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An Analysis of a Crop-Forage-Livestock System On a Representative Farm in Southeast Kansas Using Linear Programming

by

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Major Professor

I stop and look around me
To see just where I am
Realize that where that is
Depends on where I've been

Teachers, friends, and family
Combined through time and place
To change the world around me
Directions that I face

A long or short encounter
Chance meeting or by fate
It's to those who've shared my path
This work I dedicate

Steve Hildebrand

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Chapter I

INTRODUCTION

Sixty-five percent of the farms in Kansas have a beef enterprise, providing 47.1 percent of the 1982 cash receipts for all Kansas farms (Kansas Farm Facts 1982). Many of these farms do not specialize in beef or crop production but instead combine beef and crop enterprises.

When enterprises are combined which are related in terms of resource use the interrelationship among them affects enterprise selection and resource allocation. The farm manager faces the problem of selecting crop and livestock enterprise combinations that provide an efficient use of resources and a reasonable return on his limited resources.

RELATIONSHIPS BETWEEN ENTERPRISES

A farm manager of a multiproduct farm must be aware of economies to be gained through combining enterprises which can lead to more efficient resource use. Relationships between enterprises must be evaluated and the negative aspects of combining enterprises must be weighed against the benefits.

Various crop and livestock enterprises use different combinations of land, labor and capital. The relationship between enterprises with respect to a single resource can be complementary, supplementary or competitive.

> "The art of farm management centers around a knowledge of the competitive, complementary, and supplementary relationships among farm enterprises. The farm manager tries to combine enterprises to take maximum advantage of supplementary and complementary relationships" (Doll, Orazem, p. 92).

The Complementary Relationship

Three concepts or ideas usually are offered as giving rise to a complementary relationship between enterprises: "1) one production process uses as an input a by-product of another production process, 2) one process uses quantities of a factor that are "surplus" to another, or 3) technical interaction (production function shifts) occurs" (Beattie, Thompson, Boehlje, pp. 161-165).

Complementarity between the beef and the crop enterprises is one possible reason that these enterprises are frequently combined. The production of both wheat and grain sorghum produces the joint products of grain and winter pasture. The beef enterprise converts the winter pasture from crop production, which otherwise is useless, into a high quality product. When crops are produced, winter pasture from these crops is available for the production of beef. Besides providing a low cost feed, winter pasture is available during time periods when other grazed forages are unavailable.

The Supplementary Relationship

Another reason for the frequent combination of the beef enterprise and the crop enterprise is that there can be a supplementary relationship between the beef enterprise and the crop enterprise. That is, inputs such as labor, management, equipment, and infrastructure can often be used by both enterprises without having a negative effect on either one of the enterprises.

Labor often is a "lumpy" input in that it must be hired on a yearly basis. Operator labor also is often available throughout the year. The beef enterprise can be organized to use labor during periods when the crop enterprise does not require labor. Daily work can be organized to accomplish labor intensive chores for the beef enterprise such as weaning, castrating, vaccinating, branding, etc., at a time when field work cannot be accomplished.

Equipment that is primarily used for the crop enterprise can in some cases be used for beef production without reducing availability of the equipment for its primary purpose. Trucks which haul grain can be equipped to haul cattle, water and feed. Tractors can be equipped to feed cattle. Pickup trucks can be used in both enterprises.

Buildings, electrical outlets, water pumps, roads, windbreaks and storage facilities are examples of infrastructure which can be used by both a beef enterprise and a crop enterprise without reducing the productivity of the resources for either enterprise.

The Competitive Relationship

The beef enterprise and the crop enterprise exhibit competitive relationships with regard to some inputs. Although the relationship can be supplementary with respect to labor at certain times, the enterprises may require the labor at the same time and the relationship will become competitive for those hours. The relationship might become competitive if capital is limited and investing in one enterprise decreases the production of the other enterprise. Grain production and beef production can be competitive with respect to cropland if cropland is diverted from use in the production of grain to the production of forage crops needed in the production of beef.

If two enterprises use the same input at the same time the relationship between the enterprises will become competitive if the enterprises are expanded to a high enough level.

The farm manager must recognize when efficiency can be increased by combining enterprises. More efficient use of inputs through combined production is a manifestation of complementary and/or supplementary conditions which are not totally offset by competitive aspects of the relationship.

BUSINESS ENVIRONMENT

There are many variables which form the business environment on farms which produce beef and crops.

Variables which form the business environment include: 1) interest rates, 2) rate of inflation, 3) agricultural policy, 4) developed markets, 5) the prices of the final products, 6) relationships among enterprises, 7) the prices of inputs, 8) price trends and cycles, 9) tax considerations, 10) risk and uncertainty, and 11) governmental regulations.

The role of farm management is to develop a capacity to assess the business environment in order to determine and implement the most advantageous reaction to it. The business environment is not under the direct control of farm management. Management decisions in reaction to the business environment can only be through the manipulation of variables which are under its control. What to produce, how to produce and how much to produce are determined by manipulation of the variables of: 1) enterprise selection, 2) resource allocation, 3) technology selection, and 4) resource acquisition. The manager must select enterprises from the feasible production opportunity set and determine how to allocate scarce resources among them. The best suited technology must be selected from alternative technologies available. Available resources must be evaluated in terms of productivity, price, and value of product in order to determine which resources to acquire and how much.

ENTERPRISE SELECTION

Production possibilities on a farm which produces beef and crops are limited in large part by climatic conditions which exist in the area where the farm is located. For the purpose of this research, a farm situation in the southeast region of Kansas was chosen. The production possibilities may be further limited by the farm manager. Consideration must be given to the business environment, productivity and quantity of fixed resources, including land, labor and specialized equipment. The experience of the farm operator with specific enterprises and the goals of farm management are also important considerations.

Land can be broadly classified into three categories, depending on the land use possibilities. These are cropland, native rangeland and improved pastureland.

The characteristics that distinguish cropland from other land resources are gentle relief and adequate top soil. Alternative grain and forage crop possibilities in Southeast Kansas include wheat, grain sorghum, soybeans, alfalfa, sudangrass, corn, oats, barley, smooth brome, tall fescue and many other cultivars suited to a temperate climate.

Native tallgrass rangeland is generally erodable, having shallow top soils and rocky outcroppings, and as such it cannot be tilled. Portions of this land can be hayed, but the majority is suitable only for pasture.

Improved pastureland is often tillable. Perennial pasture grasses such as brome can be planted on cropland; however, perennial pasture grasses are often used on marginal soils which have unstable top soil and must be planted to perennial pasture grasses to minimize erosion.

Crop Enterprise

The grain and forage crops have labor requirements which are concentrated in a seven month period, April through October. These enterprises require cropland, labor, capital and specialized equipment. The labor requirement for the crop enterprise is not constant throughout the production period, but is concentrated in the planting and harvesting phases. Capital outlay to cover variable costs is greatest at planting and harvest. Specialized equipment is required for field operations. Alternatives to owning specialized equipment include leasing, renting and contracting custom operators.

The timing of field operations is of critical importance. The farm manager must make a plan that can be accomplished without costly delays. Field conditions determine when field operations can be accomplished and their accomplishment is dependent on the technology used and the man-hours available during critical periods.

Beef Enterprise

There are various alternative beef enterprises characterized by type of cattle and system of management. Calves go through three stages of production before slaughter and the farm manager may choose to be involved in the entire production process or only a portion of the process.

The three stages of production are birth to weaning stage (cow/calf enterprise), stocker stage, and feeder stage. Calves can be born any time of the year. Feeder or stocker cattle can be purchased and sold at any date and at a range of weight classes.

COW/CALF

The beef cow is usually bred to calve in the spring or in the fall. Requirements of the cow/calf enterprise include feed, labor, capital and specialized equipment. The feed requirement for the beef cow changes throughout the yearly production cycle and is dependent on the stage of gestation. The beef cow can be maintained on low quality roughage if supplements of essential elements in the diet are provided.

Labor requirements of the beef cow are greatest during the calving season and during the winter months when the beef cow must be fed stored forages. During the summer months when the cows are on pasture the labor requirement is low. (This corresponds to the period of high labor requirement for the crop enterprise.)

Capital required to purchase the cow herd is substantial. There are several ways of acquiring a cow herd. These include the direct purchase of cows, the purchase of heifers, and an increase in an already existing herd by keeping more heifer calves than are required to maintain the size of the herd.

Specialized equipment is needed by the beef enterprise. Much of this equipment needs to be readily accessible and must be owned; however, some equipment such as cattle hauling equipment can be contracted.

STOCKER

The stocker phase can be divided into three systems: wintering, grazing on pasture, and backgrounding in the drylot. Spring calves which will be grazed on pasture are wintered-then-grazed, or grazed only, and then transferred as feeders to the feedlot in the late summer or fall to be finished. When backgrounded in the drylot the calves are fed a high roughage ration which permits growth but not fattening.

In the stocker stage from weaning to around 800 pounds, cattle have the most efficient feed conversion. These cattle are well adapted to the utilization of high roughage rations and winter pasture from crop production. The enterprise is more flexible than the cow/calf enterprise in that numbers can be easily changed to fit feed and labor supplies. Feedlot owners/managers prefer backgrounded cattle because they have overcome the stress of weaning and are ready to be placed on high energy rations for finishing.

The feed requirement of stocker steers and heifers is the major expense of the backgrounding enterprise.

The quality of feed is a major factor in the rate of gain. Higher rates of gain are advantageous because the maintenance requirement is the same regardless of the daily gain. High rates of gain usually indicate that the animal is fattening. If cattle get too fleshy as stockers, they may reach market finish before they attain desirable market weight and will tend to gain more slowly than desirable during the feedlot finishing period. Although lightweight (400-600 pounds) calves gain more efficiently than heavier calves (600-800 pounds) due to a lower maintenance requirement, light calves require a better quality feed to maintain the same average daily gain as heavier stockers. Stockers should be purchased at the age and weight suitable to make best use of the feed supply which is available (Ensminger, pp. 1229-1237).

The labor requirement depends on the type of program and the level of mechanization. Drylot feeding requires more labor because feeding stored forages requires time. Grazing situations require less labor. Labor requirements also depend on the number of animals handled. Labor requirements per animal decrease as the number of animals handled increases.

Capital is required to cover variable and fixed costs of production and therefore, beef enterprises compete with crop enterprises. A large portion of the capital requirement for a stocker enterprise is used for purchasing the animal and for feed. If backgrounding is done in a drylot then considerable fixed capital expense is required for pens, roads, feed storage facilities and other infrastructure.

Wintering

Wintering of stocker steers and heifers on pasture in Kansas usually includes the use of crop byproducts including wheat pasture, alfalfa stubble, grain sorghum stubble or deferred pasture grasses. Stored forages are fed during times when these forage sources are not available. It is common for stocker cattle to be "roughed through" the winter as cheaply as possible, with modest average daily gains. Animals managed in this way exhibit the phenomena of compensatory growth. That is, these animals, when turned to lush spring pasture or finished on a high energy ration, gain faster and more efficiently than cattle which were fed more liberally during the wintering period (Ensminger, p. 1236). The wintering program begins in the fall and usually ends when spring grass becomes available.

Grazing on Pasture

Grazing on cool and warm season pasture can be a continuation of the wintering phase. Weaned calves born in the fall can also be grazed on cool and warm season pasture. Grazing of native range in Kansas begins in May and ends in late September or October. Stocker steers and heifers generally begin the program at a weight in the 400 to 600 pound range and have an ending weight in the 600 to 800 pound range.

Backgrounding in the Drylot

Backgrounding in a drylot situation can start any time. Often backgrounding in a drylot is part of the wintering stage. In January and February, when forage from grazing is unavailable, a drylot system can be used. The advantages of the drylot system are that the cattle can be located close to the feed source in a well protected area where they are easily monitored. Stored forages are fed during this time. The stored forages include summer annual silage, alfalfa hay, brome hay and prairie hay.

FEEDERS

Feeder cattle are steers and heifers which have reached sufficient weight and/or finish to be placed on high energy rations for finishing and slaughtering. The finishing of cattle is the laying on of fat. Beef consumers desire meat which is sufficiently marbled to have qualities of flavor and tenderness. Feeder cattle are generally in the 600 to 800 pound range although the dividing line between stockers and feeders is not always easily identifiable.

Feeder cattle in Kansas are generally finished for market in feedlots. A feedlot is a confinement system where the cattle are kept in a drylot situation and fed high energy rations.

RESOURCE ALLOCATION

The farm manager must decide how to best allocate fixed and variable resources among alternative enterprises. When resources are allocated to the alternative enterprises in such a way as to maximize profit, the questions of what to produce and how much to produce will be determined.

Resources are termed fixed or variable depending on the planning horizon considered. In the very long run all resources are variable whereas in the very short run all resources are fixed. When a resource is fixed, the amount available for use cannot be changed within the planning horizon. When a resource is variable, the amount available for use can be changed within the planning horizon.

Resources that are considered fixed to the farm are of two types, those which can be allocated among enterprises and those inputs which can be used in only one enterprise. The value or price of fixed resources is not considered when allocating fixed resources. If the return from the use of the resource is positive then the fixed resource is used. Alternative uses of fixed resources need to be evaluated in light of the productivity of the input in each alternative and the value of the output.

Variable resources are allocated according to how much they increase productivity, the value of the product, and the cost of the resource. Therefore, the purchase price and the price of the output are important considerations in the allocation of variable resources.

TECHNOLOGY SELECTION

Technology is the method and equipment used in the production of a product. The farm manager determines the best technology to use based on the cost of acquiring the technology and the ability of the technology to produce revenue. Technologies to produce crops and livestock must be combined and compatibility between them is important. In addition, existing technologies often cannot be replaced with a new technology without an increase in costs. Therefore, the decision to acquire new technology is often a long-term decision. The technology used determines the level and type of inputs required for production.

Crop production technology includes specialized equipment, seeds, herbicides, pesticides, fertilizers, storage and handling facilities, and methods of crop production. Beef production technology includes specialized equipment, breeding systems, handling facilities, growth stimulants, feed additives, identification systems, vaccinations and medicines, and methods of production.

RESOURCE ACQUISITION

Resources used as inputs in the production process can be acquired in numerous ways including renting, purchasing, inheriting, borrowing and leasing. The determination of what resources to acquire and how much to use is dependent on the productivity of the resource, the cost of the resource, and the capital available.

FORAGE MANAGEMENT AND UTILIZATION

Forage produced must be grazed or stored or it goes to waste. Therefore, production, storage and utilization decisions are inherently linked. The decisions regarding type and quantity of beef animals to utilize the forage, and the type and quantity of forage to meet the needs of the beef herd are decisions which ideally are made together.

Each forage species exibits a unique production pattern during its yearly cycle. The feed requirement of beef cattle also changes over time. The manager must develop a grazing system which uses one or more forage sources in sequence by the type and quantity of beef cattle chosen.

Pastures must be monitored to insure that under- or over-grazing is not occurring. Monitoring is necessary because yearly variations in weather conditions can change the capacity of the forage to produce. Key variables which managers must understand are plant vigor, reproduction, and changes of composition of forage species with maturity.

Once the optimum number and type of cattle have been determined and the type and quantity of forages are selected, the grazing system is defined. The remaining problem is determining the inventory of stored forages required. The management of forage inventories is basically a problem of coping with a large diversity of factors external and internal to the farm. Fluctuations occur in the supply of feed from grazed forages which are seasonal. Feed requirements need to be met every day and during these seasonal fluctuations in grazed forages, inventories of forages must be kept to meet feed requirements. In addition to meeting anticipated needs, inventories are kept for safety reasons to provide a buffer against inclement weather which affects feed requirements and forage availability.

The alternative to maintaining an inventory is to purchase forage as needed. This has the advantage of reducing the interest cost of maintaining the inventory and reducing the investment in storage facilities.

When the investment in inventory is not made, the capital that would have been used to purchase it can be put to alternative uses. Maintaining an inventory has the advantages of fixing the price and assuring availability.

The disadvantage of not maintaining inventories is possible unavailability of forage due to shortage or possible severe weather conditions which inhibit transportation. Disadvantages of maintaining an inventory of forage include the possibility of losses due to fire, required investments in storage facilities and the opportunity cost of forgone interest on capital invested in the purchasing or production of the inventory.

Determining the optimum stored forage inventory is essential in a successful forage management system. Excessive inventories are expensive and can lead to unprofitability of the beef enterprise. Failure to maintain sufficient inventories can also be costly. The inventory investment needed can be determined by identifing the quantity of stored forage required for a safety stock and the quantity required for the anticipated stock.

RESEARCH OBJECTIVES

The objective of this research was to develop a linear programming model that could be used as a decision tool for a representative farm in the southeast region of Kansas which produces both beef and crops. The model will: 1) maximize returns to the fixed resources, 2) select type and size of enterprises, 3) allocate resources among enterprises, and 4) determine the forage management and use.

The beef enterprises considered in this analysis are a spring calving cow herd (the calves are weaned November first) and stocker steers and heifers. The stockers system is a winter-then-graze system. The wintering phase begins November first and ends May first and the summer grazing period begins May first and ends October first. The crop enterprises considered are grain sorghum, wheat, soybeans, alfalfa and sudangrass. Forage sources are grain sorghum stubble, winter wheat pasture, sudangrass, brome pasture, native tallgrass range, prairie hay, brome hay, alfalfa hay and grain sorghum silage. An estimate is made of the inventories of stored forage required.

This study focuses on the benefits which arise from using winter wheat pasture and grain sorghum stubble in the production of beef. Four farm situations are compared. A description of the four situations and the relationships among the four situations is as follows:

Situation one: Determines the optimal combination of enterprises assuming winter pasture is available.

Situation two: Determines the optimal combinations of enterprises assuming winter pasture is not available.

Situation three: Takes the results of situation one as given and availability of winter pasture is removed from the model.

Situation four: Takes results of situation two as given and availability of winter pasture is added to the model.

Results from situation one and two will estimate the effect of having winter pasture available on the selection of enterprises. Comparing situation one and three estimates the added costs from not having winter pasture comparing situation two and four estimate the increase in benefits from adding winter pasture.

Chapter II

REVIEW OF LITERATURE

Research that has modeled alternative crop and livestock enterprise combinations has taken two directions. The first direction is the exploration of the relationship between livestock enterprises and the three factors of production, land, labor, and capital, with the assumption that these resources have no alternative use other than as inputs into the beef enterprise. Beef cattle are the only products that are sold. The second methodology integrates the livestock and the crop enterprises. In this methodology land, labor, and capital have alternative uses. Products from both the crop and livestock enterperises can be sold.

BEEF ENTERPRISE MODELS

A linear programming model by Miller, Brinks and Southerland was developed to determine management policy for a yearly planning horizon. The model structure was determined from an analysis of a particular ranch operation and included all management options ordinarily found in a mountain meadow beef production system.

After the optimal management plan was determined, the effects of uncertainty of some of the coefficients researchers considered most important were explored. The areas which were explored were the effects of varying hay prices, the effects of required dry matter feeding at various levels, and the effects of varying cattle prices. In their model there was no provision for crops or the utilization of winter pasture from crop production. Also, the model did not include the alternative for the purchasing or sale of stored forage. Alternative grazing systems were determined prior to optimization.

A study by Halbrook, Denton, Spooner and Ray analyzed alternative forage production and utilization plans for the Arkansas River Valley area of Arkansas. The objectives were to determine the least-cost method of producing forage crops for a beef-cow enterprise consistent with different prices for the same quality of land, and to select from the least-cost forage plans the ones that would be most profitable for a given level of gross returns per cow.

Linear programming was used to determine the farm organization that would represent least-cost production of forages for use by a beef cow herd at specific land prices.

