional guide. The nutritional philosophy is to place animals on the forage to suit previous observations of stocking rates and beef production. However, all of the needed grazing studies have not been conducted on all the forage possibilities within the study area. The stocking rate also affects the level of gain and, hence, the level of nutrient requirement. When insufficient grazing studies are available, researchers have utilized rules of thumb for estimating AUM's. The AUM coefficients were estimated in the comprehensive beef-forage model by using the assumption that one AUM is equivalent to 800 pounds of dry matter.

Optimum Beef-Forage Forage Organization-Alternative Ration Specifications

An integrated cow-calf and stocker beef organization (217 cows and 986 stockers) was selected by the balanced ration and 141 cows and 998 stockers were selected by the TDN nutritional approaches. However, the AUM approach selected a 2076 head stocker operation as the profit maximizing organization of the beef-forage farm. As the nutritional constraints were released, lower quality forages displaced high quality forages in the optimum forage system. The balanced ration relies heavily upon intensive small grain grazing augmented by lower quality forages and supplemental hay. The TDN approach shifts the forage system away from bermuda and small grains and includes more bermuda-fescue and fescue. The balanced ration has 23 percent of the total acreage in bermuda grass but no bermuda fescue and only seven percent of total acreage in fescue. The TDN approach has seven percent bermuda, 12 percent bermuda-fescue and 14 percent fescue. The AUM optimum forage system is mostly bermuda grass (73 percent of total acres) augmented with native grass and some sorghum-sudan grazing. The percentage of small grain and rye-vetch acres varies from 42 percent for the balanced ration, 38 percent for the TDN ration, to zero for the AUM ration.

Optimum Cow-Calf Organization-Alternative Ration Specifications

When the stocker enterprises were eliminated the three approaches selected the same cow-calf enterprise. The optimum cow-calf enterprise was fall calving cows with an extended weaning period. The optimum cow-calf balanced ration forage system had more acres of small grains and fescue but fewer acres in bermuda grass than the TDN and AUM ration specifications. The balanced ration approach had 314 acres of bermuda; the TDN ration had 378 acres; while the AUM approach had 847 acres of bermuda. Small grain acres dropped from 443 acres to 115 to zero for the respective nutritional approaches for the cow-calf solutions.

Optimum Stocker Organization-Alternative Ration Specifications

The profit maximizing stocker organizations from the three nutritional approaches had the same stocker enterprises but different numbers. The balanced ration solution had 433 animal unit equivalents (AUE), the TDN approach had 434 (AUE), but the AUM nutritional approach had 621 (AUE). The AUM approach had significantly more spring stockers than the other two nutritional approaches. The AUM forage system consisted mainly of bermuda (860 acres) and native grasses. The balanced ration approach for stockers left some acres of native idle because of the high forage quality demanded by the stocker operations. For stocker activities, the three nutritional approaches had significantly different optimum land use plans. Bermuda was required on only 13 percent of the total acreage for the balanced ration, 23 percent for TDN and 72 percent on the AUM appraoch. Native grass percentages varied from 20 percent for the balanced to 25 percent for both the TDN and AUM approaches. Small grains made up 54 percent, 39 percent, and zero for the respective nutritional concepts.

Complementary Relationships

A complementary relationship occurs between enterprises because forage production is not exactly distributed to fit a particular livestock enterprise. The fall stockers use small grains grazing in periods six through two but small grain forage is also produced in periods five and three. The forage in periods five and three is available to other beef enterprises at no additional cost to the beef-forage firm. The profit maximizing solution had multiple livestock enterprises that capitalized on the complementary relationships. Therefore, separate beef enterprise solutions could not be aggregated to yield the same organization as the multiple solution. The aggregated separate situations required more acres than did the multiple integrated solution, showing that complementary economies were present in the profit maximizing solution.

Empirical Rations

The ration delineation procedure used the whole farm optimum organization and allocated each forage to a beef enterprise in such a manner that nutritional feasibility was maintained. The total TDN and DP is sufficient for each livestock enterprise for each period without exceeding the dry matter or stomach capacity of the respective enterprise. For example, the profit maximizing cow-calf ration consists of all of the available bermuda grass as well as 5.33 pounds of grain sorghum per cow per day in period one. In period two, rye-vetch provides more nutrients than any other source. The cows also graze bermuda and share grazing of fescue and small grain with the competing stocker enterprise.

