AN ECONOMIC ANALYSIS OF STOCKER CATTLE GRAZING SYSTEMS ON OKLAHOMA NATIVE RANGE

By

DENNIS WAYNE RODDY

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INTRODUCTION

Livestock production is an important part of Oklahoma's economy. The cattle industry has been tied closely to Oklahoma's development. In 1891 there were a total of 787,000 head of cattle in Oklahoma. Oklahoma currently has 64,000 cattle operations with a total of 5,050,000 head. In January, 1988 the value of these cattle and calves was estimated at $2.25 billion (USDA, Oklahoma Agricultural Statistics).

The value of beef production is higher than any other agricultural commodity in Oklahoma. In 1986, cattle generated 1.15 billion dollars of revenue within the state of Oklahoma. Annual cattle production has four times the dollar value of hard red winter wheat, which is the second ranked agricultural commodity. The state of Oklahoma has ranked in the top six states in terms of national cattle inventories since 1980 and in the top four states since 1985 (USDA, Oklahoma Agricultural Statistics).

Oklahoma's rangeland provides an important forage source for Oklahoma's beef cattle industry. The combination of fertile soils and moderate to high annual precipitation provides Oklahoma stockmen with a low-cost source of high quality forage for much of the spring and summer seasons. Within the United States, rangelands occupy 54 percent of the land surface and provide 80 percent of all livestock feed (Semple). Approximately 46 percent of Oklahoma's land area (19.7 million acres) is comprised of rangeland grazed by livestock (Bernardo). Efficient utilization of this resource is critical if Oklahoma beef producers are to remain competitive in the global agricultural economy.

Beef producers face many economic pressures. Ranchers continually operate under the cost-price squeeze. The cost-price squeeze exists when livestock prices are close to the cost of production (Kohls and Uhl). Through the past two decades the real cost of producing and marketing cattle has continued in an upward trend, while cattle prices have remained volatile. Figure 1 shows the volatility of prices (in nominal terms) for 400-500 pound steers received in Oklahoma City from 1962 to 1989. In Figure 2 these prices are expressed in real terms along with a cost of production index for Oklahoma cattle producers (Bernardo). Clearly, a narrowing of the cost-price spread has occurred over the period. According to the 1987 USDA Feed Situation Outlook, the steer/corn price ratio decreased by 11 percent from 1950 to 1986. The observed trend in this indicator is further evidence of the declining profitability of beef cattle production.

In recent years, ranchers have faced problems with high interest rates, decreasing land values and a reduction in beef

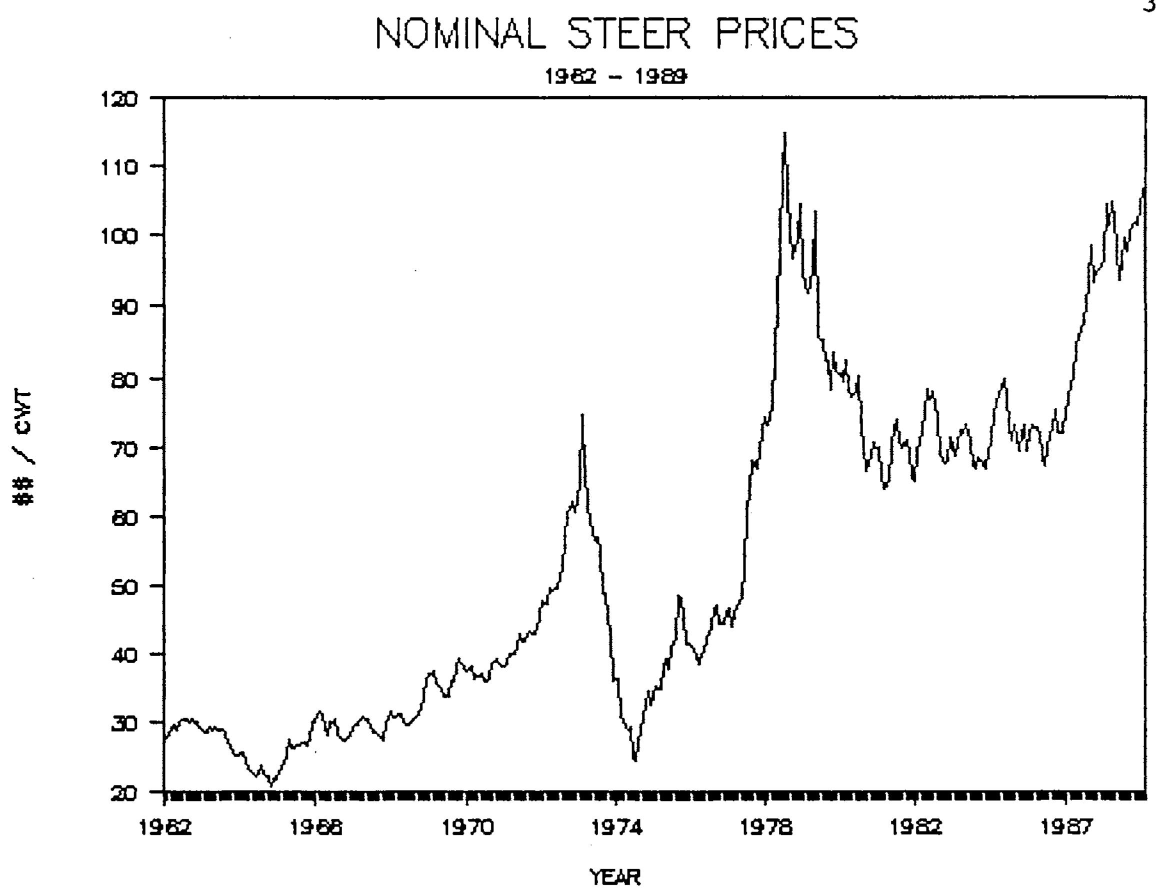

Figure 1. Nominal Steer Prices

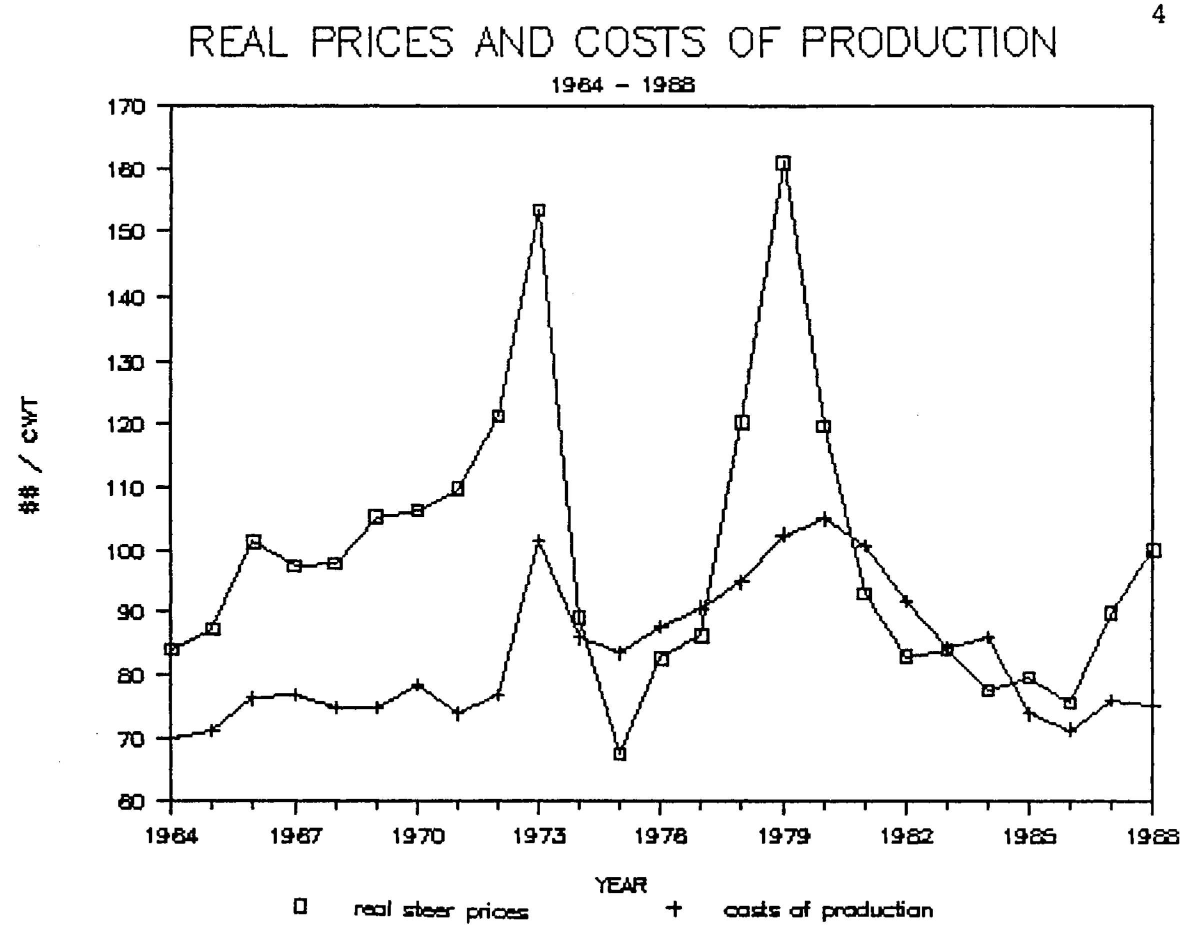

Figure 2. Real Steer Prices and Costs of Production

demand. High real interest rates in the late 1970's and early 1980's had an adverse impact upon the cattle industry where a large proportion of operating income is financed with debt. Declining land prices decreased the collateral values and put ranchers into a weakening financial position. Declining consumer demand for beef coupled with a relatively stable cattle supply has resulted in lower real prices of beef, and thus, lower incomes for producers.

Oklahoma cattle producers must operate under efficient production systems in order to remain competitive. The ranch production system contains several interrelated components. Different production practices, livestock enterprises, and alternative forage activities are combined to form a dynamic ranch production system. Each alternative component of the whole-ranch system should be evaluated to determine its contribution to the economic efficiency of the ranch. The interaction of these various components must then be analyzed to determine the most efficient beef-forage system available.

Problem

This study focuses on decisions made by Oklahoma stocker producers at the initiation of the summer grazing season. Risk and uncertainty cause a reduction in the reliability of future plans for production systems. Stocker producers use available information to determine which stocking rate, grazing system and production practices will provide the highest returns.

Each individual producer must make some form of prediction of forage production, livestock prices and other uncertain variables affecting income. When incorrect decisions are made at the beginning of the grazing season, the producer will often incur low or negative returns.

Cattle producers operate in an uncertain economic environment and face several types of risk. The principle need for management arises from the uncertainty associated with expectations of outcomes used in decision making (Hopkin et al.). The risk a producer faces can be divided into three types: production, marketing and financial.

Production risk concerns the random variability present in an agricultural production process. Stocker producers are forced to contend with weather, disease and pest problems. A primary source of production risk is derived from climatic variability. This variability is often reflected in the quantity and quality of forage produced. Livestock producers also face the production risk of converting forage into beef. Uncertainties associated with this conversion includes genetic variation, disease, response to feed additives and other factors of production.

Market or price risk results from unpredictable shifts in the supply and demand of inputs and products. Market or price risk can occur for both purchased inputs and saleable commodities. The inability of stocker producers to accurately predict output prices represents a primary source of price risk. The profitability of stocker production is critically dependent upon the spread between the purchase price of the calf and the sale price. Since small movements in this price spread can significantly affect profits, output price risk represents a significant share of the total risk facing stocker producers. Inputs that are essential to the operation of the ranch such as equipment, fuel and labor must be purchased regardless of the price. Fluctuations in their price may also contribute to market risk. Another source of market risk occurs when several marketing options are available. The stocker producer is often unsure of the most profitable time or place to market his cattle.

Producers can utilize several different tools to minimize the magnitude of production and market risk. Livestock production risk can be decreased by diversification of the whole-ranch system. Persaud and Mapp found that changes in enterprise combination within a ranch could reduce the coefficient of variation from .614 to .357 with a reduction of 37.5 percent in the gross margin. To reduce price and market risk, many producers utilize forward contracting, hedging and futures market options.

The third type of risk faced by ranchers is financial risk. This risk results in added variability of net returns due to the financial obligations associated with debt financing. Ranchers face uncertainty associated with the cost and availability of credit. Uncertain interest rates, institutional uncertainty, differing loan limits and security requirements are all factors that contribute to financial risk. Responses to reducing financial risk include maintaining liquidity, leasing of assets and incorporating insurance into the financial structure of the ranch. Liquidity can be maintained by spreading debt commitments and by utilizing long-term debt financing to lower annual cash payments. Leasing assets avoids debt commitments and provides flexible operations. Insurance reduces financial risk by utilizing a more cost effective means of maintaining a reserve of funds to offset a loss compared to a ranch generating and holding its own reserves.

In a ranch setting, different returns are realized when decisions are made under uncertain production conditions. Table I compares of per-acre returns from implementing alternative grazing systems over a 20 year period (Bernardo). Income variability in the return series is solely a result of fluctuations in input and output prices over the time period. The first column shows returns from season-long stocking, while the second column reports returns for intensive-early stocking. The third column reflects returns if the proper grazing system is selected each year. If the rancher operated in a perfectly certain environment, he could choose the optimal strategy each year and increase average returns by 50 percent. Of course, this is not the case, and the producer must select his grazing strategy based upon the expected

TABLE I

SUMMER STOCKER RETURNS PER ACRE, 1967-86

Year	SLS	IES	Max Return
1967	10.20	23.86	23.86
1968	5.48	16.95	16.95
1969	4.31	13.80	13.80
1970	-0.34	17.20	17.20
1971	3.92	18.36	18.36
1972	35.40	39.43	39.43
1973	32.97	24.75	32.97
1974	-10.76	-4.48	-4.48
1975	18.43	28.63	28.63
1976	-0.73	-2.63	-0.73
1977	8.66	7.10	8.66
1978	28.83	22.51	28.83
1979	12.08	-20.81	12.08
1980	18.79	13.34	18.79
1981	6.56	-0.60	6.56
1982	7.77	8.52	8.52
1983	0.39	-8.14	0.39
1984	8.85	10.13	10.13
1985	0.95	-7.95	0.95
1986	6.72	-5.87	6.72
mean	9.92	9.71	14.38
variance	131.39	215.87	134.77
std. dev.	11.46	14.69	11.61

distribution of enterprise net returns. An important question to be asked is "can the producer improve the probability of selecting the correct system by better using information available up to the stocking date?".