Of major interest in the Halbrook study was how non-land inputs could substitute for land, and the organizational changes that take place with more intensive use of land. The different land costs used in the model were included as costs in the farm plans presented. The alternative plans were compared on the basis of acres of land and of non-land feed costs. The major input substitution observed was that of fertilizer substituting for land as land became more expensive. During this initial stage of program development four plans were developed, each for a different land value.

Monthly feed requirements for a 100 cow herd were entered into the programming model as the minimum feed that must be produced. Different forage production and/or utilization alternatives were included as ways of meeting the feed requirements of the beef cow herd. These alternatives included different varieties, different fertility levels, deferred grazing periods and supplemental feeding.

There were several limitations in this study. First, the farm plan developed had no provision for purchasing or selling stored forage. Second, the beef herd size was specified in advance and not allowed to vary. Third, no consideration was given to the development of crop enterprises.

A study by Saez, Shumway, Rouquette and Jones evaluated the forage/beef relationship by analyzing a commercial cow-calf producer in the humid Southeast. How management decisions would be altered as the degree of risk aversion increased was also analyzed. This study made a contribution by evaluating the extent to which recommendations depend on the willingness of the manager to accept risk.

The model was limited to the beef and forage enterprises, and did not include the crop enterprises. In addition, substitution of alternative grazed forage sources in the development of a grazing system was not allowed as the grazing system was determined prior to optimization.

A study of the beef/forage relationship by Gerald Schwab included a multitude of factors that affect beef and forage production. This study was valuable in highlighting many areas that could affect the planning process. Some of these areas are length of planning period, growth and capital investment, discounting for risk and time, technological change, goals of the producer, coefficient variability, model validation, the structure of the tax system, and the costs and benefits of modeling.

The Schwab methodology was limited in scope to the evaluation of the relationship between the beef and forage enterprises. No provisions were made for dealing with the interrelationships among the beef, forage and crop enterprises.

INTEGRATED BEEF AND CROP ENTERPRISE MODELS

Wilton et al. used linear programming to integrate crops, cow-calf, and feedlot enterprises. They modeled four classes of livestock: cows, replacement heifers, feedlot heifers, and steers. The proportion of each class was fixed before running the model.

The researchers illustrated the uses of the model by investigating the effect of changing the mature weight of the cows on subsequent feed intake, weaning weight and the objective function.

The study by Wilton et al. determined the relationships among the beef, forage and crop enterprises under Canadian conditions. The relationship between the crop enterprise and the beef enterprise was limited to the use of grain by the beef enterprise and no allowance was made for the use of winter pasture from crop production.

The deficiency of this model was that the interaction between the beef enterprise and the crop enterprise was limited to the production and utilization of grains and stored forages. Also, only stored forages were considered because grazing activities were not developed. Finally, the size of the beef cow herd was determined in advance of the optimization process.

A linear programming model which analyzed and compared the economics of wheat crop alternatives was developed by Orlan Buller (1983). The alternatives considered were wheat hay, wheat silage, wheat for pasture and wheat that is grazed out. Also grain sorghum and grain sorghum silage were considered.

The livestock system considered was stocker steers, which began the program weighing 400 pounds on October 1. There were four different feeding systems developed: steers on sorghum silage and wheat pasture, steers on wheat hay and wheat pasture, steers on wheat silage and wheat pasture, and steers on sorghum silage and wheat graze-out.

The results of this model indicated that there was potential for increasing returns to fixed resources by combining a steer enterprise with the wheat enterprise. All wheat alternatives were feasible except wheat graze-out. Provided hay and silage were successfully harvested during the ten to fourteen day harvest period, the wheat for hay or wheat for silage compared favorably with the wheat pasture alternative.

The limitations of this study were the consideration of only one livestock enterprise and the primary concern of determining the best use of the wheat forage resource. Buller indicated that "Models of farms are needed that test combinations of the multitude of crop and livestock enterprises to determine the effect on farm income and resource use" (1983).

OVERVIEW

The studies reviewed illustrate the methodology of investigating and identifying important variables which are important to the success of the enterprise. The approaches and results of the prior research activities are important because they lay the groundwork for further research by indicating areas of priority.

The decision model developed for the present research is different from previous studies in that it is based on a Kansas situation with many of the possible enterprise combinations available to Kansas farmers. The inclusion of beef, forage and crop enterprises in one model requires that interrelationships among these enterprises with respect to land, labor and capital are incorporated into the model.

Provisions for storing forages are included in the model used for this study. This inventory of stored forage can be purchased or produced and excess forage can be sold. Inventory requirements of stored forage are determined on a monthly basis and can be met by three alternative hays or grain sorghum silage.

The grazing system is more flexible than in previously reported studies. The model for this study allows substitution of alternative grazed forages. Also the size of the beef enterprise is not fixed prior to optimization. The number and type of cattle are determined jointly with the type and quantity of alternative forages and crops through the optimization process.

Chapter III

THEORY OF MULTIPRODUCT PRODUCTION

Managers of multiproduct farms determine the enterprise combination and resource allocation that meet the goals of the business. Decisions are made on the allocation of resources in the production of several alternative primary and secondary products. When a product of one enterprise is used as input to another enterprise this product is referred to as a primary product. Secondary products are those products which are produced from primary products. Both primary and secondary products must be considered when determining the combination of products which can be produced from a farm's fixed and variable resources.

ECONOMIC DECISION CRITERIA

The type of resource to be allocated among enterprises determines the economic decision criteria which will be used in determining how resources are allocated. Three basic categories of resources must be considered: 1) the variable resources that can be allocated among the products, 2) the resources that are fixed to the farm but can be allocated among enterprises, and 3) the resources that are fixed to the farm and fixed in use and thus cannot be allocated between enterprises.

The theory which answers the question of how enterprises are combined using fixed and variable inputs is based on the following assumptions: 1) the production functions of the enterprises considered are given 2) prices of the resource and of the product are known 3) all products and resources are homogeneous and infinitely divisible 4) the goal of the manager is to maximize profit 5) at least one resource is fixed and the law of diminishing returns holds.

In the following cases the principles will be presented providing criteria for solving the problems of efficient resource use and enterprise selection which face the managers of farms having both beef and crop enterprises.

One Variable Factor and One Product

If one variable factor is used to produce one product Y then the production function is

$$Y = f\ (x1/\overline{x2}\ldots\overline{xn})$$

where $\overline{x2} - \overline{xn}$ are fixed and x1 is variable.

The profit equation is

$$\pi = PY * Y - Px1 * x1 - (Px2 * x2 + \ldots\ Pxn * xn)$$

where

π is profit

PY is the price of the product

Y is the quantitity of output,

Px1 is the price of the variable input,

x1 is the quantity of variable input,

(Px2 * x2 + ... Pxn * xn) are the fixed costs

The maximum profit is determined by the derivation of profit with regard to input x1.

$$\frac{\partial \pi}{\partial x1} = Py * \frac{\partial Y}{\partial x1} - Px1 - 0.$$

The maximum profit is where

$$PY * \frac{\partial Y}{\partial x1} = Px1$$

and the first term is defined as the marginal value product (MVP). Therefore, maximum profit is where

$$\frac{MVPx1\ (Y)}{Px1} = 1$$

The profit maximizing amount of input to use is where the marginal value product (MVP) is equal to the price of the input. This is point "a" in figure 1 and the level of input is "oq". At this point the additional revenue earned by the "qth" unit of input equals the cost of the input.

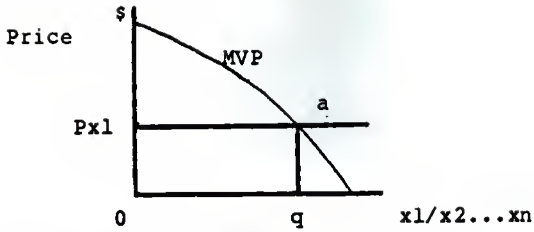

Figure 1. Profit Maximization with One Factor and One Primary Product

If there is sufficient input to produce at point "a" the resource is said to be "unlimited". The resource is considered limiting if there is not sufficient input to reach point "a". As long as input use is in the zone of economic relevance (Stage II) the input available would be used (Doll, Orazem, pp. 38-39).

One Factor and Two Products

The equimarginal principle is used to allocate a specified amount of a variable input among enterprises when there is sufficient amount of input available to reach the zone of economic relevance in each enterprise. The general equimarginal principle states that the ratio of the value of the marginal product of an input to the per unit price of the input be equal in all enterprises.

Given a specified amount of input to use in the production of two products Y1 and Y2, such as "forage" and "grain", and the production functions

$$Y1 = f(\overline{x1},\overline{x2},...\overline{xn})$$

$$Y2 = f(\overline{x1},\overline{x2},...\overline{xn})$$

where $\overline{x1}$ - $\overline{xn}$ are a specified amount of resources fixed to the farm, a production possibilities curve (PPC) can be determined. Production possibility curves depict the combinations of products that can be produced with a given amount of inputs. Since the prices of forage and grain are known, an isorevenue line can also be determined. An isorevenue line shows all the combinations of Y1 and Y2 which if sold produce the same amount of revenue. The isorevenue and production possibilities curves are illustrated in figure 2.

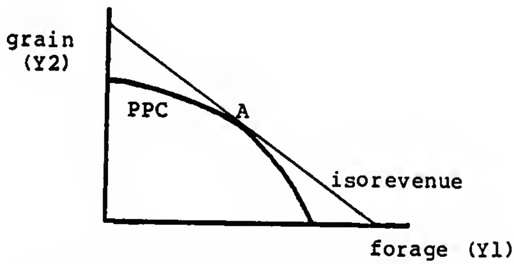

Figure 2. Profit Maximization with One Factor and Two Primary Products

At point "A" the slope of the production possibilities curve and the isorevenue line are equal and profits from the specified amount of input are maximized.

At this point

$$\frac{\Delta Y2}{\Delta Y1} = \frac{P\ (Y1)}{P\ (Y2)}.$$

or

$$\Delta Y2 * P\ (Y2) = \Delta Y1 * P\ (Y1).$$

Dividing through by Δ x1

$$\frac{\Delta Y2 * P\ (Y2)}{\Delta x1} = \frac{\Delta Y1 * P\ (Y1)}{\Delta x1}$$

yields

$$MPPx1 * P\ (Y2) = MPPx1 * P\ (Y1)$$

or

$$MVPx1\ (Y2) = MVPx1\ (Y1).$$

When an input is used in the production of two products and the input is "unlimited", indicating that there is a sufficient amount of input to maximize production in both enterprise, then the following condition holds:

$$\frac{MVPx1\ (forage)}{Px1} = \frac{MVPx1\ (grain)}{Px1} = 1.$$

or more generally

$$\frac{MVPxi\ (Yi)}{Pxi} = 1$$

Primary Products Used as Factors in the Production of a Secondary Product

Primary products produced with numerous variable factors can often be used to produce secondary products. For example, land is used to produce forage and grain which are used to produce beef. There are substitution possibilities between grain and forage which permit a given level of beef to be produced with different combinations of grain and forage. The curve representing all combinations of grain and forage that produce a given level of beef is called an isoquant. An isoquant for beef is illustrated in figure 3. If the primary products Y1 and Y2 ("forage" and "grain") are used to produce the secondary product Y3 ("beef"), the production functions are

$Y1 = f(\overline{x1},\overline{x2}...\overline{xn})$

$Y2 = f(\overline{x1},\overline{x2}...\overline{xn})$

$Y3 = f(Y1, Y2).$

where $\overline{x1}$ - $\overline{xn}$ are a specified amount of resources which are fixed to the farm.

When primary products of grain and forage are not sold but are used only in the production of beef, the optimal amount of forage and grain to produce is the amount which maximizes beef production.

The production possibilities curve for the specified amount of input available to the farm is depicted in figure 3. If the primary products are not sold, the price of forage and grain is of no consequence. The profit maximizing combination of grain and forage to produce is represented by the tangency point "A" between the production possibilities curve for grain and forage and the isoquant for beef. The combination of grain "0g" and forage "0f" represents the feed ration that maximizes beef production, given the specified amount of input available.

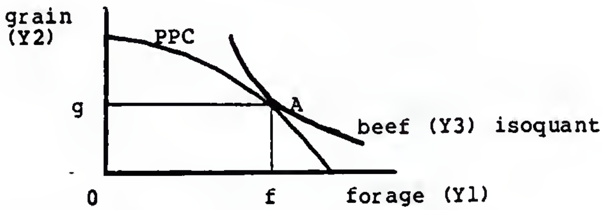

Figure 3. Profit Maximization with Two Primary and One Secondary Product (1)

At point "a"

$$\frac{MPPx1\ (Y2)}{MPPx1\ (Y1)} = \frac{MPP\ Y1\ (Y3) * P\ (Y3)}{MPP\ Y2\ (Y3) * P\ (Y3)}$$

or

$$MPPx1\ (Y2) * MPP\ Y2\ (Y3) * P\ (Y3) =$$
$$MPPx1\ (Y1) * MPP\ Y1\ (Y3) * P\ (Y3)\ .$$

Here the value of the grain and forage is determined by its productivity in producing beef. A more realistic situation is where the primary products can be sold and/or used as inputs in the production of beef. A graphical analysis of this situation is presented in figure 4.

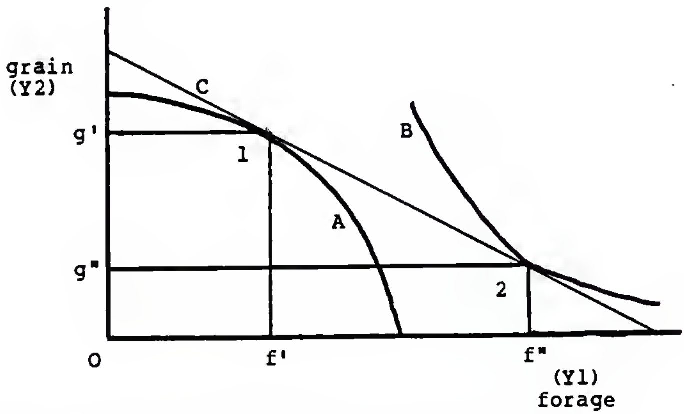

Figure 4. Profit Maximization with Two Primary and One Secondary Product (2)

The curve which is indicated by the letter "A" is the production possibilities curve for forage and grain. Curve "B" is an isoquant which indicates all the combinations of grain and forage which will produce a given level of secondary product (beef). Line "C" is the isorevenue line for the crop enterprises with the slope being the negative of the ratio of the price of forage and the price of grain. Given market prices, the optimal combination of grain and forage production is represented by point "1".

At point "1"

$$\frac{\text{MPPx1 (Y2)}}{\text{MPPx1 (Y1)}} = \frac{\text{Price Y1}}{\text{Price Y2}}.$$

or

$$\text{MPPx1 (Y2)} * P(Y2) = \text{MPPx1 (Y1)} * P(Y1)$$

Line "C" is also an isocost line for the beef enterprise. The isocost line depicts the combinations of the two inputs, forage and grain, which cost the same amount. With the possibility to buy and sell forage and grain, higher levels of beef can be produced than in the previous case because the quantity of grain from point g' to point g" can be sold and the revenue used to purchase forage represented by the distance from point f' to point f". This transaction makes producing beef at point "2" possible where in the previous case only the lower isoquant that was tangent to the production possibilities curve could be reached. At point "2"

$$\frac{\text{MPP Y1 (Y3) * P(Y3)}}{\text{MPP Y2 (Y3) * P(Y3)}} = \frac{\text{Price Y1}}{\text{Price Y2}} .$$

This equation indicates that the opportunity cost of using grain and forage in the production of beef is their market price. At point "2", the maximum possible returns from the use of primary products are obtained and the output of the secondary product is produced with the least cost combination of primary products (Doll, Orazem, pp. 180-183).

Joint Products Used as Factors in the Production of a Secondary Product

Two or more products that result from the same production process are termed joint products. For example, wheat produces grain, straw, and winter pasture and grain sorghum produces the joint products grain and winter pasture. The marginal earning power of inputs used in joint production must be determined in order to determine the optimal allocation of resources.

If

x1 = Input into the production of joint products

$Y1$ = winter pasture from crop production

$Y2$ = grain

$Y3$ = beef

P = market price

then the marginal earning power of x1 in the production of the joint primary products of grain and winter pasture, when the winter pasture can only be used in the production of the secondary product beef, is

$$MPPx1\ (Y1) * MPPY1\ (Y3) * P\ (Y3)$$
$$+ MPPx1\ (Y2) * P(Y2).$$

COST REDUCTION FROM MULTIPRODUCT PRODUCTION

When cost reduction results from simultaneous production of several different outputs by a single enterprise, there may exist economies resulting from the scope of the firm's operations (Panzar, Willig, pp. 268-272). There are economies of scope where it is less costly to combine two or more product lines in one firm than to produce them separately. In the two product case, the multiproduct cost function and the cost functions for separate production would reflect economies of scope if the cost of producing Y1 (crops) and Y2 (beef) together is less than the cost of separate production.

In equation form:

$$\text{Min Cost}(y1,y2) < \text{Min Cost}(y1,0) + \text{Min Cost}(0,y2)$$

This equation states that the minimized cost for producing beef and crops together is less than the sum of the minimized cost for producing them separately, indicating that there are economies of scope. Similarly, because profit is equal to total revenue less total cost, there are economies of scope where it is more profitable to combine two or more product lines in one firm than to produce them separately. In the two product case, the maximized multiproduct profit function and the maximized profit functions for separate production reflect economies of scope if:

$$\text{Max Profit}(y1,y2) > \text{Max Profit}(y1,0) + \text{Max Profit}(0,y2)$$

Both maximized profit functions and minimized cost functions embody the least costly means of production. If profits are higher in multiproduct production than for separate production this would be attributable to complementary and supplementary relationships in the production processes.

The present study evaluates the gross margin (total revenue less variable cost) to determine the cost reduction from complementarity attributable to the use of grain sorghum stubble and wheat pasture in the production of beef. Grain sorghum stubble and wheat pasture reduce the cost of winter feeding of beef cattle. If no grain sorghum stubble or wheat pasture is available and if beef output remains the same, then stored forage will be substituted to meet the feed requirement of the cattle herd. This is a more costly means of meeting the feed requirement. The increase in cost due to the substitution of stored forage for winter wheat pasture and grain sorghum stubble will reduce gross margin. The difference between the gross margin with the use of grain sorghum stubble and winter wheat pasture and the gross margin without the use of these resources represents the cost reduction attributable to the use of grain sorghum stubble and winter wheat pasture.

Cost complementarity is a fundamental condition for economies of scope (Baumol, Panzar, Willig p. 71). Cost complementarity is defined as the decrease in the marginal cost of producing one output as production of another output is increased. Cost complementarities arise from the complementary and supplementary relationships among enterprises with respect to resource use.

The complementarity between the beef and crop enterprises with respect to wheat pasture and grain sorghum stubble affects the value of cost complementarity. By determining the magnitude of the cost reduction attributable to the use of grain sorghum stubble and wheat pasture, an estimate is made of the effect of this complementarity between the beef and crop enterprise on cost complementarity.

Chapter IV

RESEARCH METHODOLOGY

Linear programming is used to evaluate the organization of a representative Eastern Kansas farm which produces beef and crops. Linear programming is one tool in a broad field of empirical methods known as activity analysis. Activities are things the farm manager does, including managing alternative beef and crop production processes, buying inputs, and selling products. Activities are treated separately if they differ in the timing of resource use, type of resource use or quantity of resources used. Activities are also treated separately if they differ in type of output, quantity of output or quality of output. Linear programming is a method of analyzing the general problem of efficient resource use. In this research, linear programming is used to select from numerous activities and choose the mix of activities which maximizes the return to the resources of the whole farm.