In periods 3, 4 and 5 with no steers on the farm, the cow-calf herd consumes all of the production of the optimum forage system. Bermuda provides the highest level of nutrients in those periods. The seasonal decline in bermuda in period 4 requires feeding 1.14 pounds of grain sorghum per cow per day.

The cow enterprise uses 100 percent of the bermuda, native and rye-vetch production for period 6. In addition, small grain grazing produces a large proportion of the cow requirements in period 6.

The profit maximizing balanced ration for the stocker activity in period 1 is composed of nutrients from hay and grain augmented with the cool season annual grasses. The stockers receive 45 percent of the required TDN from 8.18 pounds of dry matter of hay per head per day. Grain provides 29 percent of the TDN requirement. In period 2, the steers graze small grains and some fescue. The steers utilize 85.9 percent of the available small grain and 100 percent of the fescue produced in period 6 and receive some hay.

Cost and Return Enterprise Budgets

The nutritionally balanced profit mazimizing rations are incorporated into a revised cost and return enterprise budget format. The exact profit maximizing balanced ration provides information to aid in managing the beef-forage farm. Including the capital requirements and annual costs of the feeding system means the budget should more accurately reflect the cost of production. The improved accuracy should enable more efficient decisions by beef-forage farm managers using the budget. Including a more detailed analysis of labor requirements should help managers make decisions concerning hiring seasonal labor. Similarly, incorporating the ration should help managers in making decisions mesh the forage system to the nutritional requirements of the beef enterprise.

TDN and AUM Rations

A guideline of utilizing high quality forages by steers and lower quality by cows helped in determining the TDN profit maximizing ration. The calculated TDN rations were used to estimate nutritional feasibility. The TDN rations satisfied the protein requirements of both cow-calf and stocker activities, but the dry matter rows or stomach capacity was exceeded in periods 1, 2, 4 and 6. In essence, to obtain adequate least cost energy the TDN approach forced the livestock activities to consume more than the stomach could hold. In period 1, the steers' stomach capacity was exceeded by 1.95 pounds of dry matter per head per day. The cows' stomach capacity was exceeded by 4.08 pounds per head per day in the same time period.

In a similar feasibility test, the AUM ration exceeded the spring stockers capacity by 4.91 pounds per head per day in period 5 and the stockers capacity by 2.01 pounds per head per day, assuming the coefficients of the balanced ration model.

Ration Specification Conclusions

Deciding which ration specification (balanced, TDN or AUM) should be used in beef-forage research is a complex problem. The specification that will accurately supply information depends upon the use of the data. For the comprehensive beef-forage model objectives, the nutritionally balanced ration provides information to managers and researchers heretofore not utilized.

In determining the profit maximizing organization from varied beef enterprises (cows vs. stockers) and from various qualities of forage activities, the balanced ration specification is needed to get accurate answers to normative organization questions. In determining what to produce to maximize profits the TDN and AUM approaches are not sufficient in whole farm analysis. The widely different optimum beef and forage organizations from the three nutritional approaches (Chapter IV) indicates inconsistency in approaches. The AUM approach selected stocker livestock enterprises, while the balanced and TDN schemes combined cow-calf and stockers in the respective profit maximizing beef organization. Similarly, the optimum forage system varied from relying heavily on small grain grazing for the balanced and TDN rations to all bermuda and native grasses in the AUM solution.

The standard technique for computing the AUM requirement of stockers was shown to favor stockers compared to cows. Beef TDN requirements reported by the National Research Council were used to show that the AUM rule of thumb favors stockers by understating their requirement.

In the past the TDN and AUM procedure was used in preparing cost and returns livestock budgets for different forages or grazing patterns (i.e., seasonal, deferred, etc.). Those budgets usually included hay and cake if deemed to be insufficient in the specific grazing forage. Because of the high quality nutrient requirement of stocker enterprises, they are not feasible on most perennial grasses except at extremely low rates of gain. The forage quality is too low. Most uses of AUM and TDN in studies do not accurately reflect the nutrient requirements; therefore, nutritionally infeasible land use organizations may have been recommended.

The beef-forage organizations obtained in this study are valid only for the methods used. AUM's are frequently based on stocking rate studies, if available. The AUM ration would include cake and hay as deemed necessary by the researcher. The stocker ration selected by the AUM approach would not be considered feasible by most research personnel. Other ways of defining AUMs need to be tested against the balanced ration. The AUM and TDN approaches of this study shows what could happen if AUMs are misused.