Stocker producers in Oklahoma are in need of better and additional information to aid them in decision-making. A better understanding of the profitability and risk associated with alternative grazing systems and practices will assist producers in making decisions such as the length of the grazing period, stocking rate, supplemental feeding strategies, and when to market the cattle. The model and findings from this study will enable a producer to incorporate additional information into his selection of a method for producing stocker cattle on native range in a given season.

Objectives

The general objective of this study is to identify efficient livestock grazing systems for Central Oklahoma stocker operations.

Specific objectives are:

1. To modify and validate the ERHYM-II (Ekalaka Rangeland Hydrology and Yield Model) range site simulation model to estimate range forage production on Oklahoma tallgrass prairie range sites.
2. To integrate the modified ERHYM-II with stocker cattle intake/growth and economic submodels to develop a bio-

economic model of the complete rangeland-stocker production system.

3. To use the model to estimate the expected value and variability of net returns from alternative stocker production enterprises under stochastic forage production and price conditions.

Procedures

This study requires development of a bioeconomic simulation model to evaluate alternative production alternatives available to Oklahoma summer stocker producers. The bioeconomic model combines the ERHYM-II range site model with stocker intake/growth and economic submodels to provide a complete range-stocker system model. The model needs to be capable of estimating the physical and economic consequences of alternative production practices under a variety of environmental conditions. Specific production practices evaluated in this application include alternative stocking rates, grazing systems (intensive-early stocking (IES) versus season-long stocking (SLS)), supplemental feeding practices, and prescribed burning.

The first step in developing the simulation model is to adapt/modify the ERHYM-II range site model to Oklahoma range conditions. Soil, climatic, and agronomic data necessary to customize the model to represent a tallgrass prairie range site in central Oklahoma are required. After modification the model must be evaluated for its ability to derive reasonable estimates of seasonal peak standing crop. In addition, daily output from the model's underlying processes (e.g., transpiration, soil evaporation, soil moisture, etc.) are evaluated through interaction with Oklahoma State University range scientists. Final validation of the model's ability to predict seasonal peak standing crop employs a 20-year data set of seasonal forage yields from a range site in close proximity to Stillwater, Oklahoma.

The ERHYM-II model is modified to provide estimates of forage production and forage quality through the grazing season. Seasonal forage production is transformed to weekly production using a relative growth curve estimated from forage clipping data taken at various intervals of the grazing season. A relationship estimating forage quality as a function of time and climatic variables is also estimated from available data.

The modified ERHYM-II model is integrated with a stocker cattle intake/growth model to derive estimates of livestock response under alternative management practices and managerial conditions. The stocker intake/growth model employs an adaptation of the California Net Energy System (CNES) to derive daily estimates of forage intake and weight gain. The model's ability to predict livestock performance is assessed using results from stocker production experiments on tallgrass prairie.

Livestock performance data are input into an economic submodel to derive estimates of annual net returns. The economic submodel generates an enterprise budget specific to the production practices and environmental conditions of the simulation run. The economic submodel is programmed to operate under either deterministic or stochastic price conditions.

The complete range-stocker system model is used to evaluate alternative stocker production enterprises available to stockmen in central Oklahoma. Important decision variables evaluated include the use of intensive-early stocking versus season-long stocking, alternative stocking rates for each system, and incorporation of prescribed burning into the management plan. Estimates of the distribution of annual net returns under each of the enterprises are derived under stochastic climatic and economic conditions. The enterprises are ranked based upon appropriate risk criteria including first and second-degree stochastic dominance and generalized stochastic dominance.

A forage prediction model is estimated using climatic variables observable prior to various decision points in the grazing season (e.g., prior to stocking in mid-April) to assist producers in selecting stocker enterprises. Using the simulation model, a distribution of net returns is derived by selecting stocking densities corresponding to projected forage production levels. The distribution of net returns derived from applying the forage prediction model is then ranked with the previous estimates using first-degree stochastic dominance, second-degree stochastic dominance, and generalized stochastic dominance.

Organization of the Study

Theoretical and empirical literature relevant to the simulation and decision theory models are discussed in Chapter II. The chapter reviews the alternative types of analysis that have been used in evaluating whole-ranch decision making in the Southern Plains Region. Literature concerned with stocker production on native rangeland within a ranch system is then discussed and followed by a brief discussion of biophysical simulation of cattle production systems. The application of alternative types of methodologies for forecasting forage production are also discussed.

Chapter III contains a discussion of the theoretical basis on which the simulation model is formulated as well as a discussion of decision rules which rank alternative actions. A brief discussion of biophysical simulation and its relationship with the dynamic theory of production is given. An outline of decision criteria with and without probability estimates is disclosed.

A detailed description of the bioeconomic range-stocker simulation model as well as a description of the forage and price data is given in Chapter IV. The computational procedure and adaption of the ERHYM range site model to Oklahoma tallgrass prairie are first presented. This discussion is followed by a presentation of the computational procedures of the stocker intake/growth and economic submodels.

Chapter V contains the results obtained from the application of the simulation model to alternative grazing activities. The alternative production and grazing system activities included in the model and the associated assumptions are explained. Probability distributions of annual net returns derived from alternative stocker enterprises are reported for both the base model and a revised model. Stocker production activities are then ranked based upon several evaluative criteria. A forage production forecasting model is developed and evaluated as a possible means of identifying annual stocker enterprises. Also, several diversification opportunities among the alternative stocker enterprises are evaluated.

Chapter VI provides a review of the results obtained and a discussion of the major conclusions derived from the analysis. This chapter also contains a discussion of the limitations of the simulation model and assumptions used in this study.

CHAPTER II

REVIEW OF LITERATURE

This chapter contains a selective review of relevant studies addressing some of the important empirical and methodological issues involved in this analysis. This review of the literature is intended to provide background and direction to the research effort. There are a large number of studies available that address the primary areas of focus included in this review of the literature; only those deemed most relevant to this study will be discussed.

This review addresses three specific areas pertinent to the research project outlined in Chapter I. First, a brief review of recent studies focusing on the economic analysis of cattle production on native range will be provided. To keep the review manageable only recent studies addressing management issues in Oklahoma will be discussed. Next, a brief discussion of biophysical simulation of range-beef production systems and their use in economic analysis will be presented. Finally, a review of forage prediction techniques relevant to this study is discussed.

Recent Studies in Range Economics

A survey of the agricultural economics literature reveals numerous studies completed in the area of ranch planning and organization. Linear programming models have often been applied to derive profit maximizing enterprise combinations for a representative ranch. Simulation models have also been used to evaluate ranch management decisions under uncertainty. A selected set of recent studies focusing on the economic analysis of beef cattle production on native range are reviewed below.

Guiterrez developed a Monte Carlo simulation model to evaluate the impact of various ranch management alternatives on expected income, risk, and firm survivability. REPFARM, a Fortran based whole-farm simulation model, was adjusted to include additional stochastic variables and alternative livestock enterprises. Modifications were added to calculate stochastic steer prices, steer sale weights and weaning weights for five raised stocker steer enterprises and five purchased steer enterprises. Selected management plans and economic scenarios were analyzed for a representative ranch. Guiterrez found that implementation of a grazing system management plan increased ranch profitability. Increased range forage yields coupled with decreased variability of forage yield reduced the cost of supplemental feeding. Gains in receipts were realized from increased weaning weights and increased production per acre of summer stockers utilizing an intensive-early grazing system.

A multi-period MOTAD (Minimum of Total Absolute Deviation) model was developed by Rawlins to analyze efficient organizations of forage and livestock enterprises for an eastern Oklahoma ranch. A decision framework was developed to represent forage quality and intake considerations as well as the various sources of risk facing livestock producers. The model was specified in the form of maximizing expected net returns subject to parametric restrictions on the mean absolute deviations in net returns. Feed rations were determined endogenously by constraining the animals intake and allowing any combination of forages or supplemental feeds to meet livestock nutrient requirements within each period. Different risk levels were determined by measuring the mean absolute deviation from expected net returns due to variability in forage yields, livestock prices and purchased inputs.

The results from this study indicate that efficient ranch plans are quite sensitive to the producer's degree of risk aversion. It was found that as the degree of risk aversion increases, livestock numbers are reduced and more stable livestock enterprises are substituted for risky production alternatives. Cow-calf enterprises become more desirable as the degree of risk aversion increases. Rawlins also found that large reductions in risk were not attainable without significant reductions in expected net returns.

Studies focusing on the area of range management within a stocker operation were performed by Bernardo and McCollum. They conducted a project which compared the costs and benefits of intensive-early stocking versus season-long stocking. Intensive-early stocking (IES) involves grazing approximately twice the number of head in the first half of the grazing season. IES was compared with season long stocking (SLS) using budget information for four alternative stocker activities. Costs and returns were estimated for the four activities assuming certain economic and production settings. IES was found to have the potential to increase profitability, improve range condition, and augment a producers marketing options.

Webb conducted a study which compared intensive-early stocking (IES) and season-long stocking (SLS). These grazing systems were analyzed to determine how they might be integrated into a crop livestock farming system in northeast Kansas. Linear programming was used to compare different activities representing the intensive-early stocking and season-long stocking practices.

Several LP models were tested to determine the interaction among crop and livestock activities. The base model allowed a choice of either grazing system or a combination of wintering livestock. Other models were constructed to allow only IES or SLS enterprises or to limit pasture or working capital. It was found that the representative Kansas farm operating under a criterion of profit maximization should contain a combination of intensive-early and season-long stocking. When grassland was limiting, intensive-early stocking was determined to be the preferred enterprise.

Bernardo et al. evaluated the influence of prescribed burning of rangeland on the expected value and the variability of net returns for a representative Oklahoma stocker enterprise. A Monte Carlo simulation model was used to represent the effect of prescribed burning in a stochastic economic and production environment. The simulation model was developed to represent the marketing, financial and production aspects of a ranch over a ten year period. Factor cost, output price and livestock response variables were included in the model as stochastic variables to represent the uncertainty underlying a stocker enterprise.

The stochastic simulation analysis determined that prescribed burning is a cost-effective range improvement strategy on both shallow and eroded prairie range sites. The prescribed burning program was, however, associated with increased income variability derived from stocker production. Some of this increased variability may be attributed to an increase in the probability and magnitude of deviations above the mean level of income. Prescribed burning was shown to reduce the risk levels associated with stocker production when measured in terms of relative variability.

These studies assisted in identifying optimal ranch plans and organization. These studies contribute a broad base of information that ranchers can use when identifying enterprise combinations and making decisions under uncertainty. Studies in the area of ranch organization and risk analysis are becoming more important to the range manager. While different combinations of grazing systems have been reported for several ranch studies, additional research is needed on the profitability and risk of these systems.

Simulation

Over the past two decades, agricultural scientists have focused on developing models to represent growth processes of plants and animals in alternative environments. These models, often referred to as biophysical simulation models or process growth models, have recently received increased attention in the agricultural economics discipline. Agricultural economists have utilized biophysical simulation models to predict the outcome associated with changing one or more of the inputs to a physical system.

Brorsen designed a simulation model for analyzing stocker cattle production on improved and native forages. Given specific forage and livestock information, the model estimate growth patterns and economic outcomes for a specific stocker cattle operation. The model was constructed to calculate energy requirements for growth and maintenance, as well as estimate dry matter intake on a bi-weekly basis. Forage quality was allowed to change within the model, but stocking density was determined endogenously based upon the amount of forage production available. That is, the model was not capable of estimating the impact on stocker production of situations when forage was a limiting factor of production.

The study determined that the California Net Energy System (CNES) was a satisfactory method for measuring energy requirements of stocker cattle. The intake function allowed for forage quality changes by using two different equations for total digestible nutrients (TDN) above and below 66 percent. Digestible protein requirements were obtained in the study by regressing weight and gain upon the protein requirements exhibited in the tables in the NRC manual (National Resource Council). The model also adjusted gains internally for compensatory growth, mature sizes, implants, and use of monensin.

Brorsen attached an economic component to the simulation model which estimated gross receipts operating and costs. The model considered vet supplies, trucking costs, commissions, interest, death loss, labor, minerals and pest control in estimating per-head net returns. The user specified the expected buying and selling prices of the cattle as well as all other costs of production.

Parsch et. al employed the biological-phenological Kentucky Beef Forage Model (GRAZE) to evaluate the performance of thirty alternative production management strategies under ten states of nature. The thirty strategies were defined within the model by changing the stocking rate, the number of grazing fields within a pasture, and the rotation period. The ten states of nature were identified as alternative weather scenarios.

The GRAZE model used in the study consists of a phenological plant growth-composition component, a physiological animal-growth-feed intake component and a plant-animal interface component. The GRAZE model incorporates selective grazing logic and animal growth concepts. In the GRAZE model the animal attempts to maximize its digestible dry matter intake rate by selecting plant material among a variable number of sub-areas within the total grazing area available.

Economic results from the GRAZE model indicated that both high and low stocking rate grazing strategies result in lower net returns than an intermediate stocking rate. When stocking rates were increased past the intermediate level, excessive use of inputs reduced the marginal value productivity to the point where it was less than marginal factor cost. This study also found that a high stocking rate was a high risk strategy because its performance is highly variable as a function of weather. Results of the study also revealed that the strategy with the highest expected weight gain does not always produce the highest return.

Cartwright and Doren describe the Texas A&M Beef Herd simulation model (TAMU) as a computer model programmed in FORTRAN IV designed to represent the growth, reproduction and lactation of beef cattle. The TAMU model accounts for animals on the individual basis of classes determined by sex and age. The model contains stochastic elements which are associated with birth, death, estrus, conception and removal. The computer model requires input values which define forage quality and availability on a monthly basis.