The linear programming method of choosing the best way to combine resources is related to the decision process described in the previous chapter on economic theory. Linear programming is an application of the economic decision criteria for control of the production of primary and secondary products through the determination of the optimal allocation of inputs.

MATHEMATICAL FORMULATIONS OF THE LINEAR PROGRAMMING PROBLEM

The mathematical formulation of a linear programming problem may be expressed as follows: maximize the profit function:

$$Z = c_1 X_1 + c_2 X_2 + \ldots + c_n X_n$$

subject to the linear inequality constraints:

$$a_{11} X_1 + a_{12} X_2 + \ldots + a_{1n} X_n \leq b_1$$

$$a_{21} X_1 + a_{22} X_2 + \ldots + a_{2n} X_n \leq b_2$$

$$\vdots$$

$$a_{m1} X_1 + a_{m2} X_2 + \ldots + a_{mn} X_n \leq b_m$$

and subject to:

$$X_1 \geq 0 \quad X_2 \geq 0, \ldots, X_n \geq 0.$$

where

X_j's are the variables which represent alternative activities.

b_i's (referred to as the right hand side) are the amount of the ith resource available for allocation to the alternative decisions.

aij's are the amount of the ith resource required (if positive) or produced (if negative) by each unit of the jth activity.

cj's are the profit function coefficients and are the change in Z that would result from each unit increase in the respective Xj's.

Z is the value of the profit function which represents the gross margin (total returns less variable costs). Z reflects payment to the fixed resources such as land, capital, operator labor and management (Stanton, p. 5).

The linear inequality constraints represent resources used in production and the amount of land, labor and capital available for production. The inequalities allow for some resources to remain unused, and exclude the production of negative quantities. This ensures that the quantity of resource used will be less than or equal to the quantity available.

The production coefficient (aij) is the relationship of the activity to the resource represented by the inequality constraint. A positive coefficient indicates a resource requirement for each unit increase in the activity. If the coefficient is negative, one unit increase in the activity increases the supply of the resource represented by the inequality constraint.

Relationships among activities with respect to a resource can be expressed by the linear inequality constraints. Two activities with positive coefficients in the same inequality constraint require the same resource. They are competitive with respect to the resource represented by that inequality constraint. An activity which does not have a coefficient in a particular inequality constraint is independent of the resource. If one activity has a positive coefficient and another activity has no coefficient in the same inequality constraint, then the two activities are supplementary with respect to that resource. When two activities have coefficients with different signs in the same inequality constraint, a complementary relationship exists between the two activities with respect to the resource represented by the inequality constraint. An increase in the level of the activity with the negative coefficient increases the supply of a resource to the other activity (Heady, Candler, pp. 213-215).

LINEAR PROGRAMMING ASSUMPTIONS

Seven assumptions of linear programming (Agrawal and Heady pp. 31-32) are listed below:

1) The assumption of linearity of the objective function implies that regardless of the quantity of output sold or the quantity of resource purchased, the price is the same for each unit.
2) Additivity indicates that different activities are independent. The output in combination never exceeds or can be exceeded by the sum of the output of each activity.
3) Divisibility means that it is possible to use resources and to produce commodities in quantities that are fractional units. Divisibility can be a problem in models with inputs that in reality only exist in units that require large jumps in capacity and capital outlay. The problem arises when a fraction of the discrete input is determined to be the profit maximizing level of input use. In reality this fraction must either be rounded up or down, each of which might have a significant influence on the production process.
4) Finiteness of activities and resource restrictions means that there is a limited or finite set of activities to evaluate. The number of activities available to an operation is realistically finite. It is clear that due to limitations in land, management and equipment, only a finite number of activities needs to be evaluated.

5) The single value expectation assumption is that the input/output coefficients used in the model are known and are correct. In reality, some of the information on input/output coefficients is lacking, and therefore, must be estimated.
6) Proportionality of activity levels to resources is the assumption that there is a linear input/output relationship. That is, if inputs are doubled, then output is doubled. Constant returns to scale and constant resource productivity are implied. Nonlinear relationships such as diminishing returns to input use can be modeled by specifing several activities for alternate input levels.
7) Nonnegativity of the decision variables excludes the possibility of producing negative quantities or purchasing negative quantities of resources.

MODEL SPECIFICATIONS

The model developed for the present research is presented in matrix format in appendix "A". Abbreviations used for the columns and rows are explained next.

Columns

SCOWUNIT: one unit of this activity represents one spring calving cow unit. A cow unit includes one 1,000 pound cow, the fraction of a calf produced, the fractional number of one and two year old replacement heifers, and a fraction of a bull. Average calving date for the spring calving cow herd is April first and weaning date is November first; weaning weight is 400 pounds.

The spring cow herd has a calving percentage of 85 percent (Putnam, Warwic). Replacement heifers are produced from the cow herd which is culled at a rate of 15 percent annually. A 1.5 percent death loss in the cow herd is considered part of the cows that are culled and their feed requirements are computed through November first as for the cull cows. The feed requirements for a spring calving cow unit are in Animal Unit Months (AUM's) for all months with the exception of an additional grain requirement for the replacement heifers. An AUM is the amount of forage required to maintain a 1,000 pound beef animal for one month. The AUM requirements per cow unit per month are depicted in figure 5.

SCULLCOW: one unit of this activity sells one 1,000

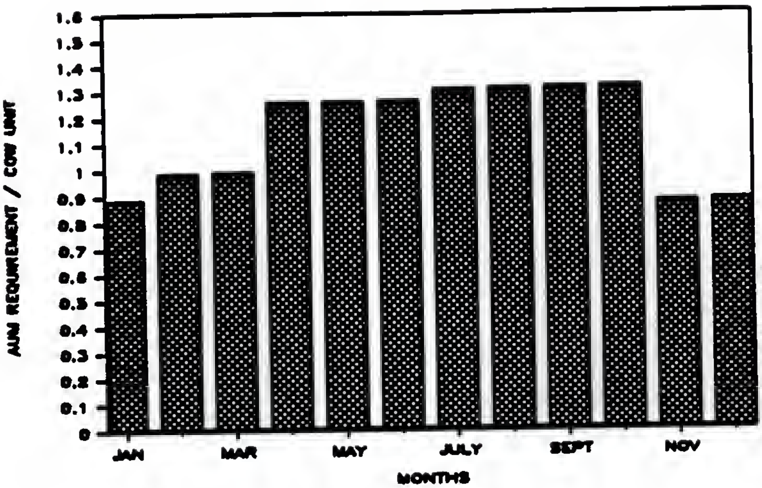

Figure 5. AUM Requirement per Cow Unit by Month

pound cull cow on November first.

WINTGRZ: one unit of this activity represents one winter-then-graze steer. The starting weight is 400 pounds and the calf can be produced in the cow/calf enterprise or purchased November first when the wintering phase begins. It is assumed that heifer calves produced in the cow/calf enterprise are sold and steers of the same weight are purchased for the winter-then-graze steer enterprise.

The wintering phase is for 180 days from November first to May first. During this period the feed requirements are in AUM's and there is no acreage requirement. The rate of gain during this phase is one pound per day. At the end of the wintering phase the calves are 13 months old and weigh 580 pounds.

The calves are grazed on tallgrass rangeland for 150 days from May first through October first. The feed requirements during this time are met by 3.5 acres of tallgrass range per head and there is no AUM requirement. The calves gain 1.33 pounds per day during this period. At the end of this period the calves are 18 months of age and sold weighing 780 pounds. The feed requirement for the winter-then-graze steer enterprise is depicted in figure 6.

GZPHST: a unit of this activity represents the grazing of one acre of owned prairie hay land by the winter-then-graze steers from May through September. Land designated as prairie hay land is tallgrass range meadows that can be hayed or grazed. Other available tallgrass rangeland can only be grazed as it is assumed that these acres have steep relief and rocky outcroppings which inhibit the hay making process.

GZTGRST: a unit of this activity represents the grazing of one acre of owned tallgrass rangeland by the winter-then-graze steers from May through September.

GZTGRRST: a unit of this activity represents the grazing of one acre of rented tallgrass rangeland by the winter-then-graze steers from May through September.

B400NOV1: one unit of this activity purchases one 400 pound steer calf on November first for the winter-then-graze steer enterprise. Capital requirements are $298.00 per head.

S780OCT1: one unit of this activity sells one 780 pound yearling steer on October first.

S400NOV1: one unit of this activity sells one 400 pound

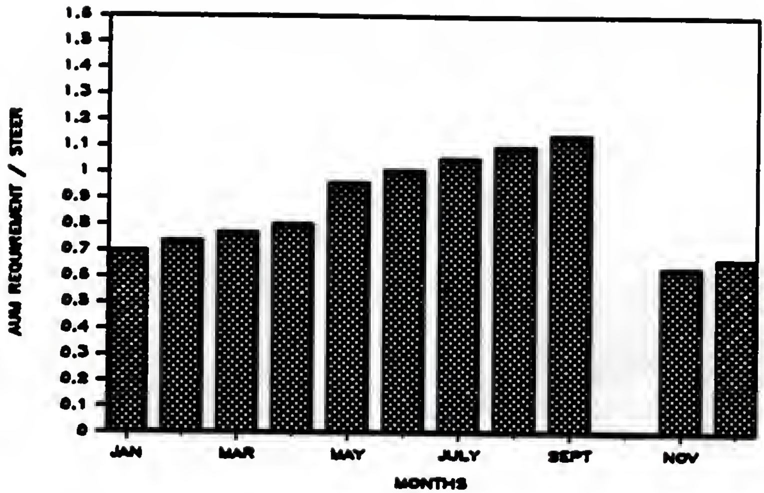

Figure 6. AUM Requirement per Winter-then-graze Steer by Month

spring calf November first.

GRZOTGR: one unit of this activity represents the grazing of one acre of owned tallgrass rangeland by the cow/calf enterprise from May through September. AUM's supplied by month from grazing one acre of owned tallgrass range are depicted in figure 7.

GRZRTGR: one unit of this activity represents the grazing of one acre of rented tallgrass rangeland by the cow/calf enterprise from May through September. AUM's supplied by month from grazing one acre of rented tallgrass range are depicted in figure 7.

FERTBROME: one unit of this activity represents the fertilization of one acre of brome pasture with eighty pounds of nitrogen fertilizer. This acre can then be used for grazing or for hay production.

HYUBROME: one unit of this activity produces brome hay on one acre of unfertilized bromeland. The hay is custom harvested and small bales are made. Two tons are harvested (Dicken). Brome hay is stored in a hay storage facility which protects the hay from rain and allows for adequate air movement. Storage losses of dry matter are 5 percent (Rees).

GZUBROME: one unit of this activity represents the grazing of one acre of unfertilized brome pasture

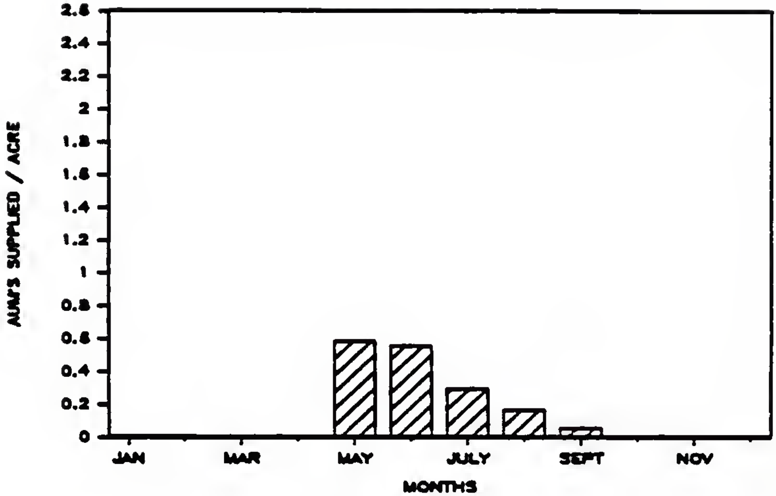

Figure 7. AUM's Supplied per Month from Grazing One Acre of Tallgrass Range

by the cow/calf enterprise or the winter-then-graze steer enterprise from April through June and from August through October. AUM's supplied by month from grazing one acre of brome pasture is depicted in figure 8.

HYFBROME: one unit of this activity produces brome hay on one acre of fertilized bromeland. The hay is custom harvested and small bales are made. Three tons are harvested (Dicken). Brome hay is stored in a hay storage facility which protects the hay from rain and allows for adequate air movement. Storage losses of dry matter are 5 percent (Rees).

GZFBROME: one unit of this activity represents the grazing of one acre of fertilized brome pasture by the cow/calf enterprise or the winter-then-graze steer enterprise from April through September. AUM's supplied by month from grazing one acre of fertilized brome pasture is depicted in figure 9.

FBRMSEPT - FBRMAPR: one unit of an activity for each month uses 1.2 tons of brome hay for feeding from September through April. The brome hay is fed in an outside bunk-type feeding system. Dry matter losses of spoilage and waste that occur during feeding are estimated to be 15 percent and storage losses of dry matter are 5 percent (Rees).

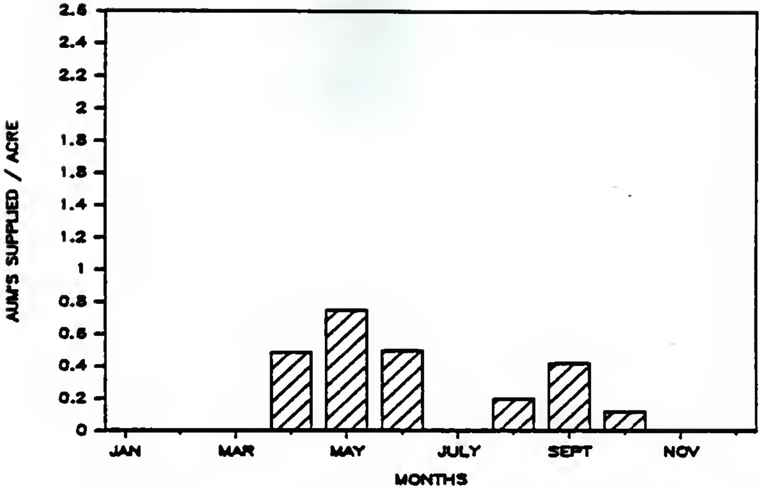

Figure 8. AUM's Supplied per Month from Grazing One Acre of Unfertilized Brome

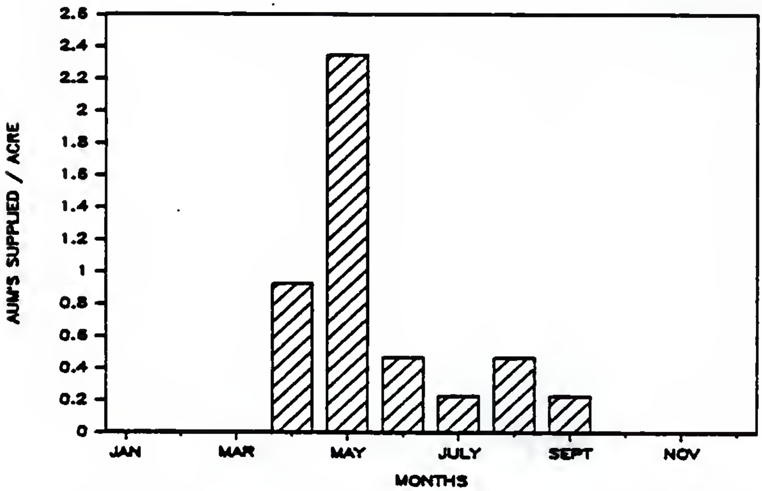

Figure 9. AUM's Supplied per Month from Grazing One Acre of Fertilized Brome

Variable costs of $4.00 per ton were estimated for feeding brome (Schrock, Figurski, McReynolds).

SELLBRM: one unit of this activity sells one ton of brome hay. Storage losses of dry matter are 5 percent (Rees).

BUYBRM: one unit of this activity purchases one ton of brome hay.

HLJAN - HLDEC: one unit of an activity for each month provides one hour of hired labor to meet monthly labor requirements. The hourly wage is $4.50 per hour (Pretzer, Sands, Tierney).

HYPRAIRY: one unit of this activity represents the use of one acre of tallgrass rangeland for prairie hay production. This land is designated as prairie hay land. Land designated as prairie hay land is tallgrass range meadows that can be hayed or grazed. Other available tallgrass rangeland can only be grazed as it is assumed that these acres have steep relief and rocky outcroppings which inhibit the hay making process. Small rectangular bales are made. The prairie hay is custom harvested. The yield is 1.17 tons per acre, based on ten year averages for the Southeast Kansas region (Kansas Farm Facts). Prairie hay is stored in a hay storage facility which protects the hay from rain and allows for adequate air movement. Storage losses of dry matter are 5 percent (Rees). Prairie hay production is only possible on 45 acres of tallgrass rangeland which are designated as prairie hay land, other available tallgrass rangeland is assumed to have rocky outcroppings and/or excessive relief and thus cannot be hayed.

GZPRAIRY: one unit of this activity represents the grazing of one acre of prairie hay land by the cow/calf enterprise from May through September. AUM's supplied by month from grazing one acre of prairie hay land are depicted in figure 7.

FPHSEPT-FPHAPR: one unit of an activity for each month uses 1.2 tons of prairie hay for feeding from September through April. Prairie hay is fed in a bunk-type feeding system. Dry matter losses that occur during feeding, in the form of spoilage and waste, are assumed to be 15 percent and storage losses of dry matter are 5 percent (Rees). Variable cost of feeding prairie hay was estimated to be $4.00 per ton (Schrock, Figurski, McReynolds).

FGSJAN-FGSDEC: one unit of an activity for each month provides one pound of grain sorghum to meet the grain requirement of the replacement heifers from January through December.

FALFSEPT-FALFAPR: one unit of an activity for each month uses 1.2 tons of alfalfa hay for feeding from September through April. Alfalfa hay is fed in a bunk-type feeding system. Dry matter losses that occur during feeding in the form of spoilage and waste are assumed to be 15 percent and storage losses of dry matter are 5 percent (Rees). Variable cost of feeding alfalfa was estimated to be $4.00 per ton (Schrock, Figurski, McReynolds).

FSILSEPT-FSILAPR: one unit of an activity for each month uses 1.22 tons of sorghum silage for feeding from September through April. A horizontal bunker type silo is assumed. The silage is fed outside in bunks. Storage and feeding losses for silage are 22 percent (Noller p. 564). Variable cost of feeding silage was estimated to be $3.27 per ton.

GROWGS: one unit of this activity produces grain sorghum on one acre of owned cropland. The joint products of winter pasture and grain are produced. Forty-eight bushels of grain are harvested, based on ten year averages for the Southeast Kansas region (Kansas Farm Facts).

GWGSSIL: one unit of this activity produces sorghum silage on one acre of owned cropland. Eight tons are harvested, based on ten year averages for the Southeast Kansas region (Kansas Farm Facts).

GROWGSR: one unit of this activity produces grain sorghum on one acre of rented cropland. The joint products of winter pasture and grain are produced. The yield is 48 bushels based on ten year averages for the Southeast Kansas region (Kansas Farm Facts). The operator's share is 32.13 bushels.

GRZGS: one unit of this activity represents the grazing of one acre of grain sorghum stubble by the cow/calf enterprise or the winter-then-graze steer enterprise from October through January. AUM's supplied by month from grazing one acre of grain sorghum stubble is depicted in figure 10.

PREPARGS: one unit of this activity transfers one bushel of grain sorghum from the grain sorghum production activity to the grain sorghum feeding activity.

SELLGS: one unit of this activity sells one bushel of grain sorghum.