The AUM concept is widely used in constructing cost and return budgets. The intent of this study was to bring some of feedlot nutrition precision to grazing livestock enterprises. The balanced ration utilizes the nutritional building blocks of energy and protein to more accurately measure input-output coefficients and uses dry matter as an upper constraint to insure quality feasibility of the profit maximizing ration. The balanced ration livestock cost and returns budgets also give detailed information to managers on the optimum grazing system. The ration shows the time distribution of the optimum grazing system, as well as the relative nutritional importance of each feed source. The ration section of the activity budget developed can be utilized by farm managers to calculate alternative forage organizations which keep nutrition requirements in balance. Ration precision is enhanced in the balanced ration approach because of insuring nutritional feasibility (quality) as well as measuring the forage output more nearly in the units that cattle nutrition requirements are stated.

A forage transfer model developed as an alternate to the balanced ration model appears to solve a model configuration problem of the balanced ration beef-forage linear programming model. It also provides additional managerial information. The forage transfer model not only obtains optimum livestock organization and optimum forage organization but also the optimum grazing and feeding system. The optimum time of using the forage mix is available from the forage transfer model. However, more research work is needed to insure realistic forage systems.

Recommendations for Further Study

More accurate measurement of nutrient yield data of forages would provide greater accuracy in the solutions obtained from the model for balancing range rations. Nutrient yield data are not readily available.

Research to find varieties and even new species with higher quality might do more to enhance the profitability than further research on high dry matter yield. Grasses that provide high dry matter yields and respond to high fertility level are available to the farm manager. However, the quality or proportion of energy to dry matter is too low for use by some beef enterprises in grazing situations. Dry matter production is of little consequence if consumption or energy intake is too low to maintain economical rates of gain. The configuration of the forage transfer balanced ration model is such that it would be easy to measure the economic impact of improved varieties that raise or alter the time distribution of energy or protein quality.

The utilization coefficients for converting from clipping to grazing yields needs further study. Insufficient study of the forage consumption might explain why so little use is made of the clipping approach to measure forage yield. Clipping forage production eliminates variation between experiments that comes from the cattle consuming the forages. The ability to reduce experimental variation should encourage chemical composition tests to more accurately measure nutrient yield.

The effect of combining feedstuffs in the ration needs to be determined. Nutrient composition tables are estimated using only the feedstuff in question. However, most practical rations are a combination of feedstuffs. The supplemental feeding of grain on pasture reportedly does not have the same relative gain response as grain fed in a feed lot. The reason for the decrease in the feed value of grain fed with grass needs to be determined and quantitative estimates made, to provide additional accuracy in beef-forage research.

The nutrient requirement source [20] needs refinements for increased accuracy. The requirements need to be adjusted for the local environment. The environment in Oklahoma may significantly differ from the setting for research used in estimating the beef cattle requirements of the NRC. Allowance for work performed by the beef animal during grazing needs included. The act of grazing by the animals requires work that is not necessary in a feedlot, but no adjustment in the nutrient requirements is made.

Economies of size that may occur in the beef production industry need additional study. Advantages for stockers or cows will affect the beef enterprise choice and hence the forage system. The economies might alter the most profitable whole farm organization but probably have little effect on the optimum range ration once the beef enterprises are determined.

The effect of risk and uncertainty of input-output coefficients and price variability needs additional research efforts. Imperfect knowledge situations in research models might help explain current resource use in the study area.

An acceptable beef-forage model needs to be incorporated into cooperative extension programs in farm management. The LP Farm[1] program used by individual farm managers could be altered to bring the nutritional sophistication and accuracy to their particular beef-forage farm. The only information change required from the present LP Farm input data would be to estimate the production of the possible forages in terms of dry matter yield. The nutrient percentages of the forages could be stored inside the LP matrix. The major changes in LP Farm would be an addition of forage production rows, converting AUM rows into a balanced nutrient set and adding new transfer activities to allocate forage production throughout the year.

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[1]LP Farm is a linear programming system available through the Oklahoma State University Extension Service, to Oklahoma farmers and ranchers.