Sullivan and Cappella outlined several economic applications of the TAMU model. They state that the model can be used for benefit-cost analysis of improvements that would otherwise would be too costly to evaluate. The TAMU model can be interfaced with a linear programming model to provide a broader use for whole-farm planning. Stokes used the TAMU model to simulate preweaning and post-weaning performance of nine different beef cattle genotypes. The results indicated that selling weaned calves directly to the feedlot had the highest average net returns per head compared to selling calves at weaning.

These studies provide several models and processes for representing plant and/or animal growth. These studies demonstrate that biophysical simulation models are a tool for evaluating the production and performance of forage and livestock. In recent years, progress has been make in taking production economics from a theoretical framework to a level that realistically portrays the situations faced by ranch managers. This study supplements this area by evaluating grazing system strategies for Oklahoma native range.

Forage Prediction

Often in plant studies, a few specific environmental factors are found to exert a major influence upon plant growth. If these factors can be isolated and measured, then growth can be predicted by measuring these factors. Numerous studies have shown herbage production to be closely correlated to precipitation.

Currie and Peterson found that specific precipitation patterns accounted for a large percent of the variation in Colorado wheatgrass yields. Their study presented a statistical approach for estimating forage production and stocking rates on crested wheatgrass ranges grazed at different seasons in the front range of Colorado. Stepwise regression analysis was employed to determine the influence of monthly precipitation during the growing season upon forage yields. Precipitation and forage production data were collected for a period of eight years. Rainfall in April was found to account for 88 percent of variation in forage yields for spring grazed ranges. May and July rainfall accounted for 94 percent of the variation in forage yields for fall grazed ranges.

Stocking rates were closely associated with the amount of forage produced. Ordinary regression analysis was used to determine the relationship between stocking rate and forage yield. Correlation coefficients between forage production and stocking rates ranged from .94 for spring grazing to .99 for ranges grazed in the fall. The authors propose that comparable relationships of production and stocking rates could be constructed from existing data for many rangelands.

Murphy conducted a study to determine the effect of precipitation on California annual grasslands. Annual yield and daily precipitation data over a 16 year period were used in the analysis. Regression analysis was performed on the data to find the correlation between monthly precipitation and the following year's herbage yield. It was found that the time of the first precipitation in the fall sufficient to initiate germination in the winter grass was an important factor in seasonal forage yield. November precipitation was found to be the most significant variable in predicting the following season's annual grassland yield.

A study which describes a method for calculating site specific yield forecasts was conducted by Wight et al. This study evaluates a method of using weather records in conjunction with a physically-based forage yield model to make yield forecasts with stated probabilities of occurrence. A forage production model known as the Ekalaka Rangeland Hydrology and Yield Model (ERHYM) was used to associate soil water and climatic parameters in determining plant growth. Forage production was estimated to be a function of soil water content at the beginning of the growing season, daily precipitation, mean air temperature, and solar radiation.

The forecast procedure was tested using 55 years of weather records and 12 years of actual yield and soil water data for a range site in eastern Montana. The model was run once for each year of weather data available. The current year's value of soil water content was used with each run. For example, to predict 1989 forage yield, the soil water content at the beginning of the 1989 growing season would be used with each model run. If 50 years of weather data were available, the model would be run 50 times with the 1989 initial soil water content. The mean of these 50 yields provided the 1989 forecasted forage production. This model was found to predict within one standard deviation of the actual forage yield.

Powell et al. conducted a study which analyzed weather factors affecting tallgrass prairie hay production and quality. The objective was to learn which weather factors acting simultaneously accounted for the greatest variation in production. The study used yield data collected on native prairie located at Stillwater, Oklahoma from 1929 to 1951.

Stepwise multiple regression was used in the study to determine the combination of independent variables which accounted for the largest percentage of variation in forage production. The independent variables considered were temperature, cumulative total monthly precipitation, wind speed, spring and fall freeze dates, and previous year's yield. Multiple regression models were formulated using only weather data obtainable by June 1 because management decisions are made early in the growing season.

Only 48 percent of the variation in forage production could be predicted with data available prior to June 1. Precipitation was less important than was expected, except in years of large deficiency. The most important variables were found to be mean minimum November temperature, absolute minimum January temperature, absolute minimum November temperature, and absolute maximum April temperature.

These studies, along with several others, demonstrate the possibility of forecasting the growth or yield of forage before the growing season. Many forage prediction models have been estimated to predict peak standing crop both during and before the grazing season. This study provides an additional model for forage prediction using weather data prior to the initiation of grazing.

CHAPTER III

THEORY

Biophysical Simulation

Agricultural economists generally use some type of analytical model when performing research. Many of the analytical models are based on technical relationships in agriculture (Mapp). A biophysical simulation model is a complex mathematical model of some process with explicit attention to biological and/or physical determinants of agricultural production (Musser and Tew).

Traditional production function analysis utilizes simple static response functions to portray input-output relationships. These response (or production) functions describe the rate at which resources are transformed into products. Static production functions are characterized by an important set of underlying assumptions. Producers are assumed to manage in environment in which perfect certainty exists. The effects of weather, disease, and pests as well as yields are assumed known and constant. Factors such as technology, product demand, and population are assumed to be fixed at certain levels. Traditional production function analysis also assumes that inputs and outputs are homogeneous and timelessness exists.

Several problems occur when these traditional assumptions are applied to practical problem solving, which promotes biophysical simulation as an attractive alternative. A recent paper by Trapp and Walker compares traditional production economics and biological simulation. They cite five problems with traditional production function fitting: (1) decision makers usually interact with other variables during the production period; (2) data are scarce concerning the effects of uncontrollable variables; (3) technology and fixed factors of production change across time and statistical production functions quickly become obsolete; (4) in general, production is not timeless and inputs are not homogeneous; (5) data tends to be produced in bits and pieces which do not suit statistical production function estimation.

The first two problems Trapp and Walker cite concern uncontrollable variables and interaction among them. Simulation models can account for the stochastic effects of uncontrollable variables. Important interactions may often exist between controllable decision variables and uncontrollable or unknown inputs. When traditional production functions are fit with only known or obtainable data, reality is ignored and simplistic statistical functions may result (Trapp and Walker). Large amounts of research resources would be required to provide data sets rich enough to estimate multi-input production functions (Musser and Tew).

Trapp and Walker state that production is more like a recipe emphasizing process management, rather than strictly a formula which only prescribes ingredients. Because production steps are recursive, the timing of inputs is an important part of the production process. Timing causes inputs to become non-homogeneous. For example, in a given production season, pasture quality declines, animal size and intake changes and solar radiation values change.

Data used to measure production and inputs in traditional production function analysis is usually highly aggregated (Trapp and Walker). The consideration of more basic processes in plant and animal growth will produce a more accurate production model. Oltjen et al. suggest that using more basic processes improves response prediction across species and production conditions. The choice of the aggregation level of data often depends upon the intended use of the model.

Biophysical simulation models provide an alternative method for representing the production process. Simulation models provide a system of analysis where simultaneous equations can be used to represent the interdependence that exists between inputs and outputs. Biophysical simulation has a clear advantage over other methodologies for empirical analysis of dynamic, stochastic production problems; although, simulation models still face the economic problem of optimization (Boggess).

Simulation models are normally used to analyze decision alternatives rather than used for analytical derivations of an optimal input level (Boggess). This reason may account for the slow application of simulation models in decision making. Most agricultural economists do recognize the benefits of biophysical simulation for describing a production response surface. Musser and Tew state that simulation does not propose to identify optimal plans, but it proposes to provide qualitative information for farm managers. Trapp and Walker point out that several recent studies have been published which are at the frontier of developing optimal solution procedures for dynamic/simulation models.

Simple response functions are often not very useful when analyzing the influence of risk on producer decision making. The optimal level of output determined by the simple response function is normally not independent of other uncontrolled variables. The decision maker often needs probability distributions of net returns over time for different enterprises in order to make a decision concerning risk. Producers may then apply decision criterion reflecting risk attitude to choose the preferred distribution.

Biophysical simulation models can make a significant contribution to the area of risk analysis because of their ability to create their own data sets. Instead of using scarce experimental data for risk analysis, simulation models can often use available time series data as well as data from other sources to generate probability distributions associated with different strategies. Experimental data could be used for risk analysis, but experiments are rarely continued for a long enough time period to provide satisfactory time series data.

Biophysical simulation has also enhanced research opportunities in the area of risk analysis because of the explicit modeling of the sources of risk in agricultural production. Simulation models focus on the interaction between production inputs. Crop growth simulators focus on the interaction between weather and crop growth. Livestock simulators focus on the interaction between forage and livestock growth (Musser and Tew). Many simulation models often have stochastic features as a component of the model. The combination of capturing the effects of interaction and stochastic processes in agricultural production allows biophysical simulation models a greater potential for application to risk analysis.

Decision Making Under Uncertainty

Agricultural producers are forced to make many decisions under risk and uncertainty. Producers seldom have complete knowledge of the input-output relationships and prices involved in decision making. Producers must use their limited information and consider both the possible outcomes and the individuals risk attitude when making decisions.

Knight divided decision making situations into a risk class and an uncertain class. He defined the risk class as one in which the decision maker knows both the alternative outcomes and their associated objective probabilities. Knight stated that uncertainty exists when the decision maker has little information about the alternative outcomes and does not know the associated probabilities of occurrence.

The decision maker's willingness to take on risk is a reflection of that individual's attitude, not his management ability. According to Boehlje and Eidman, decision makers can be divided into three categories according to their risk attitudes: risk averse, risk preferring, and risk neutral. Risk averters may be described as cautious individuals with preferences for less risky sources of income and investment. Risk averters will generally sacrifice some amount of expected income to reduce the probability of low income or losses. Risk preferrers have a preference for the chance of a higher outcome. These individuals select an alternative with some probability of a higher outcome, even though they must also accept some probability of a lower outcome. The risk neutral individual chooses the strategy with the highest expected return, regardless of the probabilities associated with the different outcomes.

Decision problems consist of many related components. Boehlje and Eidman define seven components of a decision problem: (1) actions representing the choices available to the decision maker, (2) uncontrollable events or states representing alternative levels of uncertain variables, such as weather or prices, (3) payoffs or consequences, (4) prior probabilities, (5) predictions of states obtained through the use of some predictive device, (6) posterior probabilities which combine the prior probabilities and data on the accuracy of the predictions, and (7) choice criteria used to select an appropriate course of action.

Decision theory suggests that maximization of expected utility is the appropriate choice criterion. Unfortunately, utility functions are not known and can only be estimated using limited information. An alternative approach is to have the decision maker assign a certainty equivalent to each available action. The action with the highest certainty equivalent is then chosen (Boehlje and Eidman).

Several decision rules have been developed which rank alternative actions. These rules may be divided into three groups: decision criteria without probability estimates, decision criteria with known probability estimates, and efficiency criteria. Efficiency criteria sort actions that should be considered by a specific group of decision makers from those actions that should not. The concept of efficiency criteria is to eliminate actions that are dominated by other actions being considered. The decision maker then chooses from a smaller set of actions when making the decision.

Decision Criteria Without Probability Estimates

Three decision rules that do not require probability estimates are the maximin, maximax, and the principle of insufficient reason. These three decision criteria do not require information about the probability distributions of alternative actions. Such criteria are often criticized because the situation where the manager has no information concerning these probabilities is rare. These rules can be used when a decision maker feels uncomfortable making probability estimates, but desires a basis for making comparisons.

The maximin rule suggests that the decision maker determine the worst outcome of each action and then select the action that maximizes the minimum gain. This decision rule takes a pessimistic approach by considering only the worst outcomes. The maximax rule considers only the most desirable return for each action and selects the action with the highest return. This is an optimistic rule by considering only the most desirable outcomes. Unlike the former two decision rules, the principle of insufficient reason considers all possible outcomes. This rule assumes that all events are equally likely and selects the action with the most desirable average outcome.

Decision Criteria With Probability Estimates

Some form of probability estimates of the outcome associated with particular actions are usually available to the decision maker. Two decision criteria that consider these probabilities are maximization of expected return and the safety-first criterion. These decision rules consider all outcomes and the probabilities of these outcomes. However, an important limitation of these rules is that they do not employ information on the variability of outcomes, and can only be used by risk neutral individuals.

Expected return is a single statistic that considers all outcomes and known probabilities. The expected return of a specific event is equal to the probability weighted sum of the possible returns of each outcome (Boehlje and Eidman). Utility maximizing risk neutral decision makers would select the action with the highest expected monetary value. Risk averse or risk preferring individuals would use another type of decision rule which considers other parameters of the distribution such as variability of outcomes.

The safety-first criterion involves maximizing the expected monetary value subject to a specified probability of exceeding a minimum level of net income (Boehlje and Eidman). The decision maker establishes a minimum income level and the probability by which an outcome must exceed this income level. The action with the highest expected monetary value that meets both the minimum income level and the specified probability is selected.

Efficiency Criteria

Efficiency criteria contain a preference relationship which provides a partial ordering of choices given specified restrictions on the decision maker's preferences (King and Robison). Efficiency criterion can be used to eliminate a number of alternatives from consideration without detailed information about a decision maker's risk preferences. Several types of efficiency criteria have been applied in agricultural decision-making including: first-degree stochastic dominance (FSD), second-degree stochastic dominance (SSD), and generalized stochastic dominance.

Stochastic dominance efficiency methods are used to rank uncertain outcomes in terms of continuous or discrete probability distributions. Two necessary conditions for stochastic efficiency are that the mean value of the dominant distribution must not be less than the mean value of the dominated distribution nor the smallest value of the dominated distribution (Anderson et al.).