BUYGS: one unit of this activity buys one bushel of grain sorghum.

GZSG: one unit of this activity represents the production of sudangrass on one acre of owned cropland and the use for grazing by the cow/calf

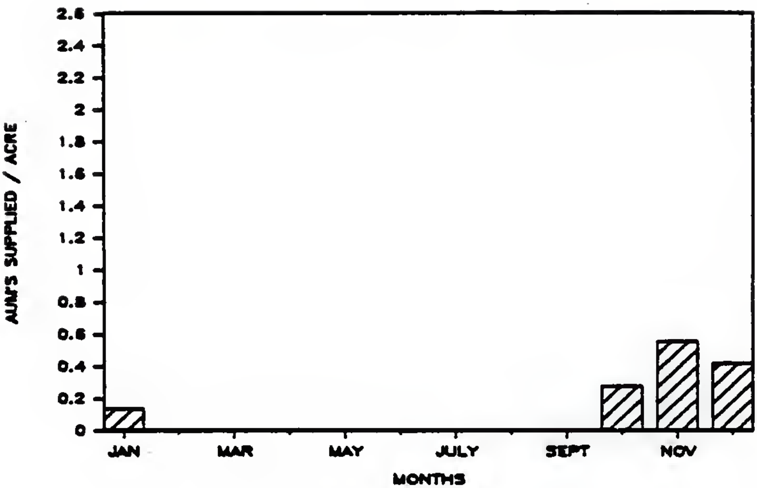

Figure 10. AUM's Supplied per Month from Grazing One Acre of Grain Sorghum Stubble

enterprise from July through September. AUM's supplied by month from grazing one acre of sudangrass is depicted in figure 11.

GROWALF: one unit of this activity produces alfalfa on one acre of owned cropland. Alfalfa hay is custom harvested and baled into small retangular bales. Alfalfa is a perennial crop, and a stand is expected to last four years. The costs of planting this crop are prorated over this period. Yield is 2.65 tons per acre based on ten year averages for the Southeast Kansas region (Kansas Farm Facts). Alfalfa hay is stored in a storage facility which protects the hay from rain and allows for adequate air movement. Storage losses of dry matter are 5 percent (Rees).

BUYALF: one unit of this activity buys one ton of alfalfa hay.

SELLALF: one unit of this activity sells one ton of alfalfa hay. Storage losses of dry matter are 5 percent (Rees).

BUYPHAY: one unit of this activity buys one ton of prairie hay.

SELLPHAY: one unit of this activity sells one ton of prairie hay. Storage losses of dry matter are 5 percent (Rees).

GROWSB: one unit of this activity produces soybeans on

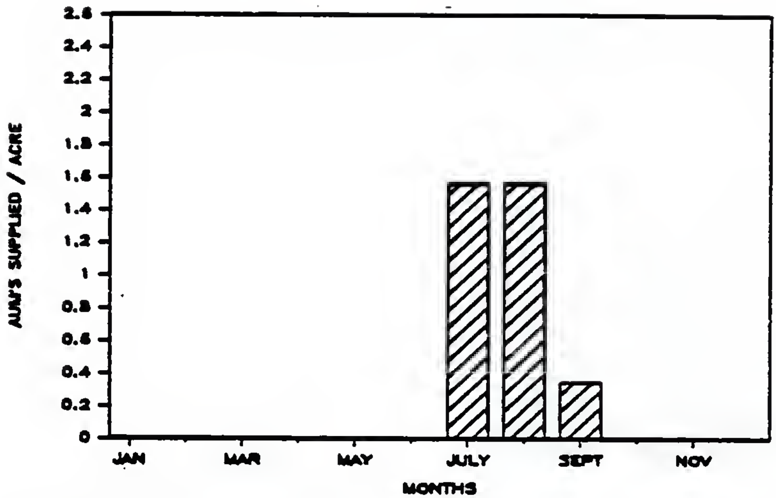

Figure 11. AUM's Supplied per Month from Grazing One Acre of Sudangrass

one acre of owned cropland. Yield is 17.86 bushels, based on ten year averages for the Southeast Kansas region (Kansas Farm Facts).

GROWSBR: one unit of this activity produces soybeans on one acre of rented cropland. Yield is 17.86 bushels, based on ten year averages for the Southeast Kansas region (Kansas Farm Facts). The operator's share is 11.91 bushels.

SELLSB: one unit of this activity sells one bushel of soybeans.

GROWWHT: one unit of this activity produces wheat on one acre of owned cropland. The joint products of grain and winter pasture are produced. Yield is 31.2 bushels based on ten year averages for the Southeast Kansas region (Kansas Farm Facts).

GROWWHTR: one unit of this activity produces wheat on one acre of rented cropland. The joint products of grain and winter pasture are produced. Yield is 31.2 bushels, based on ten year averages for the Southeast Kansas region (Kansas Farm Facts). The operator's share is 20.77 bushels.

GRZWHT: one unit of this activity represents the grazing of one acre of wheat pasture by the cow/calf enterprise or the winter-then-graze steer enterprise in March, October and November. The cattle are managed such that a reduction in grain yield is avoided. AUM's supplied by month from grazing one acre of wheat is depicted in figure 12.

SELLWHT: one unit of this activity sells one bushel of wheat.

BC6M@14 and BC12M@14: one unit of each activity represents borrowing capital for 6 months and 12 months respectively at 14 percent interest. Capital is required to cover the variable costs of production.

To estimate the cost of operating capital, it is assumed that capital for one half of the variable cost is borrowed multiplied by the fraction of the production period for which the capital is needed. The one exception to this is the purchase price of steers which incurs an interest expense for the entire period of twelve months.

Rows

The rows of the matrix in appendix "A" are of three types, objective function, resource rows and transfer rows.

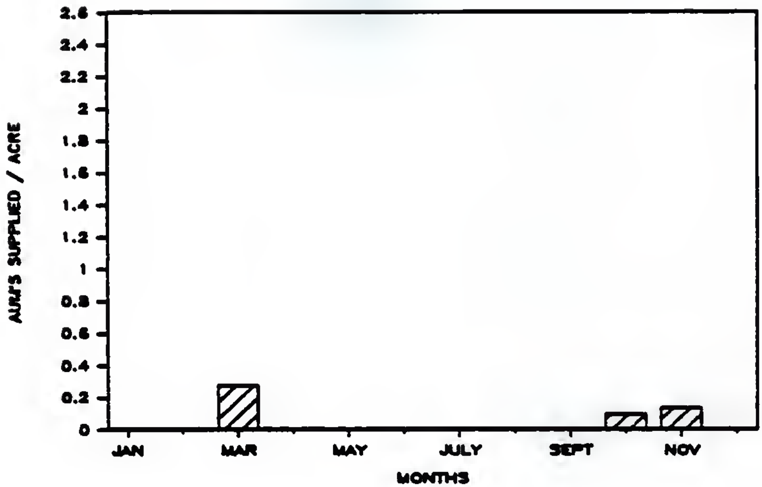

Figure 12. AUM's Supplied per Month from Grazing One Acre of Winter Wheat Pasture

OBJECTIVE FUNCTION

The objective function is the first row of the matrix in appendix "A", designated by the word profit. The value of the objective function represents the gross margin (total returns less variable costs). Individual coefficients in the objective function row represent the cost or returns of one unit of each activity.

RESOURCE ROWS

Resource rows represent the resource constraints on the optimal farm plan.

JANAUM - DECAUM: one equation for each month specifies the monthly AUM's required by the cow/calf enterprise and the winter-then-graze enterprise. An AUM is the amount of forage required to maintain a 1,000 pound beef animal for one month. The monthly AUM requirements for the cow/calf enterprise and the wintering phase of the winter-then-graze enterprise were developed using a computer program, the Forage Management and Utilization Program (FMUP). This program was developed by Buller, Munyan, and Posler. The feed requirement for the summer grazing phase of the winter-then-graze enterprise was based on an acreage requirement for season long stocking of tallgrass range (Launchbaugh, Owensby, Brethour, Smith).

The coefficients which were specified for the monthly availability of AUM's from forage crops were also derived from FMUP.

JANGRAIN - DECGRAIN: one equation for each month specifies the monthly grain requirements of the replacement heifers; there is no grain in the cow's ration or in the ration for the winter-then-graze steer enterprise. The grain to meet the requirement can either be produced or purchased.

JANLAB - DECLAB: one equation for each month specifies the monthly labor coefficients for the beef and crop enterprises. Labor requirements for the cow/calf enterprise and the winter-then-graze enterprise were developed from a Missouri study reported in Doanes Agricultural Report. The labor requirements for the crop enterprises are from a study by Langemeier, Buller, Kasper. There is no distinction between owner labor and hired labor with regard to productivity.

Caplmt: this equation places an upper limit on operating capital for purchasing variable inputs.

Cap6mo: this equation specifies the operating capital required to cover variable costs for those activities that need it for six months.

Capl2mo: this equation specifies the operating capital required to cover variable costs for those activities that need it for twelve months.

FWHJAN - FWHDEC: one equation for each month specifies the field work hour requirement to complete various field operations required for alternative crops (Langemeier, Buller, Kasper).

TRANSFER ROWS

Transfer rows provide a connecting link between activities. They are used to link activities that provide primary products to other activities using these products as inputs or selling these products.

TFCULL: this equation transfers a cull cow from the cow herd to the sell cull cow activity.

TFSCALF: this equation transfers a spring calf from the cow/calf enterprise to the winter-then-graze enterprise or to the activity that sells a 400 pound calf.

TF780LB: this equation transfers a 780 pound calf from the winter-then-graze enterprise to the sell 780 pound calf activity.

TFBROME: this equation transfers one ton of brome hay from the production or purchasing activity to the feeding or selling activity.

TFFBROME: this equation transfers one acre of fertilized bromeland to the grazing fertilized brome activity or the hay production activity.

TFPH: this equation transfers one ton of prarie hay from a purchasing or producing activity to a sales or feeding activity.

TFGSLB: this equation transfers one pound of grain sorghum from the feed preparation activity to the feeding activity.

TFALF: this equation transfers one ton of alfalfa from a producing or purchasing activity to a feeding or sales activity.

TFSIL: this equation transfers one ton of silage from the producing activity to the feeding activity.

TFGSBU: this equation transfers one bushel of grain sorghum from a producing or purchasing activity to a feeding or sales activity.

TFSTALKS: this equation transfers one acre of grain sorghum stubble from the grain sorghum producing activity to the grazing grain sorghum stubble activity.

TFWHT: this equation transfers one bushel of wheat from the wheat producing activity to a sales activity.

TFWHTGRZ: this equation transfers one acre of wheat pasture from the wheat producing activity to a grazing wheat pasture activity.

TFSB: this equation transfers one bushel of soybeans from the production activity to the sales activity.

Resources Available

The resources available as specified by the right hand side values (Appendix A) in the model are the averages of records from 55 farms that are reported in the Kansas Farm Management Association Records Summary of the Southeast Kansas region for 1983. These farms have combinations of crop and beef enterprises and are assumed to be representative of farms in the Flint Hills area having these enterprises. This group is used to construct the representative KFMA farm.

LAND CONSTRAINTS

The available land resource base of the representative farm is 1,590 acres of productive land of which 580 is owned and 1,010 rented. Of the owned land, 180 acres are cropland and 300 acres are tallgrass rangeland which can only be used for grazing. The Kansas Farm Management Association records do not differentiate the types of hays grown other than alfalfa. Therefore, it is assumed that of the 90 acres in the model 45 acres are improved pasture planted to brome and 45 acres are hay meadows in the tallgrass range pastures. These hay meadows are designated as prairie hay land. Of the available rented land, 160 acres are cropland and 850 acres are tallgrass rangeland.

Alfalfa is not assumed to be established and thus competes with other crops for cropland. Brome, another perennial forage, is assumed to be established on improved pastureland. The reason for this is that pasture renovation is a much longer term decision than alfalfa production. Pastures are renovated every 15-20 years whereas a stand of alfalfa can be maintained for a much shorter time (four years is used in this study).

LABOR CONSTRAINTS

Hours worked per day in alternative months was determine from Kansas Crop and Livestock Reporting Service data of hours worked by the farm operator in 1980. The coefficients uses to determine the monthly availability of operator labor is reported in Table 1.

Table 1. Determination of Monthly Availability of Operator Labor

Month	# of Operators	# of Days Worked Per Month	Hours Worked Per Man Per Day	Hours Worked Per Month (Operator)
Jan.	1.27	25	6.80	215.90
Feb.	1.27	25	6.80	215.90
Mar.	1.27	25	7.00	222.25
Apr.	1.27	25	7.10	225.43
May	1.27	25	9.00	285.75
June	1.27	25	10.00	317.50
July	1.27	25	10.00	317.50
Aug.	1.27	25	10.00	317.50
Sept.	1.27	25	9.00	285.75
Oct.	1.27	25	8.25	261.94
Nov.	1.27	25	7.00	222.25
Dec.	1.27	25	6.00	190.50

CAPITAL CONSTRAINTS

The capital available to cover variable costs is limited to $74,273. This is the operating expense of the representative Farm Management Association farm in 1983. Other capital assumed available and fixed to the farm is land, buildings and farm machinery. Farm machinery is fixed for the planning period and it is assumed that the proper complement of farm machinery is owned and available to accomplish the machine work required for the crop enterprise.

FIELD WORK TIME

Time is a factor during critical periods such as planting and harvesting. The optimal farm plan will be one which has a reasonable chance to be accomplished without costly delays. Time when field work can be accomplished is referred to as field work hours. The number of field work hours available each month is influenced by solar radiation, wind, precipitation and soil type. The estimation of the number of field work hours available for Southeast Kansas is based on soils which drain moderately fast (Buller, Langemeier, Kasper, Stone). The limit on field work time is assumed fixed for the planning period.

Table 2. Determination of Monthly Field Work Hours

Month	Field Work Days Per Month	Field Work Hours Accomplished Per Day	Field Work Hours
Apr.	17	10	170
May	15	10	150
June	14	10	140
July	16	10	160
Aug.	21	10	210
Sept.	16	10	160
Oct.	17	10	170

Objective Function Coefficients

With linear programming the relationship between product prices and input prices is important. Having all prices too high or too low will cause the objective function value (gross margin) to be high or low.

However, if the relative price relationship between prices is correct the most profitable plan can be chosen.

To estimate the relative price of crops and livestock sold, average market prices were used. The use of average prices tends to smooth out year to year variablity in prices. Average prices are used to estimate the long-run relative price relationship. These prices are presented in Table 3.

Table 3. Prices Used in Analysis

Commodity	Purchase Price	Sales Price
Grain sorghum/bushel	$3.13	$2.51
Wheat / bushel	*	$3.65
Soybeans / bushel	*	$6.49
Prairie Hay / ton	$45.00	$40.00
Alfalfa Hay / ton	$55.00	$50.00
Brome Hay / ton	$55.00	$50.00
400 lb calf / head	$298.00	$289.05 **
780 lb calf / head	*	$535.04 **

* Does not apply to the model
** Includes marketing cost of 3%

Prices for the beef enterprise were determined from Kansas Crop and Livestock Reporting Service data of weekly averages of the cash price at the Kansas City market for the month in which the animals were purchased or sold. The average price determined was for alternative weight classes of choice steers for the five year period from 1979 through 1983. The price difference between steers and heifers produced in the cow/calf enterprise was not taken into consideration.

The prices for wheat, soybeans and grain sorghum were determined from Kansas Crop and Livestock Reporting Service data of the average prices received by Kansas farmers at area markets during the five year period from 1979 through 1983. The area markets used were Beloit, Bennington, Cherryvale, Colby, Dodge City, Hutchinson, Salina, and Topeka.

The market for hays is not as developed as the beef and grain markets. Most hay is sold through private treaty or at auctions. Quality varies considerably and adjustments in price are made for this. Prices for hays were estimated by Pretzer, Sands, Tierney.

Input costs for variable inputs are reported in the budgets presented in appendix "B". These budgets were developed from the Kansas State University Farm Management Guides for 1984. These budgets were used to develop the profit function coefficients for the various enterprises.

Chapter V

RESULTS

Benefits from the production and use of winter wheat pasture and grain sorghum stubble are estimated by using the linear programming model to study four situations. The situations are different in how the decision variables interact with the availability of winter pasture on the representative farm.

In situation one, the model is allowed to select the crop and livestock enterprises that maximize gross margin with wheat and grain sorghum providing winter pasture. If the model selects either wheat or grain sorghum, they provide winter pasture that can be used by either beef enterprise. Thus, the selection of enterprises is affected by the complementarity between crops and livestock in the use of winter pasture.

In situation two, the model is allowed to select crop and livestock enterprises, but wheat and grain sorghum do not provide winter pasture. Crops and livestock do not have a complementary relationship with regard to use of winter pasture.

Comparing situation one and two shows the benefits from selecting enterprises that exploit their complementarity through the use of winter pasture. It also shows how this complementarity affects enterprise selection.

Situation three begins with the organization determined in situation one. The organization of situation one is held fixed, but the availability of winter pasture is removed. Comparing situation one and three estimates the benefits from winter pasture to that organization specified to use it most economically. Removing winter pasture increases feeding costs and this is an estimate of increase in cost attributed to substituting hay for winter pasture in the representative farm situation set up to use winter pasture.

Situation four begins with the organization determined in situation two, but then provides for the use of winter pasture. Comparing situation two with four estimates the value of winter pasture if the representative farm does not include its use. Having winter pasture available reduces feeding costs and increases the gross margin. This increase is an estimate of the benefits from having winter pasture available to the representative farm which excluded its use.

The four situations allow only the variable winter pasture from wheat and grain sorghum production to change. In situations three and four, however, the enterprise combination of situations one and two respectively is held fixed and is not allowed to change in response to the change in the availability of winter pasture.

RESULTS OF SITUATION ONE AND TWO

The optimal enterprise combinations for situation one and situation two include crop and beef enterprises. Table 4 specifies the type and number of units of enterprises that maximize the gross margin in situation one and two and the reduced cost of those enterprises not included. A "*" in the "number of units" column means that the enterprise is not in the optimal organization. The reduced cost is the decrease in the value of the objective function if one unit of the enterprise not included in the solution is forced into the solution (Stanton pp. 20-21). A "*" in the "reduced cost" column appears for enterprises that are in the optimal organization and thus have no reduced cost value.