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APPENDIX

TABLE XXXVI

YIELD ADJUSTMENT INDEXES FOR SOIL PRODUCTIVITY IN EASTERN OKLAHOMA[1] [18]

Soil	Percent
S_a	126
S_b	100
S_c	81
S_d	67
L_a	156
L_b	133
L_c	100
L_d	78
C_1	148
C_2	125
C_3	93
C_4	55
B_1	185
B_2	103

[1]For yields on soil used in the beef-forage model were adjusted by the percentages indicated. For example, Bermuda yield on L_d is 78 percent of L_c yield.

TABLE XXVII

ASSUMED DISTRIBUTION OF HOURS OF OPERATOR LABOR AVAILABLE BY CALENDER PERIODS FOR BEEF FARM OPERATORS IN EASTERN OKLAHOMA[1]

Period	Hours Available
1	421.5
2	434.5
3	434.5
4	341.0[2]
5	434.5
6	434.5

[1]Data are from the Procedurial Guide for Regional Study, pp. 5-6.

[2]A two week vacation was assumed.

TABLE XXXVIII

ASSUMED INVESTMENT AND COST OF EQUIPMENT NECESSARY FOR A 75 COW OR 140 STOCKER ENTERPRISE IN EASTERN OKLAHOMA

Item	Years of Life	Total Cost	Average Investment	Annual Cost
Corrals and Working Pens	10	$400	$200	$40
Bunk Feeders	10	900	450	70
Water Facilities	20	3,000	1,500	150
Salt and Mineral Feeders	10	200	100	20
Total		$4,500	$2,250	$300
$ per Cow		$60.00	$30.00[1]	$4.00[2]
$ per Steer		32.14	16.07[3]	2.14[4]

[1]This volume is included in the capital requirements of the cow-calf activities.

[2]This value is included in the objective function of the beef-forage model as part of the cost for the cow activity.

[3]Stocker equipment is a separate activity in the model. The capital requirement is included in this activity.

[4]This cost of providing one unit of stocker equipment is included in the separate stocker activity in the model.

TABLE XXXIX

ESTIMATED DIRECT LABOR REQUIREMENTS PER TIME PERIOD PER STOCKER BY OPERATION FOR BEEF-FORAGE FARM IN EASTERN OKLAHOMA

Operation	Hours per Stocker
Purchasing	.20
Other[1]	.36
Spray[2]	.08
Receiving[3]	.32
Selling	.24

[1]Normal obersvation of the condition of cattle is included in this operation.

[2]Cattle are assumed to be sprayed in March, June and July.

[3]Receiving labor includes castoration, vaccination and branding plus careful observation for shipping fever or other illnesses.

TABLE XL

ESTIMATED DIRECT LABOR REQUIREMENTS BY OPERATION[1] PER BEEF FOR A BEEF-FORAGE FARM IN EASTERN OKLAHOMA

Operations	Periods					
	1	2	3	4	5	6
			-Hours-			
Dry Cow Observation	.72	.80	.56	.56	.48	.72
Calving	1.58	1.58	1.58	1.58	1.58	1.58
Breeding	.10	.10	.10	.10	.10	.10
Pre-calf	.31	.31	.31	.31	.31	.31
Calf Care	.22	.22	.20	.20	.18	.18

[1]Labor estimates were derived by consultation with Agricultural Experiment Station personnel and cost-finder records.

[2]The labor requirements are valid only for the periods the operations are undertaken for each activity. A cow activity calving in February would require 1.58 hours in period no calving labor any other time period.

TABLE XLI

ESTIMATED CONSTRUCTION AND ANNUAL COSTS FOR SIX MILES OF FOUR STRAND BARB WIRE FENCE FOR A BEEF FORAGE FARM IN EASTERN OKLAHOMA

Item	Unit	Quantity	Price	Cost
Six Miles of Fence				
Posts	No	1920	.596	1144.32
Wire	Roll[1]	96	10.10	969.60
Staples	Lbs.[2]	90	.20	18.00
Labor[3]	Hours	480	1.75	840.00
Sub Total of Specified Costs				2971.92
Corner Assembly				
Materials	Number	6	4.65	27.90
Labor	Hours	11.5	1.75	19.95
Sub Total of Specified Costs				47.85
Steel Gate	Each	2	40.00	80.00
Total - Construction Cost				3100.77
Annual Cost[4]				103.30
Average Investment				1550.38

[1]This is an 80 rod roll of two barb wire.

[2]90 medium staples are assumed to be one pound.