First-degree stochastic dominance (FSD) is based on the assumption that a reasonable decision maker would prefer more to less. FSD holds for all individuals having positive marginal utility. In Figure 3, distribution F dominates distribution G by FSD because all points of distribution F lie

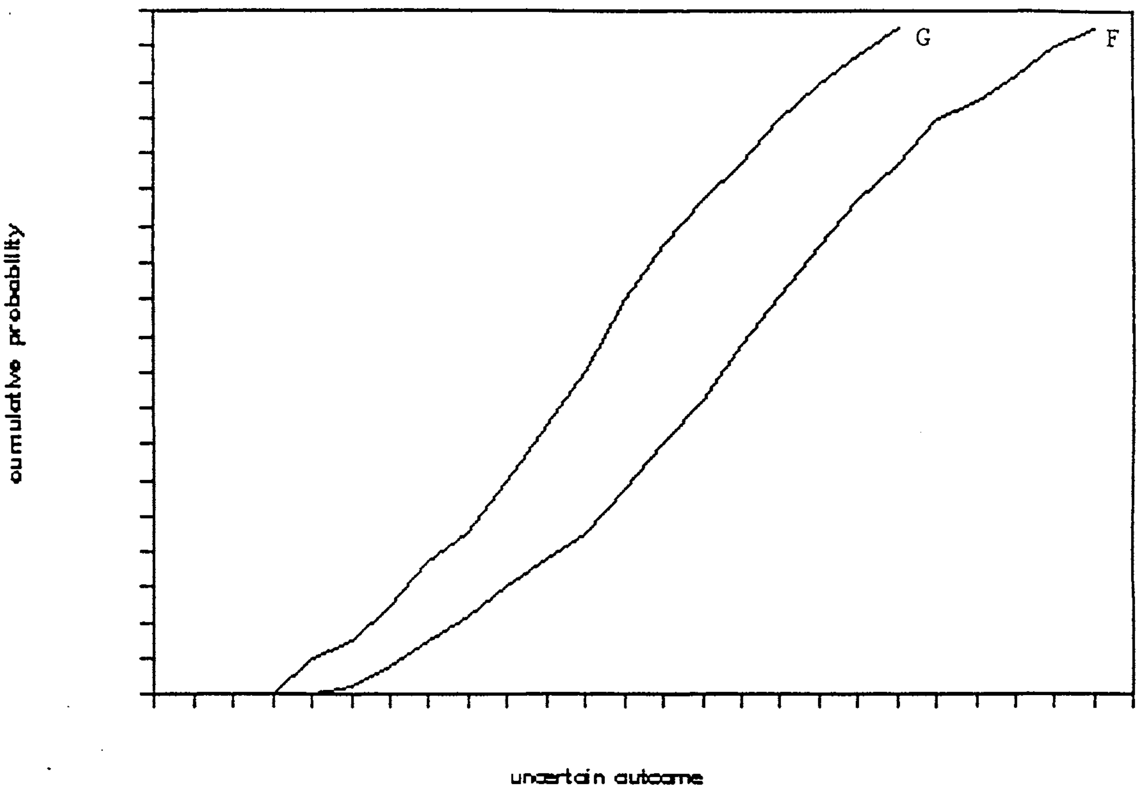

Figure 3. First Degree Stochastic Dominance

to the right of distribution G on the horizontal scale. The dominant distribution F has a larger payoff at every probability level. The cumulative probability distribution G is dominated and stochastically inefficient compared to F. The FSD rule is transitive where F is dominant to all distributions over which G is dominant.

FSD cannot rank actions whose cumulative probability distributions cross. Second-degree stochastic dominance (SSD) is a more discriminant efficiency criterion and is based upon the assumption that the decision maker is risk averse. When using the SSD rule the utility function must be increasing and strictly concave. A graphic example of SSD is depicted in Figure 4. The distribution I dominates J because more area under I lies to the right. Area 1 exceeds area 2 which leads to the dominance by distribution I.

Generalized stochastic dominance is an efficiency criterion which orders actions for classes of decision makers defined by specified lower and upper bounds on the absolute risk aversion function (King and Robison). The absolute risk aversion function r(y) is defined by:

$$r(y) = -u''(y)/u'(y)$$

where u'(y) and u''(y) are the first and second derivatives of a von Neumann-Morgenstern utility function u(y). The generalized stochastic dominance procedure can be defined for different levels of risk aversion that the decision maker may

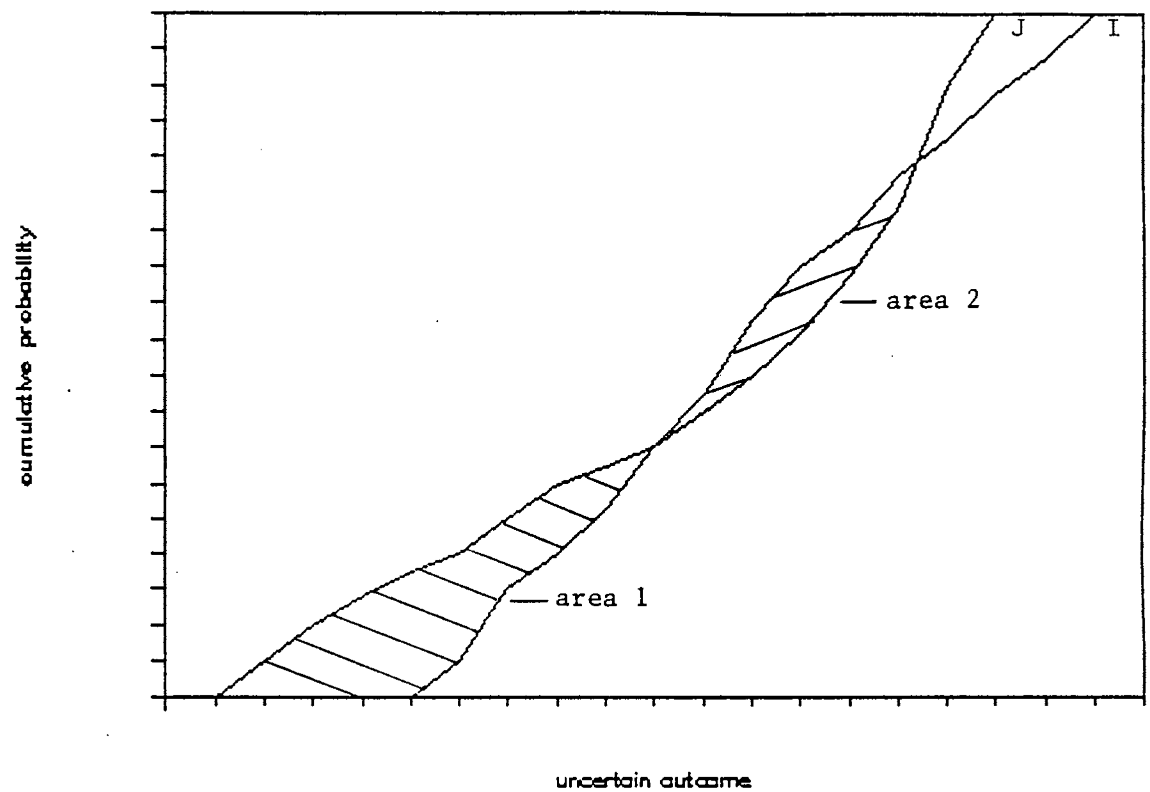

Figure 4. Second Degree Stochastic Dominance

possess. The values of the absolute risk aversion function are measures of the degree of concavity or convexity exhibited by a decision maker's utility function.

CHAPTER IV

MODEL DEVELOPMENT

A simulation model was constructed to model stocker performance and estimate net returns from alternative grazing systems on native rangeland. A simulation model may be described as an analytical process that contains several interrelated mathematical components which represents a complex real process (Anderson). Simulation analysis has been used in agriculture to model many types of systems including plant and animal growth processes, growth and intergenerational transfers of the farm firm, risk and survival projects, supply and demand relationships, and multi-objective decision processes (Mapp).

The simulation model constructed in this study consists of three main submodels and is programmed in the BASIC language. The model is designed to combine forage production with stocker performance estimates to determine the annual net returns of a specific summer stocker enterprise on a per-head and per-acre basis.

A flowchart representation of the entire simulation model, consisting of three interconnected components, is presented in Figure 5. Submodel one involves the daily

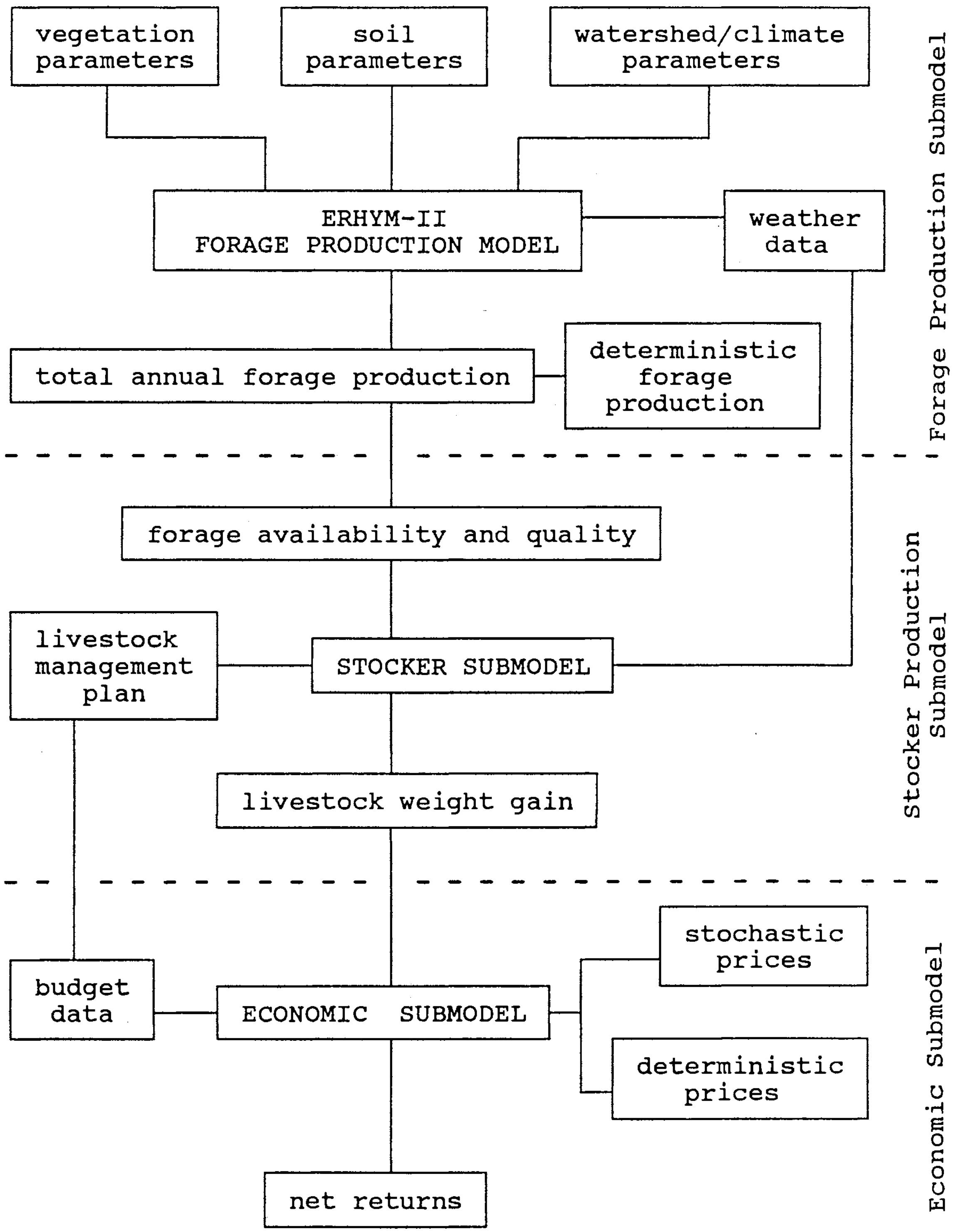

Figure 5. Flow Chart of Range-Stocker Simulation Model

simulation of range site growth processes for the purpose of determining total annual forage production. The ERHYM-II forage production model developed by Wight is used in this stage of the modeling process. Forage production may be specified deterministically in lieu of using the range site simulation component. The second submodel calculates daily forage availability and forage quality and utilizes animal growth equations to estimate animal gain. Budget and price data are combined with output from the previous stages to determine the net returns in the third submodel.

Forage Production Submodel

The forage production submodel is a modified version of the ERHYM-II (Ekalaka Rangeland Hydrology and Yield Model) model developed by Wight. The ERHYM-II model is an updated version of the ERHYM model originally developed by Wight and Neff. The ERHYM-II forage simulation model is a program which provides daily simulation of soil water evaporation, transpiration, runoff and soil water routing. The model calculates annual herbage yield at peak standing crop based upon results of the daily simulations to that point. The ERHYM-II model can utilize either actual weather records or simulate minimum and maximum air temperatures and/or daily solar radiation values.

The model has two user-specified output options -- an option that emphasizes hydrology and one that emphasizes evapotranspiration. These options can both be specified to print on a daily basis or in a yearly summary with a graph of the daily transpiration/potential transpiration (T_a/T_p) values. The ERHYM-II model is capable of processing inputs and outputs in either centimeters or inches.

The ERHYM-II model utilizes a two-step procedure to estimate the water use of the range site and associated impacts on forage production. First, daily simulations are conducted to relate meteorologic, range production, and soil moisture relationships throughout the growing season. This procedure provides estimates of the portion of daily potential transpiration utilized by the range plants for crop growth and development. Next, the results from the daily simulations are employed in water-stress yield models to estimate total annual forage production.

The ERHYM-II model employs two fundamental assumptions in estimating daily water budgets and associated yield impacts. First, transpiration is assumed to be the principal hydrologic process affecting daily water use and forage production. Transpiration represents the best available measure of energy utilized by the range plants for growth and development (Wight). Second, water stress is assumed to be the only factor inhibiting the attainment of maximum yield. All inputs besides water are assumed to be held at levels that do not constrain forage yield. Thus, yield losses resulting from nutrient stress, disease, etc. are not incorporated into the model.