The most profitable allocation of land, labor, and capital is presented in tables 5 through 8. Shadow prices of resources used are also presented. A shadow

Table 4. Type and Number of Units of Beef and Crop Enterprises that Maximize Gross Margin for Situation One and Two

		SITUATION ONE		SITUATION TWO	
Enterprise	Unit	NUMBER OF UNITS	REDUCED COSTS ($)	NUMBER OF UNITS	REDUCED COSTS ($)
SPRING COW/CALF UNIT	No.	53.28	*	*	*
WINTER-THEN-GRAZE STEERS	No.	134.23	*	135.37	*
GRAZE BROME (UNFERT.)	Acre	*	47.57	*	53.22
BROME HAY (UNFERTILIZED)	Acre	*	7.62	*	7.58
GRAZE BROME (FERTILIZED)	Acre	*	59.64	*	64.68
BROME HAY (FERTILIZED)	Acre	45.00	*	45.00	*
GRAZE PRAIRIE HAY LAND	Acre	*	20.26	*	20.17
PRAIRIE HAY	Acre	45.00	*	45.00	*
GRAIN SORGHUM (OWNED)	Acre	40.74	*	*	14.65
GRAIN SORGHUM (RENTED)	Acre	160.00	*	*	7.79
SORGHUM SILAGE (OWNED)	Acre	*	*	*	*
ALFALFA (OWNED)	Acre	*	34.66	*	25.40
SOYBEANS (OWNED)	Acre	*	14.49	*	4.78
SOYBEANS (RENTED)	Acre	*	21.08	*	4.47
WHEAT (OWNED)	Acre	139.26	*	180.00	*
WHEAT (RENTED)	Acre	*	6.90	160.00	*

Table 5. Hours of Labor Used by Month and Shadow Prices for Situation One and Two

RESOURCE	SITUATION ONE HOURS USED	SITUATION ONE SHADOW PRICES ($)	SITUATION TWO HOURS USED	SITUATION TWO SHADOW PRICES ($)
JANUARY LABOR	115.87	*	67.68	*
FEBRUARY LABOR	120.24	*	67.68	*
MARCH LABOR	121.46	*	67.68	*
APRIL LABOR	178.50	*	71.08	*
MAY LABOR	127.12	*	33.84	*
JUNE LABOR	174.49	*	193.64	*
JULY LABOR	168.05	*	231.04	*
AUGUST LABOR	125.13	*	224.24	*
SEPTEMBER LABOR	154.26	*	193.48	*
OCTOBER LABOR	126.70	*	47.60	*
NOVEMBER LABOR	156.89	*	67.68	*
DECEMBER LABOR	104.15	*	67.68	*

Table 6. Operating Capital Used and Shadow Prices for Situation One and Two

RESOURCE	SITUATION ONE NUMBER OF DOLLARS	SITUATION ONE SHADOW PRICE ($)	SITUATION TWO NUMBER OF DOLLARS	SITUATION TWO SHADOW PRICE ($)
OPERATING CAPITAL	74273.0	0.034	74273.0	0.029

Table 7. Acres of Land Used and Shadow Prices by class for Situation One and Two

RESOURCE	SITUATION ONE NUMBER OF ACRES	SITUATION ONE SHADOW PRICES ($)	SITUATION TWO NUMBER OF ACRES	SITUATION TWO SHADOW PRICES ($)
CROP LAND (OWNED)	180.00	59.43	180.00	50.05
CROP LAND (RENTED)	160.00	37.90	160.00	21.57
TALL GRASS RANGE (OWNED)	300.00	9.62	300.00	9.57
TALL GRASS RANGE (RENTED)	580.55	*	173.79	*
PRAIRIE HAY LAND (OWNED)	45.00	29.88	45.00	29.74
BROME PASTURE (OWNED)	45.00	78.41	45.00	78.05
WHEAT PASTURE	139.26	*	*	*
GRAIN SORGHUM STUBBLE	200.74	*	*	*

Table 8. Hours of Field Work by Month and Shadow Prices for Situation One and Two

RESOURCE	SITUATION ONE NUMBER OF HOURS	SITUATION ONE SHADOW PRICES ($)	SITUATION TWO NUMBER OF HOURS	SITUATION TWO SHADOW PRICES ($)
FIELD WORK HOURS APRIL	60.22	*	*	*
FIELD WORK HOURS MAY	62.23	*	*	*
FIELD WORK HOURS JUNE	100.32	*	122.40	*
FIELD WORK HOURS JULY	94.79	*	153.00	*
FIELD WORK HOURS AUGUST	59.88	*	146.20	*
FIELD WORK HOURS SEPTEMBER	55.05	*	95.20	*
FIELD WORK HOURS OCTOBER	84.18	*	34.00	*
FIELD WORK HOURS NOVEMBER	56.21	*	*	*

price is an imputed price to a resource derived from the value of the earnings of the resource. The shadow price specifies how much the gross margin would be reduced if one less unit of the limiting resource was available. A "*" in the shadow price column means that more of that resource is available than is used and thus the shadow price is zero.

As a benchmark from which the alternative situations can be evaluated, enterprise and resource use data from 55 Kansas Farm Management Association (KFMA) farms for 1983 are used. Information from these farms is averaged to obtain a farm "representative" of Southeast Kansas farms having both beef and crop enterprises. The optimal enterprise combinations and resource use determined by the model are compared with the enterprise combinations and resource use on the representative farm.

The average size of the cow/calf enterprise on the representative KFMA farm in 1983 was 115 cows and no other beef enterprises were specified. From the representative farm data it is not clear how long the calves were kept. The number of acres of tallgrass range on the representative farm indicates that if grazing levels are the same for the representative farm as are specified in the model, then there would be sufficient acreage to winter-then-graze 100 head of steers in addition to the 115 cows.

The crop enterprises reported by the representative KFMA farm are wheat, corn, grain sorghum, soybeans, alfalfa hay, silage, other grain, other hay and other cash crops. The percent of the reporting farms with acres planted to these crops and the number of acres are reported in table 9. The "other hay" category reported by 67.27 percent of the KFMA farms includes hays other than alfalfa. "Other cash crops" and "other grain crops" are not included in the model. Also corn is not in the model because only 0.05 percent of the reporting KFMA farms planted corn in 1983.

Table 9. Percent of KFMA Farms Reporting Acres Planted by Crop and Number of Acres Planted in 1983

	Percent of Farms	No. of Acres
Wheat	85.45	136
Corn	00.05	35
Grain Sorghum	56.36	67
Soybeans	56.36	113
Alfalfa Hay	60.00	35
Silage	00.14	21
Other Grain	47.00	26
Other Hay	67.27	91
Other Cash Crops	43.63	11

Optimal Enterprise Combination and Resource Allocation for Situation One

In situation one, the beef enterprises (table 4) include 53.28 cow units and 134.23 steers that are wintered-then-grazed. The calves produced in the cow/calf enterprise are weaned and then kept for the winter-then-graze enterprise. It is assumed that the heifer calves are sold and are replaced with purchased steer calves. In addition to the calves raised, 96.92 steers are purchased. Grazed pasture used by the beef enterprise is 880.55 acres of tallgrass rangeland.

Crop enterprises (table 4) are 139.26 acres of wheat, 200.74 acres of grain sorghum, 45 acres of prairie hay and 45 acres of brome hay. Wheat acreage for situation one is 3.26 acres larger than the average acreage reported by wheat producing KFMA farms whereas the grain sorghum acreage is 133.74 acres larger than the average reported by grain sorghum producing KFMA farms. Over half of the representative KFMA farms reported an average of 113 acres of soybeans, however, the soybean enterprise did not enter the enterprise combination for situation one. Average yields used in this study include double crop soybeans which lower the average. The model does not consider double cropping. A 2.23 bushel increase in soybean yield would change the optimal solution to the inclusion of soybeans. A possible reason that soybeans are planted on KFMA farms is to control weeds when planted in rotation with wheat or grain sorghum. The crop budgets used in the model do not consider the reduction in herbicide costs associated with crop rotation and the model does not allow for this management practice.

Alfalfa hay production was reported by 60 percent of KFMA farms and averaged 35 acres per farm. Alfalfa is not included in situation one. Alfalfa hay is purchased for use in the beef enterprise. If the purchase price of alfalfa increased $13.10 or more per ton, or if the per acre variable cost of alfalfa production decreased $34.66 (table 4) or more, it would be profitable to divert resources to alfalfa production. It is assumed that no alfalfa is established on the model farm and thus, the variable costs for alfalfa include the costs of stand establishment prorated over the four year life of the stand. If a stand could be maintained for longer than four years then this would spread establishment costs over more seasons and reduce variable costs per acre.

Planting and grazing sudangrass on cropland is not selected by the model in situation one. The reduced cost is $26.00 (table 4), indicating a decrease in gross margin if sudangrass is grown. The reason for this high penalty is that sudangrass provides AUM's during the months of July, August and September. During these months, AUM's are available from tallgrass range which is a lower cost alternative. More acres of tallgrass range are available for renting so that AUM's during July, August and September could be obtained at lower cost by renting more tallgrass rangeland.

Producing grain sorghum silage has a reduced cost of zero for situation one and yet does not enter the solution. This indicates that silage could be a viable alternative for meeting the needs of the beef enterprises. Silage production was reported by 0.14 percent of the representative KFMA farms.

None of the bromeland or prairie hay land is grazed. All of the 45 acres of bromeland and 45 acres of prairie hay land are harvested for hay. Hay is needed during the winter when sufficient winter pasture is not available to meet the feed requirement of the beef enterprise. Diverting one acre of brome from hay production to grazing incures a penalty of $59.64 (table 4). The reason for this is that brome pasture provides AUM's during the months of May, June, August and September when AUM's are available from tallgrass range. Additional acres of tallgrass range are available for renting. Diverting one acre of prairie hay land from hay production to grazing incures a penalty of $20.26. This indicates that in the model more tallgrass range would be hayed if allowed. An increase in prairie hay acreage is not allowed in order to maintain the same acreage as specified for the representative farm.

Brome pasture is considered established in the model due to the long life of a stand. The costs of establishment, including the loss of production during the establishment period, are not included in the budgets for brome hay production or grazing. This contributes to the shadow price (table 7) for bromeland ($78.41) being higher than the shadow price for cropland ($59.43). The high shadow price of brome indicates that the model would convert cropland to bromegrass if allowed. However, brome acreage is limited to 45 acres and establishment costs are not included in the variable costs of brome.

The feed requirements for the beef enterprises for situation one are met throughout the year. The AUM requirements per month for the beef cows and steers are presented in table 10.

AUM's supplied per head are comparable to rations developed for beef cows and winter-then-graze steers by Orwig and McReynolds. The forages used to meet the feed requirement are reported in table 11.

Table 10. AUM Requirement per Month for 53.28 Cow Units and 134.23 Winter-then-Graze Steers

	AUM's for Beef Cows	AUM's for Steers	Total AUM's
Jan.	47.35	94.39	141.74
Feb.	52.58	98.83	151.42
Mar.	52.92	103.21	156.13
Apr.	67.07	107.52	174.59
May.	67.23	128.94	196.17
June	67.39	135.32	202.71
July	69.67	141.60	211.27
Aug.	69.82	147.79	217.61
Sept.	69.98	153.89	223.87
Oct.	70.13	0.00	70.13
Nov.	46.60	85.30	131.91
Dec.	46.98	89.88	136.86

Table 11. Forages Used in Situation One

Winter Wheat Pasture	139.26 acres
Grain Sorghum Stubble	200.74 acres
Tallgrass Range	880.55 acres
Brome Hay	135.00 tons
Prairie Hay	52.61 tons
Alfalfa Hay	52.12 tons

All winter wheat pasture and grain sorghum stubble produced is grazed. From October through April, 54.64 percent of the total AUM's required are supplied by winter wheat pasture and grain sorghum stubble.

All of the 300 acres of owned tallgrass rangeland and also 580.55 acres of rented tallgrass rangeland are used. The tallgrass range is grazed at a rate of 7.71 acres per cow unit and 3.5 acres per steer. These are within the normal grazing rates for Kansas conditions (Pine, p. 7). The shadow price indicates that another acre of owned tallgrass rangeland would increase gross margin by $9.62. This is less than the current (1986) rental value of $10.90 for tallgrass range (Kansas State Board of Agriculture, Statistics Division). Rented tallgrass range is not used to the upper limit constraint but its use is limited by the availability of capital to rent it.

Including the use of 45 acres of prairie hay land with the acres of tallgrass range grazed, 925.55 acres of tallgrass range are used in situation one compared to an average of 1,195 acres of pasture reported by the representative KFMA farm. Information is not available to resolve this difference.

Beef cows and steers are fed 293.73 tons of hay. Inventory of hays includes 135 tons of brome hay and 52.61 tons of prairie hay which are produced on the farm. An additional 52.12 tons of alfalfa hay are purchased. Figure 13 reports the monthly hay requirement and the types of hay fed.

Total feed cost for situation one is $2,866.60. The representative KFMA farm reports an average total feed cost of $11,878.00 in 1983. There is not sufficient information to resolve the difference in feed purchasing costs. The higher feed costs for the

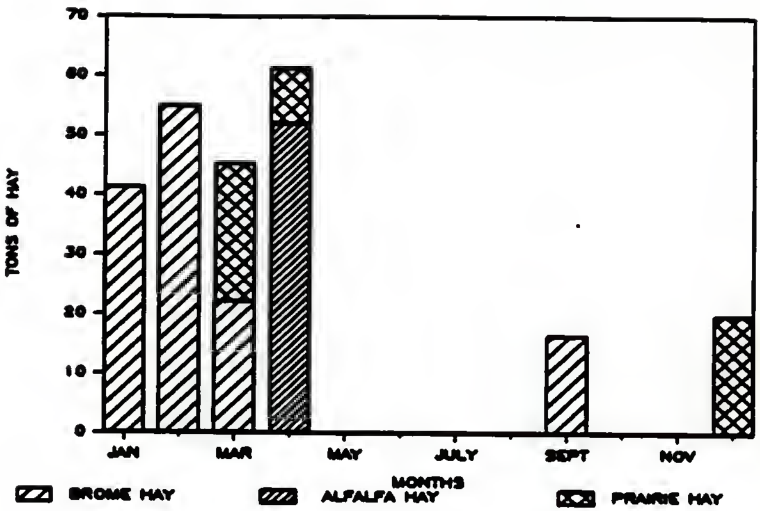

Figure 13. Monthly Feeding of Hays for Situation One

representative farm could be caused by not having winter pasture available or by lower per acre production for hays than used in the model. Yields of hay other than alfalfa were not reported by the KFMA farm.

Operating capital is limiting the size of both the beef and the crop enterprises, indicating a competitive relationship among enterprises with respect to capital. The capital constraint is estimated by using the average cash operating expense in 1983 reported by the representative KFMA farm. The model limits operating capital to $74,273.00 (table 6). The shadow price for capital is $0.034 per dollar which represents the earnings of capital above the cost of borrowing of 14 percent. The shadow price shows that the return to capital is 17.4 percent.

Owned and rented cropland are limiting the crop enterprises. The relationship among crop enterprises with respect to cropland is competitive. The shadow price of owned cropland is $59.43 whereas the shadow price of rented cropland is $37.90 (table 7). This indicates that another acre of owned cropland would return $59.43 above variable costs. This is the return to ownership costs of the land and the fixed resources used to farm the land. Another acre of rented cropland would return $37.90 which is the earnings above rental costs because the landlord's share has been subtracted from yield per acre. Thus, for situation one, the model would increase rented acreage if allowed.

Owner operator labor is not limiting in situation one and no labor is hired. Adding units of any enterprise does not require a reduction in the level of any other enterprise because of shortages of owner operator labor. This indicates that enterprises are supplementary with respect to labor. However, in 1983 the representative KFMA farm reported an expense of $1,677.00 for hired labor. This means that the representative KFMA farm could have had labor shortages at some time during the year but these are not identified in the model.

Field work hours are not limiting crop enterprises in any month. The surplus of field work hours in all months in situation one means that crop enterprises can be completed without costly delays.

Optimal Enterprise Combination And Resource Use For Situation Two

In situation two, winter pasture from grain sorghum and wheat production is not included in the model. Like in situation one, the optimal enterprise combination in situation two includes both beef and crop enterprises.

The beef enterprise is specialized in a 135.37 head winter-then-graze steer enterprise. The crop enterprises include 340 acres of wheat, 45 acres of prairie hay and 45 acres of brome hay. Three hundred acres of owned and 137.39 acres of rented tallgrass rangeland are grazed. This organization is very different from that reported by the representative KFMA farm.

The feed requirement of the beef enterprise is met throughout the year. The monthly feed requirement in AUM's is presented in table 12. No AUM's are needed in October because the steers are purchased November first and sold at the end of September.

Table 12. AUM's Required per Month for 135.37 Winter-then-Graze Steers

Month	AUM's for Steers
Jan.	95.19
Feb.	99.67
Mar.	104.09
Apr.	108.43
May.	130.40
June	136.47
July	142.80
Aug.	149.04
Sept.	155.22
Oct.	0.00
Nov.	86.03
Dec.	90.64

AUM's supplied per head are comparable to rations developed by Orwig and McReynolds for winter-then-graze steers. The forages used to meet the feed requirement are reported in table 13.

Table 13. Forages Used in Situation Two

Winter Wheat Pasture	*
Grain Sorghum Stubble	*
Tallgrass Range	437.79 acres
Brome Hay	135.00 tons
Prairie Hay	52.61 tons
Alfalfa Hay	29.33 tons

The steers are fed 216.94 tons of hay including 135 tons of brome hay and 52.61 tons of prairie hay produced on the farm and 29.33 tons of purchased alfalfa hay. Figure 14 reports the monthly feeding of hays and the type of the hays fed.

The tallgrass rangeland is grazed at a rate of 3.5 acres per steer. This is within the normal grazing rates for Kansas conditions (Pine, p. 7). Owned tallgrass rangeland is completely used. The shadow price indicates that another acre of this resource would provide $9.57 return. This is less than the current (1986) rental value of $10.90 for tallgrass range (Kansas State Board of Agriculture, Statistics Division). Rented tallgrass range is not used to the upper limit constraint but its use is limited by the

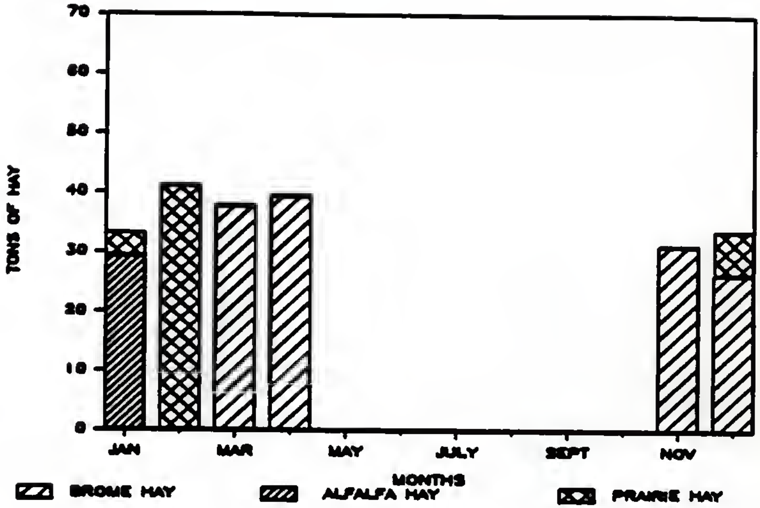

Figure 14. Monthly Feeding of Hays for Situation Two

availability of capital to rent it.

Operating capital is limiting the size of both the beef and the crop enterprises in situation two, indicating a competitive relationship between enterprises with respect to capital. The capital constraint is estimated from the average cash operating expense for 1983 reported by the representative KFMA farm. Return to capital is lower in situation two compared to situation one. The reason is that more expensive feed is substituted for the winter pasture which increases costs and lowers returns. The shadow price for capital is $0.029 per dollar (table 6) which represents the earnings of capital above the cost of borrowing which is 14 percent per year. Therefore, capital is earning 16.9 percent.

The effect of having a limiting amount of operating capital is that the model selects those enterprises that can provide the highest return to the limited amount of capital. Enterprises selected are those which used the least amount of capital, yet productively employ the fixed resources. For example, wheat production uses less capital per acre than grain sorghum production. Also, less capital is used to meet the AUM requirement for a steer than for a beef cow unit.

The relationship among crop enterprises with respect to cropland is competitive. The shadow price of owned cropland is $50.05 which is the return to the costs of owning the land and the fixed resources used to farm the land. The shadow price of rented cropland is $21.57 which is the earnings above rental costs because the landlord's share has been subtracted from yield per acre. Thus, if allowed, the model would increase rented cropland acreage.

Brome pasture is considered established in the model and the costs of establishment, including the loss of production during the establishment period, are not included in the budgets for brome hay production or grazing. This contributes to the shadow price for bromeland ($78.05) being higher than the shadow price for cropland ($50.05) (table 7). The high shadow price of brome indicates that the model would convert cropland to bromegrass if allowed. However, brome acreage is limited to 45 acres and establishment costs are not included in the variable costs of brome.