[3]The setting line posts was estimated to take ten minutes per post; the time taken to stretch and nail four wires was five minutes per rod.

[4]A 30 year life with zero salvage value was assumed.

TABLE XLII

ESTIMATED ANNUAL COST FOR FENCING ROTATIONAL ACRES[1] FOR A BEEF FORAGE FARM IN EASTERN OKLAHOMA

Item	Unit	Quantity	Price	Cost	Annual Charge
Electric Fencer	each	1	23.00	23.00	
Temporary Fencing Material					
Posts	number	160	1.11	177.60	
Wire	roll	2	10.10	20.20	
Total Specified Cost				220.80	7.36
Depreciation for Permanent Fence[2]					56.52
Labor	hour	12.65	1.75	22.14	
Average Investment Permanent Fence					77.52
Average Investment Temporary Fencing[4]					170.40
Total Average Investment					885.60

[1]The budget was estimated for 200 acres (one quarter section plus 40 acres with one corss fence in the quarter.

[2]The border fence contained three miles of permanent (½ of fence construction budget).

[3]The cost of labor was calculated inside the LP model.

[4]Temporary costs includes electric fencer and fence material.

TABLE XLIII

ESTIMATED LABOR REQUIREMENTS AND VARIABLE COSTS ASSOCIATED WITH EXTENSIVE GRAZING AND ROTATIONAL GRAZING ACTIVITIES BY OPERATION FOR A BEEF-FORAGE FARM IN EASTERN OKLAHOMA

	Hour/Year[1]	Hour/Period[1]	Hour/Acre/ Period[2]	Percent Machine Use	Hours Used Per Acre	Machine Cost Period Acre[3]
Extensive Grazing for 1000 acres						
Fence Repair	25.3					
Observe Grass		2	.002	75	.0015	.0006
Total					.0015	.0006
Rotational Grazing for 200 acres						
Fence Repair	12.65					
Moving Fences		8	.04	50	.02	.0078
Observe Grass		4	.03	75	.015	.0058
Move Cattle		4				
Total					.035	.0136

[1]Consultation with Agriculture Experiment Station personnel.

[2]1000 acres were used for the extensive grazing and 200 acres for the rotational grazing in calculating costs.

[3]The machine cost (pickup) is 39¢ per hour for fuel, etc., excluding labor cost which is determined within the LP model.

TABLE XLIV

ESTIMATED LABOR REQUIREMENTS AND VARIABLE COSTS ASSOCIATED WITH FEEDING HAY, PELLETS, OR CONCENTRATES FOR A BEEF-FORAGE FARM IN EASTERN OKLAHOMA

	Machine[1] Hours/ Day	Cwt./[2] Hour	Machine[3] Cost/Cwt. @ 39/hr.	Forage[4] Charge	Preparation[5] Cost/ Cwt.	Cost[6] Cwt.
Feeding Hay	1.5	.075	.0292	.0368		.066
Feeding Concentrate	1.35	.33	.0526		.275	.328
Feeding Pellets	.99	.135	.1287			.129

[1]Estimates were derived from consultations with agricultural experts assuming 100 cows.

[2]Assuming a total of one ton of hay, 1,000 pounds of grain or 300 pounds of cake fed per day is the rate of feeding per hour.

[3]The cost of operating a pickup is 39¢ per hour.

[4]This is the depreciation cost per cwt. for a hay barn.

[5]The assumed costs of grinding, mixing and grain delivery.

[6]The cost includes labor cost which is determined within the LP model.

TABLE XLV

ESTIMATES OVERHEAD INVESTMENT AND EXPENSES FOR A BEEF-FORAGE FARM IN EASTERN OKLAHOMA

Item	Life	New Investment	Annual Cost
Utility Shed	10	$ 500	$ 50
Shop Tools	5	400	80
Pick-up	3	3,000	650[1]
Telephone			70
Insurance			145
Bookeeping and Tax Service			100
Utilities			120
Total		$3,900	$1,215

[1]The annual cost includes $500 depreciation and $150 for repairs.

VITA

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Candidate for the Degree of

Doctor of Philosophy

Thesis: A LINEAR PROGRAMMING DERIVATION OF OPTIMUM RANGE RATIONS FROM ALTERNATIVE NUTRITIVE SPECIFICATIONS IN A WHOLE BEEF FARM FRAMEWORK

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