Soil Water Budgeting

The ERHYM-II model utilizes a common and practical approach for estimating crop-water relationships from available climatic data. First, an estimate of potential transpiration (T_p) is derived from daily climatic and agronomic data. Potential transpiration represents the energy used by range plants when water is adequate for unrestricted plant growth and development. Next, factors which limit the attainment of potential transpiration are considered in deriving an estimate of actual transpiration (T_a). Actual transpiration represents the energy actually used by plants for conversion of liquid water to vapor (Saxton). This value approximates the consumptive use of the plant. The relationship between T_a and T_p is determined by whether the available water in the soil is adequate to meet atmospheric demand placed on the soil-plant system. T_a equals T_p when soil water is sufficient to meet crop water demands. Whenever available water is not sufficient to meet crop water requirements, a water deficit occurs. In this case, T_a is less than T_p and yield is reduced below maximum. The ratio of actual to potential transpiration (T_a/T_p) is often referred to as "relative transpiration" and is directly related to crop yield (Wight)

The specific procedure used to determine potential transpiration in the ERHYM-II model was derived from Wight and Hanks. First, an estimate of potential evapotranspiration (ET_p) is derived from temperature and solar radiation data.

This value is converted to ET_p from rangeland (ET_{pr}) and then to potential transpiration (T_p) using the following equations:

$$ET_{pr} = ET_p * CROPCO$$

$$T_p = TRANCO * RGC * ET_{pr}$$

where CROPCO is a range crop coefficient, TRANCO is a site specific transpiration coefficient and RGC is a value derived from a user-specified relative growth curve. The crop coefficient used in this model was developed with lysimeter data from a mixed prairie range site. TRANCO is related to foliar cover and standing live phytomass and represents the maximum portion of ET_{pr} which can be transpired. The relative growth curve (RGC) is used to indicate seasonal changes in standing live photomass. CROPCO, TRANCO, and the relative growth curve are fully defined in the Vegetation Parameters Section.

Actual transpiration is determined by the quantity of water available in the plant root zone. To estimate this value, a daily water balance is conducted to determine the water utilization by each of the hydrologic processes of the soil-plant system. The change in soil water storage in day t ($\blacktriangle S_t$) may be expressed in simplified form as follows:

$$\blacktriangle S_t = P_t - R_t - D_t - E_t - T_{at}$$

where, P_t is precipitation, R_t is runoff, D_t is deep percolation below the root zone, E_t is soil evaporation, and T_{at} is actual transpiation. As the model operates, water is added to the soil profile by precipitation and extracted by evaporation, transpiration, and deep percolation.

Precipitation is added to the root zone after accounting for runoff losses. Runoff is predicted in the ERHYM-II model using an SCS equation, where runoff is a function of rainfall and a retention parameter. The retention parameter is a function of soil water content and soil water storage and is weighted by soil depth. Peak runoff rate is determined in the model by drainage area, slope, daily runoff and the length width ratio of the watershed. The model also accounts for snow accumulation and snowmelt by using an equation associated with daily air temperature.

The soil profile is divided into morphological horizons, and water is added or subtracted from one soil layer at a time. If, following a rain, the water content of the surface layer exceeds field capacity, water is added to the next layers until all precipitation less runoff is allocated. If field capacity is reached in all layers, excess precipitation is percolated through the root zone. Similarly, water extraction occurs layer by layer until T_p has been satisfied or all available water has been extracted. That is, if T_p cannot be satisfied by layer i, then T_p demand is applied to layer i+1; however, extraction from i+1 cannot exceed the difference between T_p and extraction from the preceding soil layers.

Actual transpiration is calculated by the equation:

$$T_a = \Sigma_{k=1}^{n} \; T_p * (SWS_i \; / \; AW_i \; * ROOTF_i * TEMFAC_i)$$

where SWS_i is the available soil water in soil layer i; AW_i is the available soil water storage capacity for soil layer i; $ROOTF_i$ is a root density index for soil layer i; and $TEMFAC_i$ is a soil temperature factor calculated for each soil layer based upon root-activity/temperature relationships.

<u>Herbage Yield Estimation</u>

The ERHYM-II model calculates annual herbage yield (Y) at peak standing crop from the equation:

$$Y = (T_a \; / \; T_p) * Y_p$$

where T_a and T_p are the actual and potential transpiration occurring over the growing season, and Y_p is the site yield potential when water is non-limiting. Annual herbage yield can also be calculated from:

$$Y = a + b \; (T_a \; / \; T_p)$$

where a and b are parameters calculated from a linear regression of field-measured yields and model-calculated climate indices (T_a / T_p).

The model-calculated climate index (T_a / T_p) is a reasonable indicator of the growing climate. The index relates to plant growth and enables comparisons of range treatments or vegetation inventories among years or range sites by accounting for a large portion of climate-induced variation in plant response (Wight). The daily T_a and T_p values are summed within the model into a cumulative ratio to calculate the climate index.

Application of ERHYM-II to the Study Area

The ERHYM-II model was applied to predict forage production on a tallgrass prairie range site in central Oklahoma. Specifically, a loamy prairie range site located near Stillwater, Oklahoma was employed as the unit of study. The range site was assumed to be in high-fair to good range condition. The dominant soil of the site was determined to be Norge loam. For a detailed description of the soil and vegetation characteristics of the range site, see Powell et al. and Harper.

Input parameters are specified in the model to identify soil and vegetation parameters specific to the range site being modeled. Nine different soil parameters and ten different vegetation parameters are identified by the user. Twenty-five watershed/climate parameters are also specified to model the range site.

Soil Parameters

Soil parameters are initially defined in the forage production submodel to describe the hydrologic properties of the Norge loam soil. Soil characteristics are defined by dividing the soil profile into unique soil layers and defining the physical characteristics of each layer. Based upon information provided by the SCS soil survey and Oklahoma State University range scientists, four soil layers were used to describe soil profile of the Norge loam soil. The depth of each soil layer was determined by dividing the soil profile into layers of similar texture and hydrologic characteristics. The top two soil layers were 9 inches deep and the bottom two twelve inches (Soil Conservation Service).

Bulk density values for each soil layer are determined from a table (adapted from Wight) in Appendix A based upon the texture of each of the four layers. The bulk density values are estimated at 1.4, 1.54, 1.58, and 1.62 inches for each respective soil layer. The rock content of each soil layer is expressed as a decimal fraction on a volumetric basis and is estimated at .03, .07, .08, and .12 percent for the four soil layers (Soil Conservation Service). Air dry soil moisture of the top soil layer is identified as .52 inches from a table (adapted from Wight) in Appendix A. Air dry soil moisture is the amount (inches) of water in the top twelve inches of the soil profile held at tensions greater than the permanent wilting point that can be removed by evaporation.

In the ERHYM-II model, soil water characteristics of each soil layer are specified by an initial input value and a value for field capacity and permanent wilting point. The soil water inputs are expressed as a decimal fraction of the percent by weight of each soil layer. The initial soil water content of each soil layer is .27, .28, .22, and .23 percent by weight, respectively. The values for soil water content at field capacity and the permanent wilting point were estimated from a table in Appendix A which relates bulk density and air-dry values to soil texture (Wight). These values are identified as percent by weight and are expressed as a decimal fraction. The field capacity values for each soil layer are .31, .29, .25, and .35, respectively. The permanent wilting point values are .17, .13, .17, and .23 for each respective soil layer.

Vegetation Parameters

A crop and transpiration coefficient (CROPCO and TRANCO) are input into the model as part of the vegetation parameters. CROPCO is identified as .85 by using the following equation from Wight.

$$\text{CROPCO} = \text{ET (lysimeter)} \;/\; \text{ET}_p \text{ (Water non-limiting)}$$

As defined earlier, TRANCO is a site specific coefficient which is related to foliar cover and standing live phytomass. The .95 TRANCO value used in the model is determined from Wight's equation.

$$\text{TRANCO} = .0213 + .0162\,[\text{average site yield (16 lbs/ac)}]^{1/2}$$

The vegetational root density (ROOTF) of each soil layer are input parameters which provide a means of restricting water uptake from the subsurface soil layer where root distribution is limited. Water uptake is directly proportional to the value of ROOTF. ROOTF is the percent root density, expressed as a decimal fraction relative to the root density in the surface soil layer (which is always one). Root densities of plant species in tallgrass prairie are a poor predictor of water uptake (Engle); thus, estimated water uptake rates by each soil layer are employed for ROOTF values. Oklahoma State University range scientists identified ROOTF for the four soil layers as 1, .8, .3, and .1. Daily soil water levels and seasonal transpiration deficit estimates better approximated actual outcomes using these values.

The ERHYM-II model utilizes a relative growth curve (RGC) to indicate seasonal changes in standing live photomass. The relative growth curve is described by a modification of the generalized Poisson density function:

$$RGC = \left(\frac{Jday-b}{a-b}\right)^{c} * \exp\left[\frac{c}{d} * \left(1-\left(\frac{Jday-b}{a-b}\right)^{d}\right)\right]$$

$$\text{for} \quad 75 \leq Jday \leq 275$$

$$RGC = RGCMIN \quad \text{for} \quad 75 > Jday > 275$$

Parameters are defined by the julian day of peak standing crop (a), the julian day the growing season starts (b), curve shape parameters (c and d), and the minimum value that the RGC can take on during the entire year (RGCMIN). The julian day of peak standing crop for central Oklahoma is estimated at day 210 (Engle, Gillen). Shape parameters are defined to develop a RGC which best represents the seasonal and aggregate growth of vegetation on the study site (c = 1, d = 7). The RGC minimum value is identified as .01; thus, the RGC values vary between .01 and 1.0 over the calendar year. The julian dates denoting the beginning and end of the growing season are identified as days 85 and 275, respectively (Gillen).

Total forage production is estimated in the simulation model from the procedure described earlier. A regression equation based upon 20 years of forage production data in Payne County, Oklahoma (Powell et al.) is used to determine the slope and intercept parameters. The equation derived to estimate total forage production is:

$$Y = -1000 + 8800 * (T_a / T_p)$$

where T_a and T_p are the accumulated transpiration values generated in the ERHYM-II model.

Watershed/Climate Parameters

The ERHYM-II model maintains a continuous water balance so mixed-land use watersheds are subdivided to reflect differences in evapotranspiration (ET) for various crops (range sites). The ERHYM-II model considers only a single range site per run. The model user must identify several key characteristics of the watershed being modeled.

The ERHYM-II model requires that the area or field size of the watershed be defined. The watershed length-width ratio and the condition II SCS runoff curve number also identify specific watershed characteristics. Runoff numbers represent the normal antecedent moisture condition for range sites (Wight). The SCS runoff curve used in this application was number 65. This curve number is determined from a table provided by Wight which relates range condition and soil texture.

Watershed and climate parameters are weighted in the model for each specific range site. The watershed weighting factor consists of a weight for the range site latitude. Climate weights involve a temperature weighting factor and the mean and coefficient of variation of wet and dry temperatures.

Climatic information can be read into the model program from a data file or generated using a daily stochastic climate generator. Daily weather variables necessary for application of ERHYM-II include precipitation, minimum and maximum air temperature, and solar radiation. In this application, actual values of daily precipitation and temperature are input into the model. Solar radiation values were not available from the study region and were generated by the climate simulator based upon observed temperature and precipitation values. Daily temperature and precipitation data were recorded at the National Climatic Center Weather Station located in Stillwater, Oklahoma from 1929-73 and 1980-88. Omission of years having incomplete weather records provided 52 years of annual weather data for the analysis.

Model Validation

Model validation concerns the relationship of the model with the actual production system. Mapp states that agricultural economists should provide plant growth models to scientists in related disciplines to evaluate both the soil water calculations and the plant growth relationships, assist with modifications to fit local growing conditions and help judge the reasonableness of the model's output. This procedure was used in validating the simulation model used in this study.

The general procedure used in validating the ERHYM-II model consisted of evaluating the performance of the basic, intermediate, and final parameters of the model. The ERHYM-II model calculates and reports several intermediate values including potential transpiration, actual transpiration, and soil water levels on a daily basis. These daily components of the model as well as the herbage yield per acre were compared with actual values and evaluated by Oklahoma State University range scientists to determine their validity.