Prairie hay land has a shadow price of $29.74 which is higher than the shadow price of tallgrass rangeland. This indicates that additional tallgrass range would be harvested for hay if allowed in the model.

Owner operator labor is not limiting in situation two and no labor is hired. Adding units of any enterprise would not require a reduction in the level of other enterprises because of a shortage of owner operator labor. This indicates that enterprises are supplementary with respect to labor. However, the representative KFMA farm reported spending an average of $1,677.00 for hired labor in 1983. This means that the representative KFMA farm could have had labor shortages some time during the year but these are not identified in the model.

Because only wheat is planted in situation two the field work time is concentrated in the months from June through October. There is sufficient field work time, however, efficiency is critical if costly delays are to be avoided.

COMPARISON OF SITUATION ONE AND SITUATION TWO

By comparing the enterprise combinations and resource use of situation one and situation two, it is apparent that winter pasture from crop production significantly affects the model results.

One major difference is that beef cows are excluded when winter pasture from wheat and grain sorghum production is not available. There are two reasons for the shift away from the cow/calf enterprise. 1) In situation one, the gross margin for the cow/calf enterprise is positive whereas in situation two, a negative gross margin would be realized if the enterprise was forced into the solution. 2) The capital requirement increases relatively more for the cow/calf enterprise than for the winter-then-graze enterprise when grain sorghum stubble and winter wheat pasture are not available. When grain sorghum stubble and winter wheat pasture are not available, feed costs rise because hays are substituted for the less costly winter pasture. The capital requirements increase relatively more for the cow/calf enterprise than for the winter-then-graze enterprise, because the cow/calf enterprise has a much higher feed requirement than the winter-then-graze enterprise during the wintering period. The feed requirement per cow unit is higher because during the wintering period a cow unit is composed of a 1,000 pound pregnant cow, the required percentage of a bull, and replacement heifers. One unit of the winter-then-graze enterprise begins this period as a 400 pound steer which is gaining one pound per day.

The difference in feed requirements between the two enterprises is estimated by the computer program FMUP. If the relationship between feed requirements developed by FMUP for the cow/calf enterprise and the winter-then-graze enterprise is correct, then there is a valid reason for favoring the winter-then-graze enterprise when winter pasture from crop production is not available.

The major difference in crop enterprises of situation one and two is the specialization in wheat in situation two. A reason for this is that excluding the use of winter pasture from crop production affects the return to grain sorghum more than wheat. Beef production can be increased when AUM's from winter pasture are available for use in the beef enterprise. Production of AUM's is relatively higher per acre for grain sorghum stubble (1.4 AUM/Acre) than for winter wheat pasture (0.55 AUM/Acre). Removing the possibility for the beef enterprise to use the winter pasture therefore decreases the return from grain sorghum more than from wheat. Another reason for specializing in wheat is that the capital required per acre for wheat is less than the capital required per acre for grain sorghum. Because operating capital is limiting in the model, this influences the selection.

The gross margin for situation one is $27,008.44, and $22,299.45 for situation two. The gross margin is total revenue from all the enterprises less variable costs associated with these enterprises. Gross margin is the return to the resources which are fixed to the farm and can be used to compare alternative farming systems.

The main reason for the higher gross margin in situation one is the decrease in feeding costs by using winter pasture in the beef enterprises. Table 14 can be used to compare situation one and two. Despite having a 53.28 unit cow/calf enterprise only 22.79 additional tons of alfalfa hay are purchased in situation one. All of the brome and prairie hay is produced on the farm in both situations.

Table 14. Comparison of Hays Used in Situation One and Situation Two

	Situation One	Situation Two
Brome Hay	135.00 tons	135.00 tons
Prairie Hay	52.61 tons	52.61 tons
Alfalfa Hay	52.12 tons	29.33 tons

The decrease in feeding costs by using winter pasture makes the cow/calf enterprise and the winter-then-graze enterprise more profitable. Also, capital not used to buy feed when winter pasture is available allows more capital to be used for other enterprises leading to a more complete use of other fixed resources.

More operator labor is productively employed in situation one than in situation two. Total hours of owner operator labor required for situation one are 1,672.87 hours. For situation two, 1,333.32 hours of owner operator labor are required. Most of the difference in labor use between situation one and two (339.55 hours) can be attributed to the cow/calf enterprise which in situation one uses 318 hours of labor and is not included in situation two. The remainder of the difference is attributable to the change from grain sorghum to wheat in situation two which requires less labor.

The model assumes the same labor requirement for winter feeding on pasture or in drylot. The labor requirements for the beef enterprise are based on average labor requirements for the cow/calf and the winter-then-graze enterprises. These requirements reflect an average of alternative feeding systems. Situation two requires feeding of more hay which would be expected to require more labor than when the cattle forage for themselves on winter pasture as in situation one.

RESULTS OF SITUATION THREE AND FOUR

Situations three and four control enterprise combinations in order to determine the benefits attributable to the complementarity between the crop and livestock enterprise with respect to the production and use of winter pasture from grain sorghum and winter wheat.

As in situations one and two, situations three and four control the availability of winter pasture by allowing only the availability of winter pasture from wheat and grain sorghum production to change. In situations three and four, however, the enterprise combination is fixed.

In situation three, the enterprise combination determined optimal for situation one is fixed and then the model is reoptimized with winter pasture from wheat and grain sorghum production removed from the model. In situation four, the enterprise combination determined optimal for situation two is fixed and then the model is reoptimized with winter pasture from wheat and grain sorghum production available to the model.

Situation Three

The gross margin for situation three is $19,696.39 which is $7,312.05 less than for situation one. The only reason for this difference is the change in variable costs during the winter feeding period. The sources of change in variable costs from situation one to situation three are reported in table 15.

In situation three, hay requirements are increased because hay is substituted for winter pasture. An additional 122.59 tons of alfalfa hay are purchased in situation three. The change in the hay requirement is reported in table 16.

Table 15. Sources of Change in Variable Costs From Situation One to Situation Three

	Change in Variable Costs
Cost of Alfalfa Hay	+ $6742.55
Feeding Cost	+ $ 490.36
Interest on Alfalfa Hay	+ $ 240.59
Interest on Feeding Hay	+ $ 17.17
Cost of Winter Pasture	- $ 170.00
Interest on Winter Pasture	- $ 6.80
Rounding Error *	- $ 1.82
Net Change in Variable Costs	$7312.05

* Rounding errors occur when activities of situation one are locked into situation three.

Table 16. Hay Requirements for Situation One and Situation Three

	Situation One	Situation Three
Brome Hay	135.00 tons	135.00 tons
Prairie Hay	52.65 tons	52.65 tons
Alfalfa Hay	52.12 tons	174.71 tons

The change in hay requirement by month from situation one to three can be visualized by comparing figures 13 and 15 which report the monthly hay

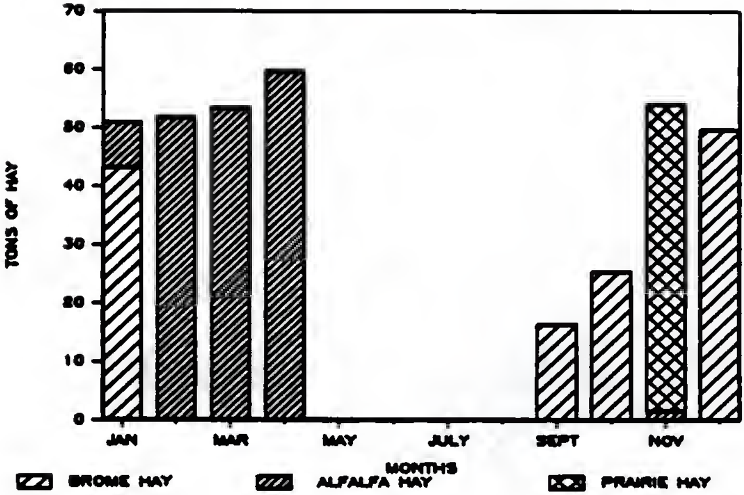

Figure 15. Monthly Feeding of Hays for Situation Three

requirement and the types of hay fed for situation one and three respectively.

In order to meet the increased operating capital requirements necessary to purchase the additional feed, the operating capital constraint is increased. An additional $7,063.09 is used bringing total operating capital used to $81,336.09.

The model assumes the same labor requirement for winter feeding on pasture or in drylot. The labor requirements for the beef enterprise are based on average labor requirements for the cow/calf and the winter-then-graze enterprises. These requirements reflect an average of alternative feeding systems. Information is not available to distinguish between labor requirements for winter feeding of cows or steers on winter pasture or in drylot. However, one would expect labor requirements for feeding would be less for winter pasturing than for feeding in a drylot under most arrangements. Therefore, the model probably underestimates labor use in situation three.

The cost reduction attributable to the complementarity between the crop and the beef enterprises with respect to winter pasture from crop production is $7,312.05. The cost reduction per acre of winter pasture is $21.50. The cost reduction per cow unit is $64.02 and $29.04 per steer.

Situation Four

The gross margin in situation four is $25,184.14 which is $2,884.68 higher than in situation two. This change is due to an increase in income from the $1,169.00 sale of brome hay and a decrease in variable feeding costs of winter feeding. Sources of change in variable costs from situation two to situation four are reported in table 17.

Table 17. Sources of Change in Variable Costs From Situation Two to Situation Four

	Change in Variable Cost
Cost of Alfalfa Hay	- $1613.15
Feeding Cost	- $ 215.44
Interest on Alfalfa Hay	- $ 56.61
Interest on Feeding Hay	- $ 7.54
Cost of Winter Pasture	+ $ 170.00
Interest on Winter Pasture	+ $ 6.80
Rounding Error *	+ $ 0.26
Net Change in Variable Costs	- $1715.68

* Rounding errors occur when activities of situation two are locked into situation four.

When the optimal enterprise combinations for situation two are locked in and winter pasture from crop production is allowed to enter the solution, the winter wheat pasture substitutes for hay in November and March. The change in the hay requirement from situation two to situation four is reported in table 18. Situation four uses 53.86 tons less hay than situation two. Alfalfa hay is purchased in situation two and is not in situation four. Situation four has a surplus of 24.53 tons of brome hay which are sold.

The change in hay requirement by month from situation two to four can be visualized by comparing figures 14 and 16 which report the monthly hay requirement and the types of hay fed for situation two and four respectively.

Table 18. Hay Requirements for Situation Two and Situation Four

	Situation Two	Situation Four
Brome Hay	135.00 tons	110.47 tons
Prairie Hay	52.65 tons	52.65 tons
Alfalfa Hay	29.33 tons	0.00 tons

The labor requirements reflect an average of alternative feeding systems. Situation four requires feeding less hay than situation two. It is expected that situation four is a less labor intensive system although this is not shown in model results.

The increase in the gross margin by $2,884.68 results from substituting winter pasture for purchased hay. This is a cost reduction of $8.48 per acre of winter pasture and $21.31 per steer.

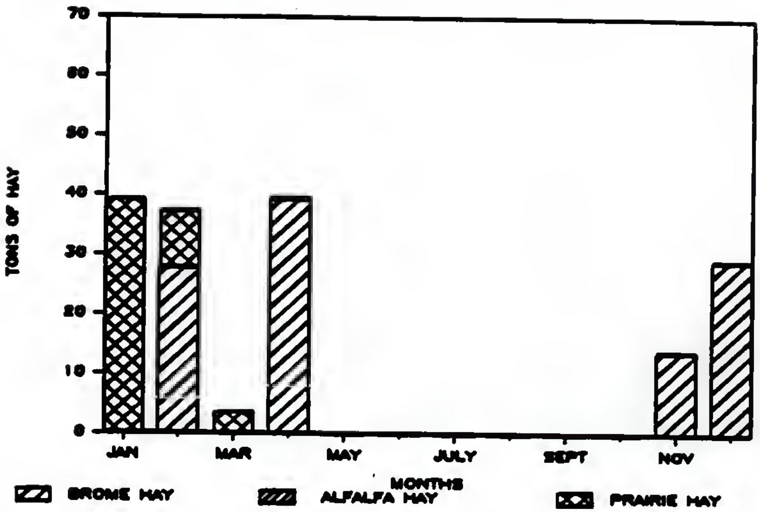

Figure 16. Monthly Feeding of Hays for Situation Four

Chapter VI

SUMMARY AND CONCLUSIONS

A linear programming model is used to determine the benefits of using grain sorghum stubble and winter wheat pasture in the production of beef. A representative Southeast Kansas farm is developed from Kansas Farm Management Association data on farms that produce beef and crops. The beef enterprises considered in this analysis are a spring calving cow herd and a winter-then-graze steer enterprise. The crop enterprises considered are grain sorghum, wheat, soybeans, alfalfa and sudangrass. Forage sources are grain sorghum stubble, winter wheat pasture, sudangrass, brome pasture, native tallgrass range, grain sorghum silage, prairie hay, brome hay and alfalfa hay. Hays can be purchased or sold.

Monthly feed requirements and monthly feed supplies from alternative feed sources are expressed in animal unit months (AUM's) except for the grazing requirements of the winter-then-graze steer enterprise from May through September which are expressed in acres of tallgrass range. An AUM is the amount of forage it takes to maintain a 1,000 pound beef animal for one month. Alternative forage sources are substituted to meet the AUM requirements of the beef enterprises. Anticipated inventory requirements of hays and/or silage are determined on a monthly basis.

The model is used to: 1) maximize returns to the fixed resources, 2) select type and size of enterprises, 3) allocate resources among enterprises, and 4) determine forage management and use. The study focuses on the benefits which arise from using winter wheat pasture and grain sorghum stubble in the production of beef.

BENEFITS OF USING WINTER WHEAT PASTURE AND GRAIN SORGHUM STUBBLE

The benefits of using winter wheat pasture and grain sorghum stubble in the production of beef are estimated by evaluating four alternative farm situations.

In situation one and two, the effect of availability of winter wheat pasture and grain sorghum stubble on optimal enterprise combination and resource use for the representative farm is determined. In situation one, winter wheat pasture and grain sorghum stubble are available as feed for the beef enterprise whereas in situation two these forages are not included.

In situation three and four, adjustments to availability of winter wheat pasture and grain sorghum stubble are evaluated to determine the cost reduction attributable to the complementarity between the crop and beef enterprises with respect to production and use of winter wheat pasture and grain sorghum stubble. In situation three, enterprises are fixed at levels optimal for situation one of the representative farm, and another optimal solution is determined with winter pasture from grain sorghum and wheat production removed from the model. In situation four, the enterprises are fixed at levels optimal for situation two of the representative farm and another optimal solution is determined with winter pasture from grain sorghum and wheat production added.

Situation One

The profit maximizing enterprise combination for situation one of the representative farm includes beef and crop enterprises. The beef enterprises are 53.28 cow units and 134.23 steers that are wintered-then-grazed. The calves produced in the cow/calf enterprise are weaned and wintered-then-grazed. The crop enterprise includes 139.26 acres of wheat, 200.74 acres of grain sorghum, 45 acres of prairie hay and 45 acres of brome hay.

All the winter wheat pasture and grain sorghum stubble produced on the farm is grazed. From October through April, 54.64 percent of the total AUM's required are supplied by winter wheat pasture and grain sorghum stubble. Additional forage sources used to meet the feed requirement of the beef enterprise include 880.55 acres of tallgrass range, 135.00 tons of brome hay, 52.61 tons of prairie hay and 52.12 tons of alfalfa hay. Brome hay and prairie hay are produced on the farm whereas alfalfa hay is purchased.

Owner operator labor is not limiting and no labor is hired. An additional unit of any enterprise does not require a reduction in the level of any other enterprise because of a shortage of owner operator labor. This indicates that the enterprises included in situation one are supplementary with respect to labor.

Operating capital is limiting both the beef and the crop enterprises indicating a competitive relationship among enterprises with respect to operating capital. Return to operating capital is 17.4 percent.

Situation Two

The profit maximizing enterprise combination for situation two of the representative farm includes a 135.37 steer winter-then-graze enterprise, 340 acres of wheat, 45 acres of prairie hay and 45 acres of brome hay.

The feed requirement of the beef enterprise is met by 437.79 acres of tallgrass range, 135 tons of brome hay, 52.61 tons of prairie hay and 29.33 tons of alfalfa hay. Brome hay and prairie hay are produced on the farm and alfalfa hay is purchased.

Owner operator labor is not limiting and no labor is hired. An additional unit of any enterprise would not require a reduction in the level of any other enterprises because of a shortage of owner operator labor. This indicates that enterprises are supplementary with respect to labor in situation two.

Operating capital is limiting both the beef and the crop enterprises in situation two indicating a competitive relationship between enterprises with respect to operating capital. Return to operating capital is 16.9 percent which is 0.5 percentage points less than in situation one.

Comparison of Situation One and Situation Two

The winter-then-graze enterprise is of similar size in situation one (134.23 steers), and situation two (135.37 steers) whereas the cow/calf enterprise is included in situation one and not in situation two. The major difference in crop enterprises of situation one and situation two is the specialization in wheat in situation two.

In situation one, the gross margin is $27,008.44 versus $22,299.45 in situation two. The return to both the beef and crop enterprises is increased by the production and use of winter wheat pasture and grain sorghum stubble. The use of winter pasture from crop production reduces the costs of producing beef because less hay is purchased. With less hay purchased, more capital becomes available for other enterprises.

The return to the crop enterprise is increased in two ways when winter pasture from crop production is available. First, a more capital intensive crop (grain sorghum) can be grown which has a higher gross margin per acre. Second, the production of beef using winter pasture produced jointly with grain provides a return from the winter pasture which otherwise would be unused.

The return to the beef enterprise is also increased in two ways when winter pasture from grain sorghum and wheat production is available. First, feeding costs are lower for both the winter-then-graze enterprise and the cow/calf enterprise thus increasing profitability of these enterprises. Second, additional return is derived from a cow/calf enterprise that can be maintained in situation one because less capital is used for purchasing hay.

Situation Three

For situation three, the optimal enterprise combination for situation one is fixed and another optimal solution is determined with winter pasture from grain sorghum and wheat production removed. The gross margin for situation three is $19,696.39 which is $7,312.05 lower than in situation one. This decrease in the gross margin results from substituting purchased hay for winter pasture and is an estimate of the value of the complementarity between the crop and beef enterprises with respect to winter pasture from crop production. An additional 122.59 tons of alfalfa are required when winter pasture from crop production is not available. The availability of winter pasture lowers feed costs by $21.50 per acre, $64.04 per cow unit and $29.04 per steer.

Situation Four

For situation four, the optimal enterprise combination for situation two is fixed and another optimal solution is determined with the availability of winter pasture from grain sorghum and wheat production added.

The gross margin for situation four is $25,184.14 which is $2,884.68 higher than in situation two. The increase in gross margin results from reducing feed costs by using winter pasture from crop production to replace purchased hay in the production of beef. The availability and use of winter pasture lowers feed costs by $8.48 per acre of pasture, and $21.31 per steer. When winter pasture from crop production is available 24.53 fewer tons of brome hay and 29.33 fewer tons of alfalfa hay are required. The brome hay is sold for $1,169.00 which accounts for part of the change in gross margin from situation two to situation four. The remainder of the change in the gross margin can be attributed to the change in other variable costs associated with feeding less hay.

CONCLUSIONS

The study of four different situations on a representative farm producing both beef and crops evaluates benefits to be gained from using winter wheat pasture and grain sorghum stubble in the production of beef. The availability of these forage sources has a substantial positive effect on the returns above the variable cost of production, and thus contributes to a more profitable use of fixed resources because of a decrease in feed costs for the beef enterprises and a change in the optimal beef and crop enterprise combination.

Operating capital available on the representative farm is a limiting factor in all four situations and influences enterprise selection and resource use. Labor available on the representative farm is adequate to meet all labor requirements for crop and beef enterprises included in the optimal solution. All owned land is used to the upper limit available on the representative farm in every situation studied. Rented cropland is also used to the upper limit available. Rented tallgrass range is not used to the upper limit.

The use of winter pasture from wheat and grain sorghum production reduces operating capital required for the beef enterprises by reducing the amount of hay purchased. The feed costs are reduced for both the cow/calf and the winter-then-graze enterprise on the representative farm.

The cow/calf enterprise derives more benefit from the use of winter pasture from crop production than the winter-then-graze enterprise. The reason is that the feed requirement of the cow/calf enterprise is higher in the months when winter pasture from crop production is available.

The effect of the use of winter pasture produced jointly with grain on the crop enterprises of the representative farm is to encourage a mix of wheat and grain sorghum production rather than a specialization in wheat. Summer annuals are not grown on cropland as a feed for the beef enterprises. All the cropland available on the representative farm is used for grain crops and the model would use more cropland for grain production if available. Because cropland is limiting, growing summer annuals as forage for the beef enterprises would take cropland away from wheat and grain sorghum production. Summer annuals are not required to provide AUM's on the representative farm during the summer months because there is unused tallgrass range available for rent. During the winter months AUM requirements are met by wheat pasture, grain sorghum stubble and/or hays. Winter wheat pasture and grain sorghum stubble were grazed when available during the winter months because they can supply AUM's at lower variable cost than when hay is fed. All smooth brome and prairie hay acreage available to the representative farm is hayed and used to meet winter forage requirements.

The complementarity between crop and beef enterprises with respect to the production and use of winter wheat pasture and grain sorghum stubble is important to the success of farms combining crop and beef enterprises. By taking advantage of this complementarity, farms producing both beef and crops reduce costs and increase returns to the whole farm enterprise.

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APPENDIX A

MATRIX STRUCTURE AND VALUES AND RIGHT HAND SIDE VALUES OF THE LINEAR PROGRAMMING MODEL

	SCOWURIT	SCULLCOW	WINTGRZ	OZPHST	OZTGNST	OZTGRNST	B400NOV1	S780OCT1	
PROFIT	59.80000-	436.00000	41.95000-	1.00000-	1.00000-	10.00000-	298.00000-	535.04000	PROFIT
JANAUM	.88870	.	.70320	.	.	.	.	.	JANAUM
FEBAUM	.98690	.	.73630	.	.	.	.	.	FEBAUM
MARAUM	.99320	.	.76890	.	.	.	.	.	MARAUM
APRAUM	1.25690	.	.80100	.	.	.	.	.	APRAUM
MAYAUM	1.26180	.	.	.	.	.	.	.	MAYAUM
JUNEAUM	1.26480	.	.	.	.	.	.	.	JUNEAUM
JULYAUM	1.30770	.	.	.	.	.	.	.	JULYAUM
AUGAUM	1.31050	.	.	.	.	.	.	.	AUGAUM
SEPTAUM	1.31340	.	.	.	.	.	.	.	SEPTAUM
OCTAUM	1.31620	.	.	.	.	.	.	.	OCTAUM
NOVAUM	.87470	.	.63550	.	.	.	.	.	NOVAUM
DECAUM	.88180	.	.66960	.	.	.	.	.	DECAUM
JANGRAIN	.86230	.	.	.	.	.	.	.	JANGRAIN
FEBGRAIN	.88030	.	.	.	.	.	.	.	FEBGRAIN
MARGRAIN	.91040	.	.	.	.	.	.	.	MARGRAIN
APRGRAIN	.38420	.	.	.	.	.	.	.	APRGRAIN
MAYGRAIN	.39750	.	.	.	.	.	.	.	MAYGRAIN
JUNGRAIN	.41080	.	.	.	.	.	.	.	JUNGRAIN
JULGRAIN	.42390	.	.	.	.	.	.	.	JULGRAIN
AUGGRAIN	.43680	.	.	.	.	.	.	.	AUGGRAIN
SEPGRAIN	.44960	.	.	.	.	.	.	.	SEPGRAIN
OCTGRAIN	.46240	.	.	.	.	.	.	.	OCTGRAIN
NOVGRAIN	.79960	.	.	.	.	.	.	.	NOVGRAIN
DECGRAIN	.83120	.	.	.	.	.	.	.	DECGRAIN
JANLAB	.91500	.	.50000	.	.	.	.	.	JANLAB
FEBLAB	.99700	.	.50000	.	.	.	.	.	FEBLAB
MARLAB	1.02000	.	.50000	.	.	.	.	.	MARLAB
APRLAB	.59500	.	.50000	.	.	.	.	.	APRLAB
MAYLAB	.24900	.	.25000	.	.	.	.	.	MAYLAB
JUNELAB	.21100	.	.25000	.	.	.	.	.	JUNELAB
JULYLAB	.21700	.	.25000	.	.	.	.	.	JULYLAB
AUGLAB	.25500	.	.25000	.	.	.	.	.	AUGLAB
SEPTLAB	.25400	.	.50000	.	.	.	.	.	SEPTLAB
OCTLAB	.27900	.	.	.	.	.	.	.	OCTLAB
NOVLAB	.29100	.	.50000	.	.	.	.	.	NOVLAB
DECLAB	.69500	.	.50000	.	.	.	.	.	DECLAB
TFCULL	.15000-	1.10000	.	.	.	.	.	.	TFCULL
TFSCALF	.70000-	.	1.00000	.	.	.	1.00000-	.	TFSCALF
TF780LB	.	.	.98000-	.	.	.	.	1.00000	TF780LB
TUN	.	.	.	.	1.00000	.	.	.	TUN
TFPH	.	.	.	1.00000	.	.	.	.	TFPH
RENTTUN	.	.	.	.	.	1.00000	.	.	RENTTUN
TFTUN	.	.	3.50000	1.00000-	1.00000-	1.00000-	.	.	TFTUN
CAPLMT	59.80000	.	41.95000	1.00000	1.00000	10.00000	298.00000	.	CAPLMT
CAP6MO	.	.	.	.50000	.50000	5.00000	.	.	CAP6MO
CAP12MO	29.90000	.	20.97500	.	.	.	298.00000	.	CAP12MO

	S400NOV1	ORZOTOR	ORZRTON	FRTBROME	HYOBROME	GZOBROME	HYFBROME	GZFBROME	
PROFIT	289.05000	1.00000-	10.00000-	22.50000-	37.00000-	1.00000-	59.00000-	1.00000-	PROFIT
APRAUM	.	.	.	.	.	.49000-	.	.93000-	APRAUM
MAYAUM	.	.59000-	.59000-	.	.	.75000-	.	2.35000-	MAYAUM
JUNEAUM	.	.56000-	.56000-	.	.	.50000-	.	.47000-	JUNEAUM
JULYAUM	.	.30000-	.30000-	.	.	.	.	.	JULYAUM
AUGAUM	.	.17000-	.17000-	.	.	.20000-	.	.23000-	AUGAUM
SEPTAUM	.	.06000-	.06000-	.	.	.42000-	.	.47000-	SEPTAUM
OCTAUM	.	.	.	.	.	.12000-	.	.23000-	OCTAUM
TFSCALF	1.00000	.	.	.	.	.	.	.	TFSCALF
TON	.	1.00000	.	.	.	.	.	.	TON
TFBROME	.	.	.	.	2.00000-	.	3.00000-	.	TFBROME
RENTTON	.	.	1.00000	.	.	.	.	.	RENTTON
BROMELNO	.	.	.	1.00000	1.00000	1.00000	.	.	BROMELNO
TFFBROME	.	.	.	1.00000-	.	.	1.00000	1.00000	TFFBROME
CAPLMT	.	1.00000	10.00000	22.50000	37.00000	1.00000	59.00000	21.00000	CAPLMT
CAP6MO	.	.50000	5.00000	11.25000	18.50000	.50000	29.50000	10.50000	CAP6MO

	FBRMJAN	FBRMFEB	FBRMMAR	FBRMAPR	FBRMSEPT	FBRMOCT	FBRMNOV	FBRMDEC	
PROFIT	4.80000-	4.80000-	4.80000-	4.80000-	4.80000-	4.80000-	4.80000-	4.80000-	PROFIT
JANAUM	3.30000-	.	.	.	.	.	.	.	JANAUM
FEBAUM	.	3.30000-	.	.	.	.	.	.	FEBAUM
MARAUM	.	.	3.30000-	.	.	.	.	.	MARAUM
APRAUM	.	.	.	3.30000-	.	.	.	.	APRAUM
SEPTAUM	.	.	.	.	3.30000-	.	.	.	SEPTAUM
OCTAUM	.	.	.	.	.	3.30000-	.	.	OCTAUM
NOVAUM	.	.	.	.	.	.	3.30000-	.	NOVAUM
DECAUM	.	.	.	.	.	.	.	3.30000-	DECAUM
TFBROME	1.20000	1.20000	1.20000	1.20000	1.20000	1.20000	1.20000	1.20000	TFBROME
CAPLMT	4.80000	4.80000	4.80000	4.80000	4.80000	4.80000	4.80000	4.80000	CAPLMT
CAP6MO	2.40000	2.40000	2.40000	2.40000	2.40000	2.40000	2.40000	2.40000	CAP6MO

	SELLBRM	BUYBRM	HLJAN	HLFEB	HLMAR	HLAPR	HLMAY	HLJUNE	
PROFIT	50.00000	55.00000-	4.50000-	4.50000-	4.50000-	4.50000-	4.50000-	4.50000-	PROFIT
JANLAB	.	.	1.00000-	.	.	.	.	.	JANLAB
FEBLAB	.	.	.	1.00000-	.	.	.	.	FEBLAB
MARLAB	.	.	.	.	1.00000-	.	.	.	MARLAB
APRLAB	.	.	.	.	.	1.00000-	.	.	APRLAB
MAYLAB	.	.	.	.	.	.	1.00000-	.	MAYLAB
JUNELAB	.	.	.	.	.	.	.	1.00000-	JUNELAB
TFBROME	1.05000	1.00000-	.	.	.	.	.	.	TFBROME
CAPLMT	.	55.00000	4.50000	4.50000	4.50000	4.50000	4.50000	4.50000	CAPLMT
CAP6MO	.	27.50000	2.25000	2.25000	2.25000	2.25000	2.25000	2.25000	CAP6MO

	HLJULY	HLAUG	HLSEPT	HLOCT	HLNOV	HLDEC	NYPMAINY	GZPMAINY	
PROFIT	4.50000-	4.50000-	4.50000-	4.50000-	4.50000-	4.50000-	24.55000-	1.00000-	PROFIT
MAYAUM	.	.	.	.	.	.	.	.59000-	MAYAUM
JUNEAUM	.	.	.	.	.	.	.	.56000-	JUNEAUM
JULYAUM	.	.	.	.	.	.	.	.30000-	JULYAUM
AUGAUM	.	.	.	.	.	.	.	.17000-	AUGAUM
SEPTAUM	.	.	.	.	.	.	.	.06000-	SEPTAUM
JULYLAB	1.00000-	.	.	.	.	.	.	.	JULYLAB
AUGLAB	.	1.00000-	.	.	.	.	.	.	AUGLAB
SEPTLAB	.	.	1.00000-	.	.	.	.	.	SEPTLAB
OCTLAB	.	.	.	1.00000-	.	.	.	.	OCTLAB
NOVLAB	.	.	.	.	1.00000-	.	.	.	NOVLAB
DECLAB	.	.	.	.	.	1.00000-	.	.	DECLAB
TFPH	.	.	.	.	.	.	1.17000-	.	TFPH
PMAYLAND	.	.	.	.	.	.	1.00000	1.00000	PMAYLAND
CAPLMT	4.50000	4.50000	4.50000	4.50000	4.50000	4.50000	24.55000	1.00000	CAPLMT
CAP6MO	2.25000	2.25000	2.25000	2.25000	2.25000	2.25000	12.27000	.50000	CAP6MO

	FPMJAN	FPMFEB	FPMMAR	FPMAPR	FPMSEPT	FPMOCT	FPMNOV	FPMDEC	
PROFIT	4.80000-	4.80000-	4.80000-	4.80000-	4.80000-	4.80000-	4.80000-	4.80000-	PROFIT
JANAUM	2.90000-	.	.	.	.	.	.	.	JANAUM
FEBAUM	.	2.90000-	.	.	.	.	.	.	FEBAUM
MARAUM	.	.	2.90000-	.	.	.	.	.	MARAUM
APRAUM	.	.	.	2.90000-	.	.	.	.	APRAUM
SEPTAUM	.	.	.	.	2.90000-	.	.	.	SEPTAUM
OCTAUM	.	.	.	.	.	2.90000-	.	.	OCTAUM
NOVAUM	.	.	.	.	.	.	2.90000-	.	NOVAUM
DECAUM	.	.	.	.	.	.	.	2.90000-	DECAUM
TFPM	1.20000	1.20000	1.20000	1.20000	1.20000	1.20000	1.20000	1.20000	TFPM
CAPLMT	4.80000	4.80000	4.80000	4.80000	4.80000	4.80000	4.80000	4.80000	CAPLMT
CAP6MO	2.40000	2.40000	2.40000	2.40000	2.40000	2.40000	2.40000	2.40000	CAP6MO

	FUSJAN	FUSFEB	FUSMAR	FUSAPR	FUSMAY	FUSJUNE	FUSJULY	FUSAUG	
JANGMAIN	1.00000-	.	.	.	.	.	.	.	JANGMAIN
FEBGMAIN	.	1.00000-	.	.	.	.	.	.	FEBGMAIN
MARGMAIN	.	.	1.00000-	.	.	.	.	.	MARGMAIN
APRGMAIN	.	.	.	1.00000-	.	.	.	.	APRGMAIN
MAYGMAIN	.	.	.	.	1.00000-	.	.	.	MAYGMAIN
JUNGMAIN	.	.	.	.	.	1.00000-	.	.	JUNGMAIN
JULGMAIN	.	.	.	.	.	.	1.00000-	.	JULGMAIN
AUGGMAIN	.	.	.	.	.	.	.	1.00000-	AUGGMAIN
TFUSLB	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	TFUSLB

	FUSSEPT	FUSOCT	FUSNOV	FUSDEC	FALFJAN	FALFFEB	FALFMAR	FALFAPR	
PROFIT	.	.	.	.	4.80000-	4.80000-	4.80000-	4.80000-	PROFIT
JANAUM	.	.	.	.	3.50000-	.	.	.	JANAUM
FEBAUM	.	.	.	.	.	3.50000-	.	.	FEBAUM
MARAUM	.	.	.	.	.	.	3.50000-	.	MARAUM
APRAUM	.	.	.	.	.	.	.	3.50000-	APRAUM
SEPGRAIN	1.00000-	.	.	.	.	.	.	.	SEPGRAIN
OCTGRAIN	.	1.00000-	.	.	.	.	.	.	OCTGRAIN
NOVGRAIN	.	.	1.00000-	.	.	.	.	.	NOVGRAIN
DECGRAIN	.	.	.	1.00000-	.	.	.	.	DECGRAIN
TFUSLB	1.00000	1.00000	1.00000	1.00000	.	.	.	.	TFUSLB
TFALF	.	.	.	.	1.20000	1.20000	1.20000	1.20000	TFALF
CAPLMT	.	.	.	.	4.80000	4.80000	4.80000	4.80000	CAPLMT
CAP6MO	.	.	.	.	2.40000	2.40000	2.40000	2.40000	CAP6MO

	FALFSEPT	FALFOCT	FALFNOV	FALFDEC	FSILJAN	FSILFEB	FSILMAR	FSILAPR	
PROFIT	4.80000-	4.80000-	4.80000-	4.80000-	4.00000-	4.00000-	4.00000-	4.00000-	PROFIT
JANAUM	.	.	.	.	.90000-	.	.	.	JANAUM
FEBAUM	.	.	.	.	.	.90000-	.	.	FEBAUM
MARAUM	.	.	.	.	.	.	.90000-	.	MARAUM
APRAUM	.	.	.	.	.	.	.	.90000-	APRAUM
SEPTAUM	3.50000-	.	.	.	.	.	.	.	SEPTAUM
OCTAUM	.	3.50000-	.	.	.	.	.	.	OCTAUM
NOVAUM	.	.	3.50000-	.	.	.	.	.	NOVAUM
DECAUM	.	.	.	3.50000-	.	.	.	.	DECAUM
TFSIL	.	.	.	.	1.22000	1.22000	1.22000	1.22000	TFSIL
TFALF	1.20000	1.20000	1.20000	1.20000	.	.	.	.	TFALF
CAPLMT	4.80000	4.80000	4.80000	4.80000	4.00000	4.00000	4.00000	4.00000	CAPLMT
CAP6MO	2.40000	2.40000	2.40000	2.40000	2.00000	2.00000	2.00000	2.00000	CAP6MO

	FSILSEPT	FSILOCT	FSILNOV	FSILDEC	GROWGS	GWGSSIL	GROWGSH	GRZOS	
PROFIT	4.00000-	4.00000-	4.00000-	4.00000-	80.47000-	83.75000-	62.87000-	.50000-	PROFIT
JANAUH	.	.	.	.	.	.	.	.14000-	JANAUH
SEPTAUH	.90000-	.	.	.	.	.	.	.	SEPTAUH
OCTAUH	.	.90000-	.	.	.	.	.	.26000-	OCTAUH
NOVAUH	.	.	.90000-	.	.	.	.	.56000-	NOVAUH
DECAUH	.	.	.	.90000-	.	.	.	.42000-	DECAUH
APRLAB	.	.	.	.	.39000	.29000	.39000	.	APRLAB
MAYLAB	.	.	.	.	.40000	.40000	.40000	.	MAYLAB
JUNELAB	.	.	.	.	.32000	.32000	.32000	.	JUNELAB
JULYLAB	.	.	.	.	.21000	.21000	.21000	.	JULYLAB
SEPTLAB	.	.	.	.	.11000	.53000	.11000	.	SEPTLAB
OCTLAB	.	.	.	.	.46000	2.52000	.46000	.	OCTLAB
NOVLAB	.	.	.	.	.37000	.96000	.37000	.	NOVLAB
CHOPLAND	.	.	.	.	1.00000	1.00000	.	.	CHOPLAND
NCHPLAND	.	.	.	.	.	.	1.00000	.	NCHPLAND
TFUSBU	.	.	.	.	48.20000-	.	32.13000-	.	TFUSBU
TFSIL	1.22000	1.22000	1.22000	1.22000	.	8.00000-	.	.	TFSIL
FWHAPR	.	.	.	.	.30000	.22000	.30000	.	FWHAPR
FWHMAY	.	.	.	.	.31000	.31000	.31000	.	FWHMAY
FWHJUNE	.	.	.	.	.25000	.25000	.25000	.	FWHJUNE
FWHJULY	.	.	.	.	.16000	.16000	.16000	.	FWHJULY
FWHSEPT	.	.	.	.	.08000	.41000	.08000	.	FWHSEPT
FWHOCT	.	.	.	.	.35000	1.94000	.35000	.	FWHOCT
FWHNOV	.	.	.	.	.28000	.75000	.28000	.	FWHNOV
TFSTALKS	.	.	.	.	1.00000-	.	1.00000-	1.00000	TFSTALKS
CAPLMT	4.00000	4.00000	4.00000	4.00000	80.47000	83.75000	62.87000	.50000	CAPLMT
CAP6MO	2.00000	2.00000	2.00000	2.00000	40.23000	41.87000	31.44000	.25000	CAP6MO