Figure 6 shows daily actual and potential transpiration values calculated by the model under average climatic and range production conditions. Figure 7 shows daily soil water levels for each soil layer over the same year. These graphed values were evaluated along with the actual air temperature

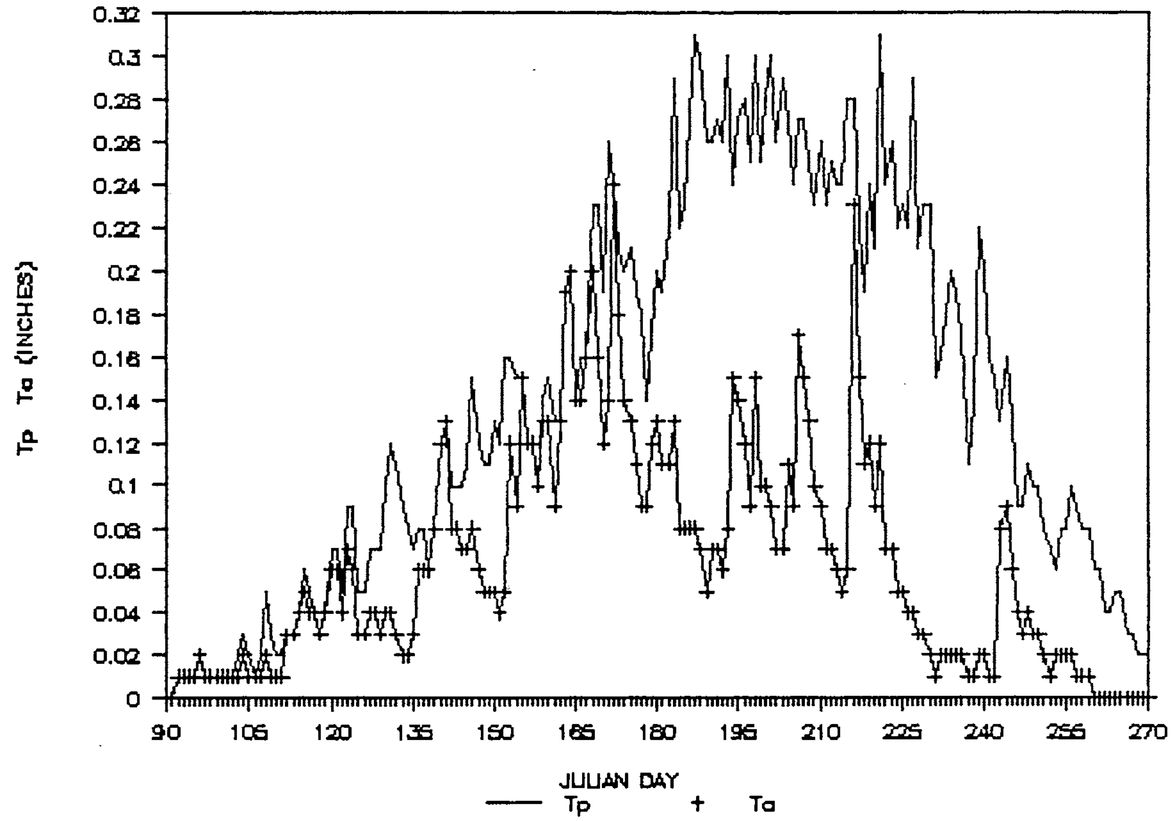

Figure 6. Daily Actual (Ta) and Potential Transpiration (Tp) Values

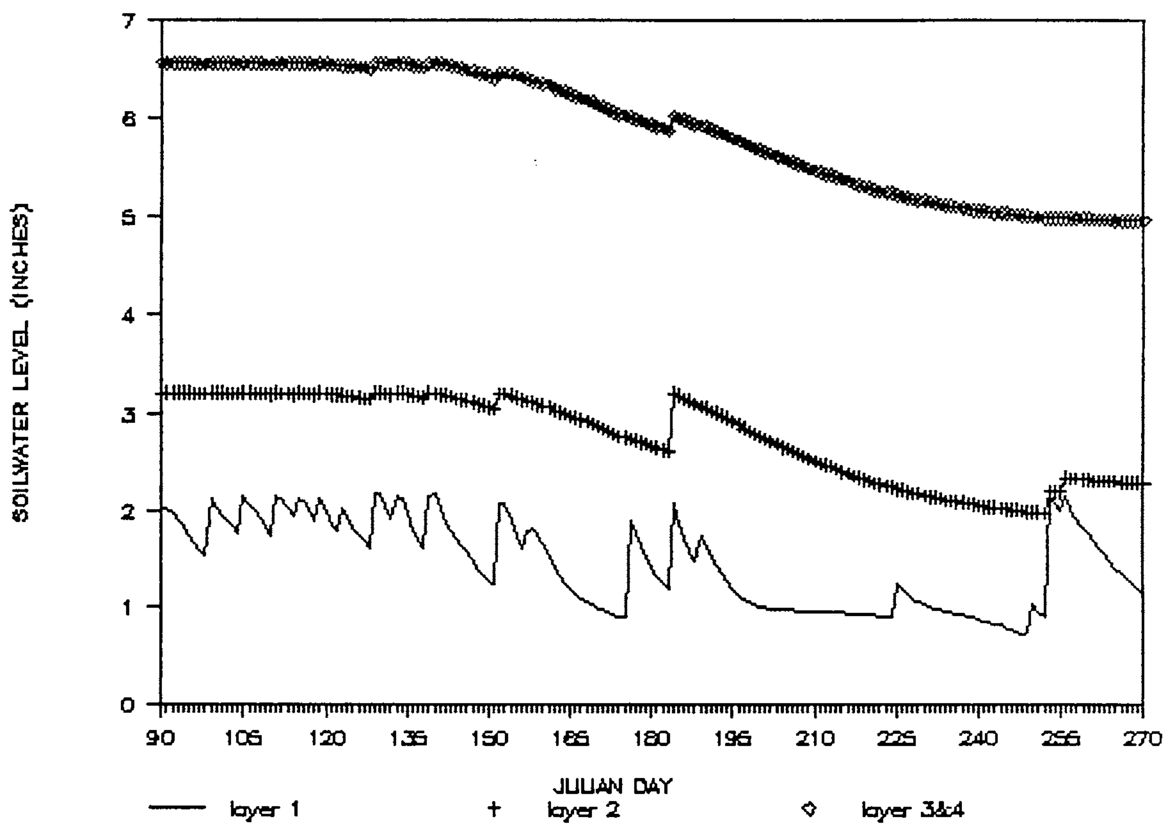

Figure 7. Daily Soil Water Levels by Layer

and precipitation values. By comparing these variables of interest across climatic events, it was determined that the model was reasonably representing these subprocesses (Gillen, Engle).

The model was tested against 20 years of actual forage production data (Powell et al.). The original data was derived from a Norge loam soil prairie range site near Stillwater, Oklahoma. The forage yields were determined from annual clipping data collected using procedures reported in Harper. The model produced reasonable estimates of herbage production for the 1929-49 test period. The R^2 value of the regression was calculated to be 0.75. The capability to explain 75 percent of the variation in annual forage production based on soil moisture stress met our expectations concerning the power of the model. Other factors influencing range productivity that are not represented in the model (e.g., nutrient stress, disease and pests, etc.) certainly are significant sources of variation as well. Figure 8 shows the relationship between field measured herbage yields and model predicted yields. The model predicts slightly low in favorable years and slightly high in low production years.

Stocker Intake/Growth Submodel

The stocker submodel was constructed to use the forage production data from the ERHYM-II program and determine the total gain for steers. The stocker model considers varying

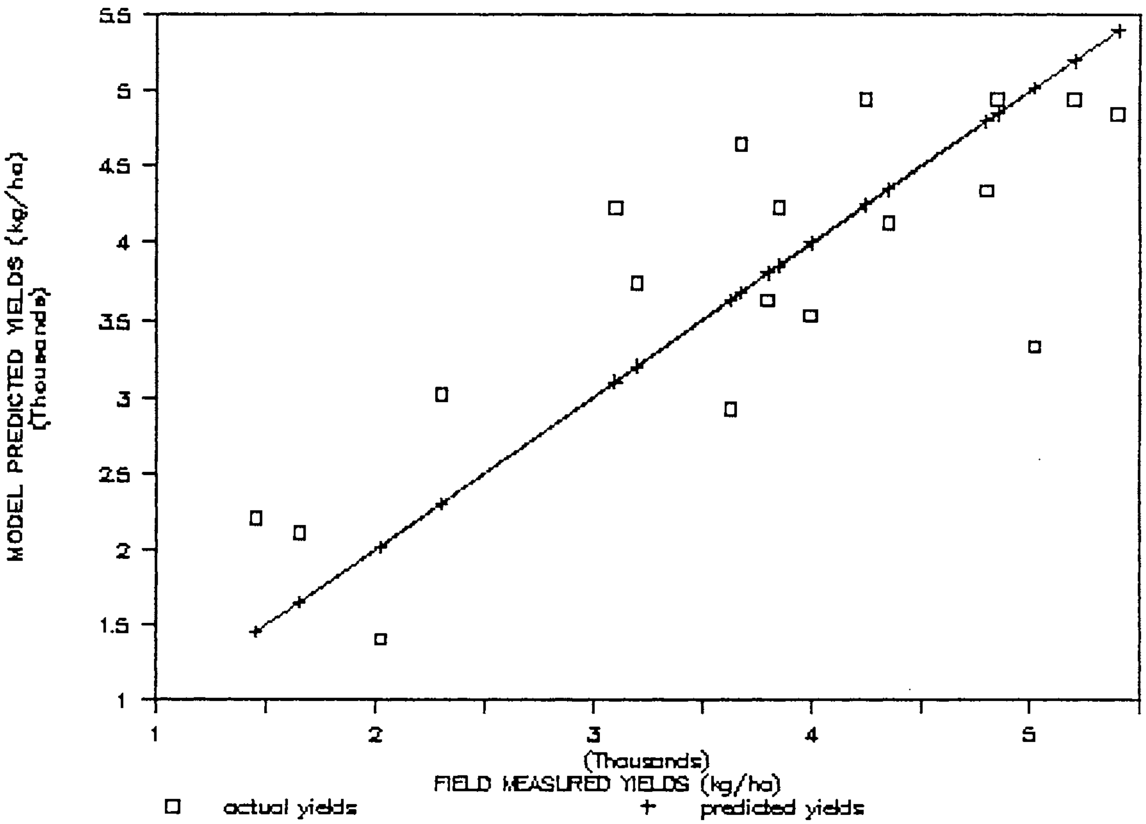

Figure 8. Relationship Between Actual and Predicted Yields

forage quality and the impact of feeding supplement when forage quality is low. The following description of the stocker model explains how forage quantity and quality determine animal intake. Animal growth components are described as well as other environmental conditions which may affect intake.

The total forage production determined earlier must be converted to production on a weekly and daily basis to determine forage availability for each day. Total forage production (TFP) is converted to weekly forage production (WFP) through the use of an estimated regression equation. This equation is based upon four years of forage production data from a shallow prairie range site located in Payne County, Oklahoma. Five standing crop measurements taken at monthly intervals were available for each year. Standing crop measurements were converted to a percent of the peak standing crop for each year. The estimated regression equation is:

$$PSC = -2.0448688 + .024474(Jday) - .00005011(Jday)^2$$

where PSC is the cumulative percent of peak standing crop produced, and Jday is the julian day of the year. The percent of total standing crop produced in week i is estimated by subtracting PSC_{i-1} from PSC_i. WFP is then determined by multiplying the generated percentage of peak standing crop by TFP. Daily forage production is WFP/7.

Forage Quality

The stocker submodel calculates forage quality on a random basis. Monthly protein estimates are derived for the months of April through September to represent forage quality in the model. An attempt was made to develop a forage quality model by regressing monthly forage quality estimates (crude fiber and percent protein) on historical weather data. Monthly, crude fiber and protein values used in the estimation were based upon data from Waller et al. These values were derived from monthly grass samples on a range site near Stillwater, Oklahoma for the year's 1947-62. Due to the poor statistical properties of these models, this effort was abandoned, and a random forage quality generator was developed.

A procedure for generating correlated random outcomes, reported in Clements et al., is used to derive monthly protein estimates in the model. This procedure rests on the covariance between the forage dry matter protein content in each month of the grazing season. Monthly protein values used in estimating the covariance matrix are from Waller et al.

Generalized equations from Clements et al. are used to develop an A matrix which correlates the monthly protein estimates employed in the simulation model. The following equations are used to calculate the a_{ij}'s of the upper triangular matrix.

$$a_{ii} = (\sigma_{ii}^2 - \Sigma_{k+1}^{m} a_{ik}^2)^{.5} \qquad 1 \leq i \leq k < m$$

$$a_{im} = \sigma_{im} / \sigma mm \qquad 1 \leq i \leq m - 1$$

$$a_{ij} = \sigma_{ij} - \Sigma_{k=j+1}^{m} a_{ik}\, a_{jk} / a_{jj} \qquad 1 \leq i \leq j \leq m-1$$

Once the A matrix is calculated, these estimated coefficients are combined with a series of uniform random normal deviates to generate the monthly protein estimates. Random normal deviates are generated with a random number generator within the BASIC computer program. The following equation illustrates the calculation process.

$$\begin{bmatrix} \text{MAYPROT} \\ \text{JUNPROT} \\ \text{JULPROT} \\ \text{AUGPROT} \end{bmatrix} = \begin{bmatrix} P_{my} \\ P_{jn} \\ P_{jl} \\ P_{ag} \end{bmatrix} + \begin{bmatrix} a11 & a12 & a13 & a14 \\ 0 & a22 & a23 & a24 \\ 0 & 0 & a33 & a34 \\ 0 & 0 & 0 & a44 \end{bmatrix} \begin{bmatrix} w1_i \\ w2_i \\ w3_i \\ w4_i \end{bmatrix}$$

where MAYPROT, JUNPROT, JULPROT, and AUGPROT are the protein estimates for the months of May, June, July, and August, respectively. P_{my}, P_{jn}, P_{jl}, and P_{ag} are the mean protein values for the months of May, June, July, and August and $w1_i$ through $w4_i$ are uniform random normal deviates.

The variance-covariance matrix of May through August monthly protein levels was developed from a 17-year time series of monthly protein estimates and is shown in Table II. Attempts were first made to represent forage quality variability using crude fiber data, since this measurement is more closely correlated with the quality variable of interest (digestibility). However, trends in the data did not correspond to expected changes in forage quality over the grazing season.

TABLE II

COVARIANCE MATRIX OF DRY MATTER PROTEIN VALUES

	May	June	July	August
May	10.4499	2.6731	-.4761	-.9135
June		3.7812	.3834	.0317
July			1.0303	.2699
August				.6515

The following equation shows the forage quality model with mean protein values and the calculated a_{ij}'s.

$$\begin{bmatrix} \text{MAYPROT} \\ \text{JUNPROT} \\ \text{JULPROT} \\ \text{AUGPROT} \end{bmatrix} = \begin{bmatrix} 10.65 \\ 8.722 \\ 6.651 \\ 5.020 \end{bmatrix} + \begin{bmatrix} 2.66 & 1.44 & -0.1 & -1.13 \\ 0 & 1.91 & 0.38 & 0.039 \\ 0 & 0 & 0.96 & 0.334 \\ 0 & 0 & 0 & 0.807 \end{bmatrix} \begin{bmatrix} w1_i \\ w2_i \\ w3_i \\ w4_i \end{bmatrix}$$

April protein levels are estimated as one percent less May values and September values are equal to August values. Each estimate corresponds to the mid-point of the month, and linear interpolations between adjacent points are used to represent daily changes in forage quality. Protein values are then converted to in vitro digestibility using the following relationship estimated from four years of monthly protein and digestibility data (Bogle et al.):

$$DIG = (28.178 + (4.512 * PROT) + (-.512 * (PROT)^2)) / 100$$

Forage quality is also affected if range burning is employed. Forage quality is increased through higher digestibility when forage is burned (Bernardo et al.). The following equations illustrate how daily digestibility values are adjusted in response to prescribed burning.

$$RESID = ENDDM / 2,000 \qquad (ENDDM < 2,000)$$

$$RESID = 1.0 \qquad (ENDDM > 2,000)$$

$$PDB = (\exp (4.85 - (.0236 * Jday))) * RESID$$

$$DIG_b = (1 + PDB) * DIG$$

where ENDDM is the forage dry matter (kg/ha) left ungrazed from the previous year and PDB is the percentage increase in digestibility derived from burning. The RESID coefficient allows the model to decrease the effectiveness of a prescribed burn as a function of the quantity of fuel carried over from the previous year. Engle estimates the effectiveness of prescribed burning to be maximized when a minimum of 2,000 kg/ha is left ungrazed in the previous year. The increase in forage quality derived from burning is assumed to be directly proportional to the proportion of this fuel requirement available.