	PREPAROS	SELLGS	BUYGS	OZSG	GROWALF	BUYALF	SELLALF	SELLHAY	
PROFIT	.25000-	2.51000	3.13000-	56.94000-	122.57000-	55.00000-	50.00000	40.00000	PROFIT
JULYAUH	.	.	.	1.57000-	.	.	.	.	JULYAUH
AUGAUH	.	.	.	1.57000-	.	.	.	.	AUGAUH
SEPTAUH	.	.	.	.35000-	.	.	.	.	SEPTAUH
APRLAB	.	.	.	.39000	.	.	.	.	APRLAB
MAYLAB	.	.	.	.40000	.	.	.	.	MAYLAB
JUNELAB	.	.	.	.32000	.	.	.	.	JUNELAB
NOVLAB	.	.	.	.37000	.	.	.	.	NOVLAB
CHOPLAND	.	.	.	1.00000	1.00000	.	.	.	CHOPLAND
TFUSBU	1.00000	1.00000	1.00000-	.	.	.	.	.	TFUSBU
TFUSLB	56.00000-	.	.	.	.	.	.	.	TFUSLB
FWHAPR	.	.	.	.30000	.	.	.	.	FWHAPR
FWHMAY	.	.	.	.31000	.	.	.	.	FWHMAY
FWHJUNE	.	.	.	.25000	.	.	.	.	FWHJUNE
FWHNOV	.	.	.	.28000	.	.	.	.	FWHNOV
TFALF	.	.	.	.	2.65000-	1.00000-	1.05000	.	TFALF
TFPH	.	.	.	.	.	.	.	1.05000	TFPH
CAPLMT	.25000	.	3.13000	56.94000	122.57000	55.00000	.	.	CAPLMT
CAP6MO	.13000	.	1.57000	28.47000	61.29000	27.50000	.	.	CAP6MO

	BUYPHAY	GROWSB	GROWSBR	SELLSB	GROWWHT	GROWWTR	GRZWHT	SELLWHT	
PROFIT	45.00000-	66.42000-	56.60000-	6.49000	60.02000-	51.00000-	.50000-	3.65000	PROFIT
MARAUM	.	.	.	.	.	.	.28000-	.	MARAUM
OCTAUM	.	.	.	.	.	.	.10000-	.	OCTAUM
NOVAUM	.	.	.	.	.	.	.14000-	.	NOVAUM
DECAUM	.	.	.	.	.	.	.03000-	.	DECAUM
APRLAB	.	.23000	.23000	.	.01000	.01000	.	.	APRLAB
MAYLAB	.	.33000	.33000	.	.	.	.	.	MAYLAB
JUNELAB	.	.61000	.61000	.	.47000	.47000	.	.	JUNELAB
JULYLAB	.	.07000	.07000	.	.58000	.58000	.	.	JULYLAB
AUGLAB	.	.	.	.	.56000	.56000	.	.	AUGLAB
SEPTLAB	.	.13000	.13000	.	.37000	.37000	.	.	SEPTLAB
OCTLAB	.	.50000	.50000	.	.14000	.14000	.	.	OCTLAB
NOVLAB	.	.67000	.67000	.	.	.	.	.	NOVLAB
CROPLAND	.	1.00000	.	.	1.00000	.	.	.	CROPLAND
RCRPLAND	.	.	1.00000	.	.	1.00000	.	.	RCRPLAND
FWRAPR	.	.18000	.18000	.	.	.	.	.	FWRAPR
FWRMAY	.	.25000	.25000	.	.	.	.	.	FWRMAY
FWRJUNE	.	.47000	.47000	.	.36000	.36000	.	.	FWRJUNE
FWRJULY	.	.05000	.05000	.	.45000	.45000	.	.	FWRJULY
FWRAUG	.	.	.	.	.43000	.43000	.	.	FWRAUG
FWRSEPT	.	.10000	.10000	.	.28000	.28000	.	.	FWRSEPT
FWROCT	.	.38000	.38000	.	.10000	.10000	.	.	FWROCT
FWRNOV	.	.51000	.51000	.	.	.	.	.	FWRNOV
TFPH	1.00000-	.	.	.	.	.	.	.	TFPH
TFSB	.	17.86000-	11.91000-	1.00000	.	.	.	.	TFSB
TFWRT	.	.	.	.	31.20000-	20.77000-	.	1.00000	TFWRT
TFWRTGRZ	.	.	.	.	1.00000-	1.00000-	1.00000	.	TFWRTGRZ
CAPLMT	45.00000	66.42000	56.60000	.	60.02000	51.00000	.50000	.	CAPLMT
CAP6MO	22.50000	33.21000	28.30000	.	30.01000	25.50000	.25000	.	CAP6MO

	BC6M#14	BC12M#14	MHS1	
PROFIT	.07000-	.14000-	.	PROFIT
CAP6MO	1.00000-	.	.	CAP6MO
CAP12MO	.	1.00000-	.	CAP12MO

Table A-1. Right Hand Side Values of the Model

	Resource Units Available
Crop Land (Acres)	180.00
Rented Crop Land (Acres)	160.00
Improved Brome Pasture (Acres)	45.00
Prairie Hay Land (Acres)	45.00
Tall Grass Range Land (Acres)	300.00
Rented Tall Grass Range Land (Acres)	850.00
January Labor (Hours)	215.90
February Labor (Hours)	215.90
March Labor (Hours)	222.25
April Labor (Hours)	224.79
May Labor (Hours)	285.75
June Labor (Hours)	317.50
July Labor (Hours)	317.50
August Labor (Hours)	317.50
September Labor (Hours)	285.75
October Labor (Hours)	261.94
November Labor (Hours)	222.25
December Labor (Hours)	190.50
Operating Capital (Dollars)	74,273.00
April Field Work Time (Hours)	170.00
May Field Work Time (Hours)	150.00
June Field Work Time (Hours)	140.00
July Field Work Time (Hours)	160.00
August Field Work Time (Hours)	210.00
September Field Work Time (Hours)	160.00
October Field Work Time (Hours)	170.00
November Field Work Time (Hours)	170.00

APPENDIX B

CROP AND BEEF ENTERPRISE BUDGETS

Table B-1. Variable Costs and Returns per Head of Winter-then-Graze Steer Enterprise[1]

VARIABLE COSTS INCLUDED IN OBJECTIVE FUNCTION COEFFICIENT	
Protein......................................$	15.75
Minerals and Salt............................	1.20
Veterinary Drugs, and Supplies...............	7.50
Repairs......................................	7.00
Fuel, Oil, Utilities.........................	5.50
Miscellaneous	5.00
Total..$	41.95
VARIABLE COSTS NOT INCLUDED IN OBJECTIVE FUNCTION COEFFICIENT	
Labor (4.5 Hours)[2]	
Feeding Costs[2]	
Alfalfa Equivalent (tons)[2]	
Tallgrass Range (3.5 acres)[2]	
Interest Expense on Variable Costs[2]	
Marketing Costs (3 percent of sales).............$	16.55
RETURNS/HEAD	
Market Steer (780 lb. @ $0.7071/lb.).............$	551.54
Less Cost of Steer (400 LB. @ $0.745/lb.)........	-298.00
Less Death Loss (2 percent of sales).............	-11.03
GROSS RETURNS/HEAD ....$	242.50

1 Developed from Farm Management Guide MF-594 "Winter and Graze Beef"

2 Variable cost of these inputs depends on the levels determined by the model

Table B-2. Variable Costs and Returns per Cow Unit for the Cow/calf Enterprise.[1]

VARIABLE COSTS INCLUDED IN OBJECTIVE FUNCTION COEFFICIENT	
Protein Minerals and Salt.........................$	12.60
Veterinary, Drugs, and Supplies..................	7.25
Repairs...	14.00
Fuel, Oil, Utilities..............................	17.25
Miscellaneous	8.70
Total...$	59.80
VARIABLE COSTS NOT INCLUDED IN OBJECTIVE FUNCTION COEFFICIENT	
Labor (5.987 hours)[2]	
Feeding Costs[2]	
Alfalfa Hay Equivalent (3.9 tons)[2]	
Tallgrass Range[2]	
Interest Expense on Variable Costs[2]	
Marketing Costs (3 percent of sales)............$	8.02
Grain Sorghum Required (7.249 lbs.)	
RETURNS/COW UNIT	
Market Calves (400 lb. @ $0.745/lb x 0.70[3]).....$	208.60
Market Cull Cows (1000 lb. @ $0.436 x 0.135[4])....	58.86
Gross Returns/Cow Unit ....$	267.46

1 Develop from KSU Farm Management Guide MF-266 "Beef Cowherd"
2 Use of these inputs and thus variable costs depend on the optimal levels determined by the model
3 An 85 percent calf crop is produced and 15 percent of the calves are maintained for replacement heifers
4 15 percent of the cows are culled which include a 1.5 percent death loss

Table B-3. Variable Costs and Returns per Acre of Unfertilized Brome Hay (Custom Hire)[1]

VARIABLE COSTS INCLUDED IN OBJECTIVE FUNCTION COEFFICIENT	
Swath	$ 7.00
Bale	14.00
Haul	16.00
Total	$ 37.00
VARIABLE COSTS NOT INCLUDED IN OBJECTIVE FUNCTION COEFFICIENT	
Interest on Variable Costs[2]	$ 1.30
5 Percent Storage Loss	-5.50
YIELD PER ACRE	2.00 Tons
PRICE PER TON	$ 55/Ton
RETURNS PER ACRE	$ 110.00

1 Kansas Crop and Livestock Reporting Service. "Rates Paid by Kansas Farmers For Custom Work", Topeka, Kansas, 1983.

2 Use of these inputs and thus variable costs depend on the optimal levels determined by the model

Table B-4. Variable Costs and Returns per Acre of Fertilized Brome Hay (Custom Hire)[1]

VARIABLE COSTS INCLUDED IN OBJECTIVE FUNCTION COEFFICIENT		
Swath	$	14.00
Bale		21.00
Haul		24.00
Total	$	59.00
VARIABLE COSTS NOT INCLUDED IN OBJECTIVE FUNCTION COEFFICIENT		
Interest on Variable Costs	$	1.30
Fertilizer and Lime		22.50
5 Percent Storage Loss		8.25
YIELD PER ACRE		3.00 Tons
PRICE PER TON	$	55/Ton
RETURNS PER ACRE	$	165.00

1 Kansas Crop and Livestock Reporting Service. "Rates Paid by Kansas Farmers For Custom Work", Topeka, Kansas, 1983.

Table B-5. Variable Costs and Returns per Acre of Prairie Hay (Custom Hire)[1]

VARIABLE COSTS INCLUDED IN OBJECTIVE FUNCTION COEFFICIENT	
Swath....................................$	7.00
Bale.....................................	8.19
Haul.....................................	9.36
Total....................................$	24.55
VARIABLE COSTS NOT INCLUDED IN OBJECTIVE FUNCTION COEFFICIENT	
Interest on Variable Costs...............$	0.86
5 Percent Storage Loss...................	2.63
YIELD PER ACRE...........................	1.17 Tons
PRICE PER TON............................$	45/Ton
RETURNS PER ACRE.........................$	52.65

1 Kansas Crop and Livestock Reporting Service. "Rates Paid by Kansas Farmers For Custom Work", Topeka, Kansas, 1983.

Table B-6. Variable Costs and Returns per Acre of Alfalfa (Custom Hire)[1]

VARIABLE COSTS INCLUDED IN OBJECTIVE FUNCTION COEFFICIENT		
Seed[2]	$	6.00
Fertilizer and Lime[2]		22.50
Plant[2]		1.23
Sweep[2]		1.11
Plow[2]		4.41
Harrow		3.62
Herbicide and Insecticide		10.20
Swath		21.00
Bale		18.55
Haul		21.13
Total	$	122.57
VARIABLE COSTS NOT INCLUDED IN OBJECTIVE FUNCTION COEFFICIENT		
Interest on Variable Costs	$	4.13
5 Percent Storage Loss		7.28
YIELD PER ACRE		2.65 Tons
PRICE PER TON	$	55/Ton
RETURNS PER ACRE	$	145.75

1 Kansas Crop and Livestock Reporting Service. "Rates Paid by Kansas Farmers For Custom Work", Topeka, Kansas, 1983.
2 Prorated over 4 years

Table B-7. Variable Costs and Returns per Acre of Sorghum Silage[1]

VARIABLE COSTS INCLUDED IN OBJECTIVE FUNCTION COEFFICIENT	
Seed	$ 3.33
Herbicide and Insecticide	9.00
Fertilizer and Lime	17.80
Fuel and Oil	30.62
Repairs	17.00
Miscellaneous	6.00
Total	$ 83.75
VARIABLE COSTS NOT INCLUDED IN OBJECTIVE FUNCTION COEFFICIENT	
Interest on Variable Costs	$ 2.93
Labor Requirement[2]	
YIELD PER ACRE	8 Tons

1 Developed from KSU Farm Management Guide MF-648, "Dryland Sorghum Silage in Central Kansas"

2 Use of these inputs and thus variable costs depend on the optimal levels determined by the model

Table B-8. Variable Costs per Acre for Grazing Sudangrass[1]

VARIABLE COSTS INCLUDED IN OBJECTIVE FUNCTION COEFFICIENT	
Seed	$ 2.75
Herbicide and Insecticide	9.24
Fertilizer and Lime	26.20
Fuel and Oil	7.00
Repairs	8.00
Miscellaneous	3.75
Total	$ 56.94

VARIABLE COSTS NOT INCLUDED IN OBJECTIVE FUNCTION COEFFICIENT
Interest on Variable Costs[2]
Labor Requirement (1.48 hours)[2]

1 Estimated from KSU Farm Management Guide MF-573, "Dryland Grain Sorghum in Eastern Kansas"

2 Use of these inputs and thus variable costs depend on the optimal levels determined by the model

Table B-9. Variable Costs and Returns per Acre of Grain Sorghum[1]

VARIABLE COSTS INCLUDED IN OBJECTIVE FUNCTION COEFFICIENT	Owned Land	Rented Land
Seed.................................$	2.75	2.75
Herbicide and Insecticide..............	26.50	17.65
Fertilizer and Lime....................	26.20	17.45
Fuel and Oil...........................	10.69	10.69
Repairs................................	10.08	10.08
Miscellaneous..........................	4.25	4.25
Total.................................$	80.47	62.87
VARIABLE COSTS NOT INCLUDED IN OBJECTIVE FUNCTION COEFFICIENT		
Interest on Variable Costs............$	2.81	2.20
Labor Requirement (2.26 hours)[2]		
YIELD PER ACRE...................bushels	48.20	48.20
Operator Share...................bushels	48.20	32.13

1 Developed from KSU Farm Management Guide MF-573, "Dryland Grain Sorghum in Eastern Kansas"

2 Use of these inputs and thus variable costs depend on the optimal levels determined by the model

Table B-10. Variable Costs and Returns per Acre of Soybeans[1]

VARIABLE COSTS INCLUDED IN OBJECTIVE FUNCTION COEFFICIENT		Owned Land	Rented Land
Seed	$	12.00	12.00
Herbicide and Insecticide		16.20	10.79
Fertilizer and Lime		13.20	8.79
Fuel and Oil		10.69	10.69
Repairs		10.08	10.08
Miscellaneous		4.25	4.25
Total	$	66.42	56.60
VARIABLE COSTS NOT INCLUDED IN OBJECTIVE FUNCTION COEFFICIENT			
Interest on Variable Costs	$	2.32	1.98
Labor Requirement (2.54 hours)[2]			
YIELD PER ACRE	bushels	17.86	17.86
Operator Share	bushels	17.86	11.91

1 Developed from KSU Farm Management Guide MF-570, "Soybean Production In Eastern Kansas"

2 Use of these inputs and thus variable costs depend on the optimal levels determined by the model

Table B-11. Variable Costs and Returns per Acre of Wheat[1]

VARIABLE COSTS INCLUDED IN OBJECTIVE FUNCTION COEFFICIENT	Owned Land	Rented Land
Seed....................................$	8.00	8.00
Herbicide and Insecticide..............	4.40	2.90
Fertilizer and Lime....................	22.60	15.05
Fuel and Oil...........................	10.69	10.69
Repairs................................	10.08	10.08
Miscellaneous..........................	4.25	4.25
Total...................................$	60.02	51.00
VARIABLE COSTS NOT INCLUDED IN OBJECTIVE FUNCTION COEFFICIENT		
Interest on Variable Costs.............$	2.10	1.79
Labor Requirement (2.59 hours)[2]		
YIELD PER ACRE...................bushels	31.20	31.20
Operator Share...................bushels	31.20	20.77

1 Developed from KSU Farm Management Guide MF-572, "Continuous Cropped Winter Wheat In Eastern Kansas."
2 Use of these inputs and thus variable costs depend on the optimal levels determined by the model

Table B-12. Variable Costs per Acre for Grazing Pasture Grasses of Bromegrass and Tallgrass Range[1]

VARIABLE COSTS INCLUDED IN OBJECTIVE FUNCTION COEFFICIENT	
Water	$ 0.25
Fuel, Oil, Repairs	0.25
Fence Materials	0.25
Weed Control, Herbicides, Burning	0.25
Total	$ 1.00
VARIABLE COSTS NOT INCLUDED IN OBJECTIVE FUNCTION COEFFICIENT	
Interest on Variable Costs	$ 0.07
Labor Requirement[2]	
Fertilizer for Bromegrass[3]	22.50

1 Estimated
2 Included in the budgets for the beef enterprises
3 Use of these inputs and thus variable costs depend on the optimal levels determined by the model

Table B-13. Variable Costs per Acre for Grazing Winter Wheat Pasture and Grain Sorghum Stubble[1]

VARIABLE COSTS INCLUDED IN OBJECTIVE FUNCTION COEFFICIENT		
Water	$	0.25
Fuel, Oil, Repairs, Materials		0.25
Total	$	0.50
VARIABLE COSTS NOT INCLUDED IN OBJECTIVE FUNCTION COEFFICIENT		
Interest on Variable Costs	$	0.04
Labor Requirement[2]		

1 Estimated
2 Included in the budgets for the beef enterprises

An Analysis of a Crop-Forage-Livestock System
On a Representative Farm in Southeast Kansas
Using Linear Programming

by

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Abstract

Linear programming is used to study the most profitable farm organization on a representative Southeast Kansas farm which produces both beef and crops. Beef, forage, and small-grain crop enterprises are included into one whole farm planning model allowing the interrelationships among these enterprises to be incorporated into the decision framework.

A whole farm plan is developed that maximizes gross margin of the representative farm. Key variables reported are enterprise selection, resource allocation, forage management and use and gross margin.

The model allows for substitution of alternative grazed forage sources to meet the forage reqirements of the cow/calf or winter-then-graze enterprise. Also the beef enterprise is not fixed prior to optimization allowing the profit maximizing number and type of cattle to be determined jointly with the type and quantity of alternative forage sources.

Prairie hay, bromegrass hay or alfalfa hay can be purchased or produced and excess can be sold. Hay inventories are determined on a monthly basis.

For the representative farm, cropland and

operating capital are limiting but labor and tallgrass pasture are not.

Of special interest in this study are the benefits which arise from using winter wheat pasture and grain sorghum stubble in the production of beef. Four situations are compared. By reducing the hay required by the beef enterprise, winter pasture from crop production reduces the cost of beef production. These cost savings result in an increased gross margin for the beef enterprise. Operating capital not used to purchase hay can be used in other enterprises thus increasing returns to fixed resources and increasing gross margin for the whole farm plan.