Metabolizable energy (ME) is a measure of the dietary energy available for metabolism after energy losses that occur in the urine and rumen are subtracted from digestible energy (National Resource Council). The stocker model calculates metabolic energy based upon an equation used by Oh et al. This equation calculates total digestible nutrients (TDN) which can be converted to ME by multiplying by .0362. Thus,

$$ME = .0362 * (16.7 + (.74 * (100 * DIG)))$$

Available dry matter (ADM) is calculated by multiplying a use coefficient by the dry matter produced. Dry matter produced for intake is found by subtracting the product of intake and stocking density from daily forage production. The use coefficient in the equation is input by the user and accounts for the percent of the total forage that is useable for grazing.

Stocker Intake

To accurately predict the gain of a specific animal, one must first predict the intake of that animal. The rate of intake is affected by forage quality, forage availability, and other environmental factors. The stocker submodel accounts for these factors through estimates of forage digestibility and availability.

Voluntary intake (VI) is determined in the model based upon forage quality and livestock metabolic weight. The

National Resource Council (NRC) suggests the following equation used in the model to calculate VI.

$$VI = WT^{.75}\ (.1493NEM - .046NEM^{2} - .0196)$$

where $WT^{.75}$ is the metabolic weight of the animal (Kg/head) and net energy for maintenance (NEM) is a measure of the quality of forage available to the animal.

Voluntary forage intake can be significantly affected by the environment. Effective ambient temperatures outside the thermoneutral zone of 15 degrees to 25 degrees celsius affect the amount of intake (National Resource Council). The impact of temperature upon intake is incorporated into the model based upon the findings of a study by Fox and Black. Voluntary intake is decreased one-half of one percent for every 1 degree celsius above 25 degrees celsius. That is, an intake adjustment factor (AVI) may be specified as:

$$AVI = 1 - ((TPC - 25) * .005)$$

where TPC is average daily temperature in degrees celsius. The effect of temperature below the thermoneutral region was not considered relevant for summer grazing systems.

Forage availability (FA) is considered in the model to be a function of available dry matter, cumulative animal weight and stocking density. FA is expressed in terms of grams of dry matter per kilogram of live weight and represents an amount of forage supply with respect to an estimatable forage demand (Rodriguez). FA is found by dividing ADM by the product of stocking density and animal weight. FA is inversely related to weight and stocking density.

Relative forage dry matter intake (RFI) is incorporated into the model to adjust actual intake estimates based upon the quantity of forage available. There exists a threshold value of forage available per unit of animal live weight where intake starts to decrease as FA decreases (Rodriguez). An RFI equation is specified to represent the effect of limiting forage quantities on animal intake and may be expressed as:

$$RFI = 1 - e^{(-.013 * FA)}$$

where RFI is a proportionate measure of which fluctuates between zero and one.

The RFI relationship is specified using estimates of the effect of daily forage allowance on relative dry matter intake reported in Rayburn, Fox, and George. Similar data is not available from research on tallgrass prairie rangeland; however, by specifying the results in terms of grams of dry matter per kilogram of live weight, the transferability of the findings was improved. As shown is Figure 9, the threshold level of forage availability exists at point B. When FA is above the threshold level B, forage is non-limiting. In this case, intake depends only on forage quality (voluntary intake) and environmental (temperature) affects. Below threshold level B, forage quantity becomes a limiting factor on intake.

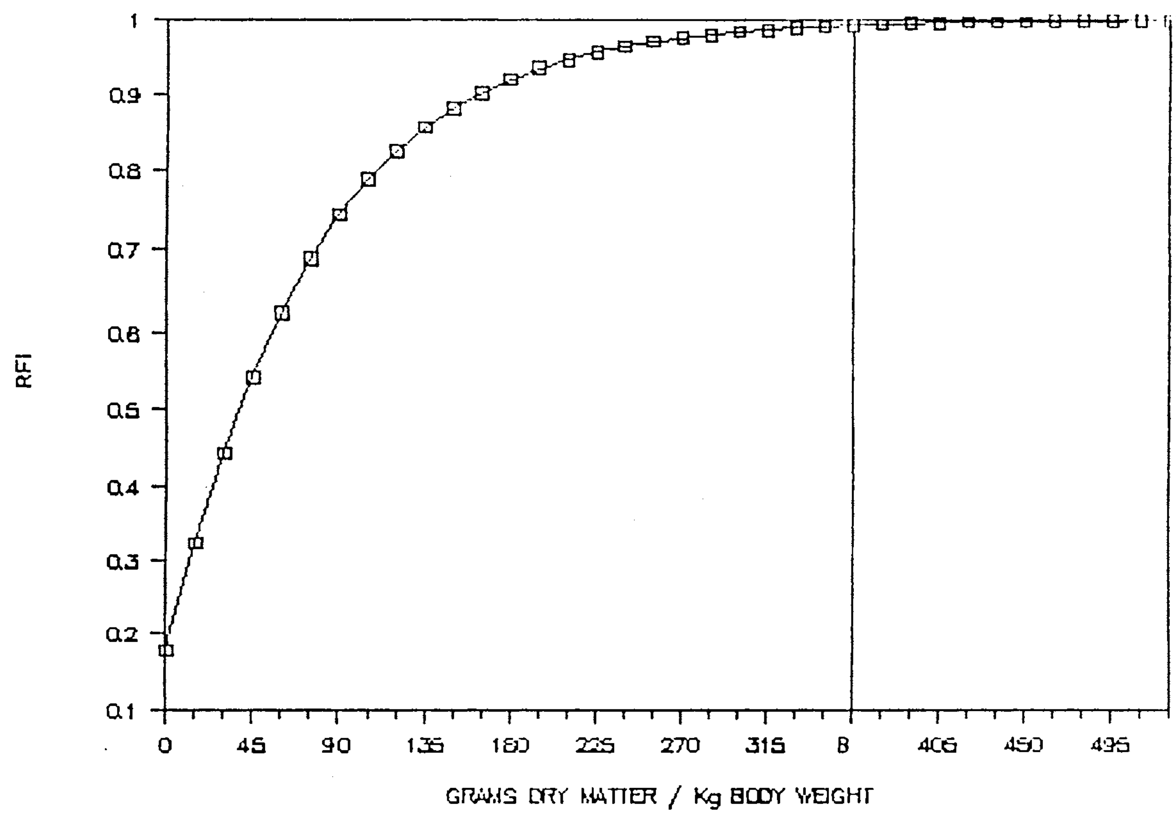

Figure 9. Relationship Between Dry Matter Availability and Relative Forage Intake

Actual intake (I) is determined in the stocker submodel by multiplying VI, RFI, and AVI. Thus, intake of the animal is adjusted for forage quality, forage availability, and temperatures above the thermoneutral zone. Forage quality effects are transformed from the initial quality measure of digestibility to metabolizable energy, and thus, to NEM. VI is then affected by forage quality through NEM. Forage quantity effects are determined from RFI which is a function of FA. Temperature adjustments of intake take place through AVI.

Stocker Growth

The California Net Energy System (CNES) is an energy system which is often used to project gain in cattle. The CNES is also used as the base for the energy requirements by the NRC. The CNES is primarily developed using high quality rations, but it appears to also be an appropriate method of evaluating energy requirements of cattle on a high roughage diet (Brorsen). Brorsen compared the actual and predicted gains of Oklahoma stocker cattle using several different energy systems and found the net energy system to be the best method of evaluating energy requirements.

The net energy system separates net energy into net energy for gain (NEG) and for maintenance (NEM). NEG measures the amount of energy stored in body tissue due to the addition of feed above the maintenance requirement of the animal

(National Resource Council). This measure expresses the value of a given feed for producing weight gain. NEM measures the amount of feed required to maintain an animal in energy balance with no weight loss or gain (Rodriguez).

The animal growth component of the stocker submodel utilizes equations suggested by the National Resource Council. Average daily gain (in g per steer) is calculated as:

$$ADG = 15.54 * (NEAG^{.9116}) * (WT^{-.6837})$$

where NEAG is the net energy available for weight gain and WT is the cumulative live weight of the animal. NEAG are revised daily to reflect environmental, managerial, and nutritional factors.

NEAG is a function of the net energy required for maintenance (NERM), intake, net energy for maintenance of the feedstuff (NEM), and the net energy for weight gain in the feedstuff (NEG). Using the procedure of Fox and Black NEAG is calculated as:

$$NEAG = (I - (NERM/NEM)) * NEG$$

Availability of nutrients from feedstuffs can be altered by environmental temperature. The digestibility of roughage feed and temperature appear to be positively related (National Resource Council). The following equation is used to adjust the maintenance requirement for temperatures above 20 degrees Celsius.

$$ATF = .0007 * (TPC - 20)$$

where ATF is the adjusted temperature factor and TPC is the temperature in degrees celsius. As defined below, ATF is used in determining the net energy required for maintenance. NERM accounts for an adjusted maintenance requirement due to temperatures outside the thermoneutral range and is calculated by:

$$NERM = (.077+ATF) * WT^{.75}$$

Net energy equations for maintenance and weight gain in the forage are polynomial functions of metabolizable energy (NRC). ME is defined a function of DIG; thus, these energy equations account for the quality of the forage.

$$NEM = 1.37ME - .138ME^2 + .0105ME^3 - 1.12$$

$$NEG = 1.42ME - .174ME^2 + .0122ME^3 - 1.65$$

The stocker submodel allows for supplement to be fed while cattle are grazing on pasture. The model user specifies the number of days that cattle are fed and the quantity fed per day. This procedure allows the model to avoid the situation where protein becomes limiting.

The model is designed to capture the effects of feeding protein supplement on net energy, and hence, animal gain. When the model reaches the julian day that supplemental feeding starts, digestibility is automatically recalculated to reflect the quality of the composite feed (protein supplement and native forage). Total digestibility is determined through an iterative process which determines the percentage composition of the two feeds in the diet and uses these weights to determine the average digestibility. The percent digestibility of supplement is an input in the model while the percent digestibility of the forage is determined using the stochastic process explained earlier. For this application, soybean meal is fed as protein supplement, and a 90 percent digestibility is assumed.

Model Validation

Validation of the stocker submodel involved comparison of model predicted gains with actual gains from grazing experiments. A four year study comparing season-long and intensive-early stocking enterprises was conducted in Pawhuska, Oklahoma from 1984 through 1987 (McCollum et al.). Grazing treatments were applied in a manner that allowed each pasture to be grazed under each management system. Average gains of stocker cattle under each enterprise are reported in Table III. In vitro digestibility data of range forage were also collected at various intervals over the growing season. This forage quality data was input into the stocker submodel, and linear interpolations were used to estimate daily digestibility values between these points. Seasonal weight gains projected by the simulation model are also reported in Table III. Approximately 86 percent of the variation in season-long weight gains is captured by the simulation model, while 63 percent of the variation in IES gains is explained.

TABLE III

AVERAGE GAINS OF STOCKER CATTLE

Year	Enterprise	Actual	Predicted
1984	IES	206	189
	SLS	295	278
1985	IES	125	95
	SLS	210	175
1986	IES	154	161
	SLS	218	213
1987	IES	131	157
	SLS	261	241

Various subprocesses of the stocker submodel were also evaluated by comparing daily and annual simulation results with additional experimental data in the study area. Daily trends in forage intake, average daily gain, energy requirements and forage quality were compared with available data (McCollum). Daily forage intakes estimates appeared reasonable over the early portion of the grazing season, but the model may overestimate intake in the latter portion of the season. This result can be explained by the fact that the data used to estimate the intake equation was primarily derived from experiments feeding high quality forage. An intake equation estimated using data from grazing lower quality forage was evaluated in the stocker model; however, resulting gains were consistently low.

Simulation results over a 20-year time horizon were also compared to experimental data to evaluate the stocker submodel. Experimental data from Kansas and Oklahoma indicate IES steer gains to be approximately 67 to 70 percent of SLS gains. Results from the 20-year simulation indicate IES gains of 67.6 percent of season-long gains. Increased gains from prescribed burning reported by Oklahoma State University range scientists average 10 percent for SLS and 18 percent for IES; this compares to increases of 10.8 and 16.7 percent in the simulation results.

Economic Submodel

The economic submodel uses weight gain and other outputs generated from the forage and stocker submodels to calculate net returns for each strategy simulated. The economic component requires the input of several key values. Economic input data requirements are shown in Table IV. The economic submodel uses the total gain generated in the stocker submodel to calculate sell weight. Sell weight is adjusted by one minus a death loss percentage.

TABLE IV

ECONOMIC INPUTS

buy price $/lb	XX	salt & mineral $/lb	XX
sell price $/lb	XX	salt & min lbs/hd/mo	XX
buy weight lbs	XX	hauling charge $/cwt	XX
total gain lbs	XX	cattle treated %	XX
number head	XX	cattle sickpen cost $/hd	XX
days on pasture	XX	vet med supplies	XX
# times fed hay	XX	marketing charge $/cwt	XX
# times fed suppl.	XX	death loss %	XX
lbs hay/hd/day	XX	interest rate %	XX
lbs suppl./hd/day	XX	labor charge $/hr	XX
supplement $/cwt	XX	hay $/ton	XX

Stocking rate is determined in the model by multiplying the number of head grazing by the number of days on pasture and dividing by the total number of acres. Stocking density is calculated by dividing the number of head by the number of acres. Average daily gain is determined by utilizing the total gain determined in the stocker submodel and dividing by the number of days on pasture.

Stochastic Price Generator

The economic submodel is constructed to simulate the effect of random events upon the system. The calf price, sell price, hay price, and supplemental feed price can be input by the model user or generated within the system to represent a source of randomness. The procedure for generating these random prices is reported in Clements et al. and was explained earlier in terms of its application in generating random forage quality variables.

The variance-covariance matrix for the four prices is shown in Table V and is generated from a 20-year series of real prices. The cattle prices were obtained from the Oklahoma City Livestock Auction for the period 1969-88. Hay and protein supplement prices were obtained from the Oklahoma Crop Reporting Service for the years 1969-88.

TABLE V

COVARIANCE MATRIX OF PRICES

	Sell Price	Buy Price	Hay Price	Suppl. Price
Sell Price	249.1816	239.9334	70.8207	.2468
Buy Price		258.8571	35.9326	-2.1584
Hay Price			102.3077	.2826
Suppl. Price				2.9870

The following equation shows the calculation process for generating random prices.

$$\begin{bmatrix} SELLP \\ BUYP \\ HAYP \\ SUPP \end{bmatrix} = \begin{bmatrix} P_{sl} \\ P_{by} \\ P_{hy} \\ P_{sp} \end{bmatrix} + \begin{bmatrix} a11 & a12 & a13 & a14 \\ 0 & a22 & a23 & a24 \\ 0 & 0 & a33 & a34 \\ 0 & 0 & 0 & a44 \end{bmatrix} \begin{bmatrix} w1_i \\ w2_i \\ w3_i \\ w4_i \end{bmatrix}$$

where P_{sl}, P_{by}, P_{hy}, and P_{sp} are the means of the respective prices for the 20 year series. The random price model with actual mean and a_{ij} values is shown below.

$$\begin{bmatrix} SELLP \\ BUYP \\ HAYP \\ SUPP \end{bmatrix} = \begin{bmatrix} 76.09 \\ 84.65 \\ 60.93 \\ 13.11 \end{bmatrix} + \begin{bmatrix} 3.51 & 13.57 & 7.26 & 0.142 \\ 0 & 15.52 & 4.07 & -1.24 \\ 0 & 0 & 9.70 & 2.86 \\ 0 & 0 & 0 & 1.73 \end{bmatrix} \begin{bmatrix} w1_i \\ w2_i \\ w3_i \\ w4_i \end{bmatrix}$$

Operating Cost Estimation

Cost of production information for alternative stocker activities was obtained from Oklahoma State University livestock budgets developed by Walker et al. and Bernardo and McCollum. Modification of these budgets is necessary to characterize the assumptions underlying each grazing activity analyzed in this study. The stocker budgets created in this study reflect only the returns above operating costs. This study considers resource situations only in the short run; therefore, fixed costs are not considered.

Operating costs in the economic submodel include all money outlays for purchased inputs that are consumed during the production period. The model calculates expenses for the period when cattle are grazing on pasture and during the receiving program.

Salt and Minerals. The price and quantity of salt and minerals are input by the user. The total per head cost of salt and minerals is determined by multiplying the input cost by the amount fed over the grazing season. The total mineral requirement for the season is determined by dividing the days on pasture by 30 and multiplying by the monthly requirement.

Salt, mineral and vitamin requirements are met in part by the daily forage intake of the animal. Two pounds of salt and mineral mix per steer per month is assumed for all grazing activities. This assumption is based upon Walker et al., who determined that a steer which is .7 animal units would use 2.1 pounds of salt and minerals per month. Each animal is assumed to consume the entire 2 pounds of salt and minerals for every thirty days the animal is on pasture.

Hauling Charges. Hauling charges are based upon the method developed by Walker et al. A custom charge of $.35 per cwt. is used for hauling cattle to and from a market. An average 50 mile haul at $2.75 per mile with a 393 cwt. truck pay weight is used to calculate the $.35 per cwt. cost. On-farm hauling costs are reflected in machinery repairs.

The hauling charge per head is determined by multiplying the quantity of livestock hauled by the hauling charge. The quantity hauled is determined by adding sell weight (adjusted for death loss) and buy weight and dividing by 100.

<u>Marketing Charge</u>. The marketing charge used in the budgets is based upon average marketing costs for cattle and calves at Oklahoma auctions. A marketing charge of $1.72 per cwt. is found to represent the cost of marketing calves in Oklahoma (Walker et al.). A marketing cost is assumed for only the selling activity, as the purchase price reflects a marketing cost for the buying activity. The marketing charge for stocker cattle is found by multiplying adjusted sell weight by the input cost per cwt.

<u>Veterinary Medicine and Supplies</u>. Veterinary costs consist of three components: (1) per-head costs associated with processing each animal upon arrival, (2) sickpen costs incurred for a fraction of the total head, and (3) routine veterinary calls. To represent veterinary and medical costs, the user must input four values: per head cost of veterinary medicine supplies, percent of new cattle treated for sickness, new cattle sickpen cost per head, and the cost for processing new cattle.

Estimates of vet-med expenses are based on information from Walker et al. and reflect the expenses for recommended practices rather than the typical practices followed by livestock producers. Expenses are different for IES and SLS activities due to the shorter time cattle are on pasture and increased stocking density. Total veterinary and medical expenses are calculated by multiplying the percent of cattle treated for sickness by the sickpen cost and adding the processing charge per head and the charge for routine vet calls. Total vet-med costs per steer are $9.00 for SLS and $7.67 for IES.

Routine processing includes a charge for implants, eartags, worming, and routine vaccinations. SLS activities have a routine processing charge of 4.67 $/head and IES activities 3.98 $/head. This study assumes 25 percent of the calves will be treated for sickness, with a sickpen cost of $12.00 per head for SLS activities and $10.23 for IES activities. Thus, a charge of $3.00 per head is used in SLS budgets and $2.56 per head in IES budgets to reflect sickpen costs. Sickpen costs consist of a treatment for pinkeye, calf scours, and pneumonia.

Additional vet-med expenses result from routine veterinary calls. Based upon Walker et al. all budgets assume that 4.4 percent of all cattle are treated. SLS activities have a charge of 1.33 $/hd while IES activities have a charge of 1.13 $/hd.

The vet-med supplies cost are $2.08 for SLS and $1.88 for IES and include a charge for expendable items as well as reusable equipment. The charge for expendable items includes syringes, needles, ear taggers, wormer guns, implant guns, thermometers and other supplies. The charge for reusable equipment consists of assessed cost for pliers, hammers, tools, branding equipment, horse, tack, ropes, refrigerator, clippers, knives, and dehorners. Many of these items have several years of useful life but, replacement items are purchased each year and represent a regular expense (Walker et al.).

Supplemental Feed. Protein supplement and hay requirements can be specified within the economic submodel for any quantity and/or length of time to reflect different receiving and supplementation programs. The quantity of supplement and hay fed during the receiving program and the length of the program are exogenous inputs provided by the user. The model also considers feeding protein supplement late in the grazing season to meet the animal's nutrient requirements. In the stocker submodel, the model user specifies the number of days and the quantity of protein supplement fed. This information is transferred to the economic submodel to determine the cost of supplementation.

Hay charge is determined by multiplying the hay cost ($/lb) by the total quantity of hay fed. Total protein supplement cost is determined by multiplying the number of times protein supplement is fed during the receiving program by the quantity fed and adding the product of pounds of supplement fed late in the season and the number of days fed.

Interest on Operating Capital. Interest costs are computed in the model by using the interest factor approach (Boehjle and Eidman). Interest on operating capital is dependent upon the number of days each of the money outlays is held. To determine the interest cost, each expense is weighted by the fraction of a year elapsing between when the expense was incurred and the sale date. The sum of all operating interest expenses are then multiplied by an exogenously determined interest rate to determine the total interest cost.

Labor. Per head labor requirements of activities such as purchasing, feeding, and normal observation of cattle should be reduced as a consequence of increased cattle density (Bernardo and McCollum). The labor component of the economic submodel is constructed to reflect any economies of size that are associated with stocking density. As the number of head per acre increases, the stocking density increases and the labor requirements per head decreases. Per-head labor costs are assumed to decline until a stocking density of 1.6 hd/ac is reached. After this point, a reduction in per-head labor use associated with increased stocking density is considered to be minimal or zero.

Labor quantity is calculated in the model through the use of several "if-then" statements, each having a different set of labor-use coefficients dependent upon the prevailing stocking rate. The equations for determining labor quantity consider the number of times supplement and hay are fed and a coefficient which reflects daily labor quantity requirements from other activities such as purchasing, hauling, treatment for sickness, and normal observation. These coefficients range from .008 hours per head per day for a stocking density of .05 hd/ac to .002614 hours per head per day for a stocking density of 1.3 hd/ac. The coefficients and equations used in the labor calculation are based upon labor requirements used in existing budgets and previous studies (Bernardo et al., Walker et al.). Labor charge is found by multiplying the appropriate labor quantity by labor cost per hour.

The costs of range burning are based upon Bernardo et al. who estimated a per-acre prescribed burning cost in Central Oklahoma of $3.00/acre. Approximately one-third of this cost may be attributed to an increase in labor quantity. When the burning option is chosen by the model user, labor is automatically recalculated to reflect the additional charge.

Machinery and Equipment Operating Costs. Machinery and equipment repair costs are based upon Walker et al. The equipment costs account for livestock handling and feeding equipment. Machinery costs result from the use of a pickup and trailer. These charges were determined from standardized equations for estimating fuel, lubrication, and repairs (Walker et al.).

The machinery and equipment costs are also constructed within the model to reflect economies of size. Repair costs are reduced as stocking density is increased, by employing several "if then" equations as in the labor calculation. These equations use different coefficients in the calculation dependent upon the prevailing stocking density. The coefficients for machinery operating costs range from $.8 per-head per month for a stocking density of .2 hd/ac to $.43 per-head per month for a stocking density of 1.1 hd/ac. Coefficients for equipment operating costs range from $.22 to $.13 per-head per month for stocking densities of .2 to 1.1 hd/ac.

Range burning also increases the per-head costs of operating machinery and equipment. As stated earlier, operating costs for prescribed burning in Central Oklahoma are $3.00 per acre (Bernardo et. al). Approximately two thirds of this cost may be attributed to increased use of machinery and equipment. An equation is incorporated in the model to increase these costs when burning occurs.

CHAPTER V

MODEL APPLICATION

Description of Stocker Production Activities

To represent stocker production decisions faced by ranchers, eighteen alternative production and grazing system activities are evaluated. These activities include four stocking rates for the season-long stocking (SLS) enterprise and five for intensive-early stocking (IES). Each grazing system is considered with and without prescribed burning. The base or lowest stocking rate considered approximates the SCS recommendation for Central Oklahoma range sites of similar production potential. All grazing programs assume a 14 day receiving program for purchased steers. Each steer is fed ten pounds of hay and two pounds of protein supplement per day during the receiving period. All steers are assumed to weigh 450 pounds at the initiation of the grazing season.

All grazing systems are considered for a 1,000 hectare (2,471 acres) range. SLS activities are increased from 750 head (SLS-1) by 250 head increments to 1,000 head (SLS-2), 1,250 head (SLS-3), and 1,500 head (SLS-4). These activities translate to stocking densities of .3, .4, .51, and .61 hd/ac, respectively. SLS burning activities consist of the same stocking densities and are labeled SLS-1B through SLS-4B. All SLS activities consider grazing from April 15 to September 15 (150 days). Stockers are fed one pound of 43 percent protein supplement per day for the last 80 days of the grazing season.

IES activities involve grazing from April 15 to July 5 (80 days). The number of head represented in IES activities are 1125 head (IES-1), 1500 head (IES-2), 1875 head (IES-3), 2250 head (IES-4), and 2625 head (IES-5). Burning activities with the same stocking densities are labeled as IES-1B through IES-5B. The stocking densities from these practices are 1.5X, 2X, 2.5X, 3X and 3.5X the SCS recommended season-long stocking rate, and are .46, .61, .76, .91, and 1.06 hd/ac. Stocking densities of 2X the season-long density have been researched and recommended by Oklahoma State University researchers; however, densities of up to 3X have been applied successfully on prairie range sites in Kansas. Input costs are the same for IES and SLS activities. Supplemental feed is not used in the IES activities except during the receiving program.

Sell price in the IES activities is two percent higher than the sell price in SLS activities to reflect the added benefits from the sale of a lighter class of cattle earlier in the grazing season. July and September prices were compared from the Oklahoma City Livestock Auction for a period of 10 years to estimate this price differential.

Budgets at Average Levels

Appendix B contains budgets for each grazing activity at average prices, forage quality, and forage production. Each budget contains the input data at the top, followed by all costs incurred, gross receipts, and the return above operating costs expressed on a per-head and per-acre basis. A breakeven price for the activity is listed at the bottom of the budget.

Factor costs change among the different activities and stocking densities to reflect economies of size (labor, machinery and equipment operating cost). These costs also change to reflect the cost of burning. Vet-med expenses and supplies as well as the interest charge associated change among different activities due to a difference in the time period cattle are held and stocking density.

Labor quantity is reduced from 1.43 hrs/hd to 1.32 hrs/hd in the no-burning SLS activities to correspond to increasing stocking density from .3 hd/ac to .61 hd/ac. Reductions in per-head labor requirements reflect labor savings in day-to-day activities such as feeding and checking cattle; little economies of size can be derived from such tasks as receiving cattle, vaccinating, etc. In the SLS burning activities, the labor requirement is reduced from 2.19 hrs/hd to 1.7 hrs/hd when moving across stocking densities. Labor savings is more pronounced in the burning activities since the labor used in burning a given land area is spread over a large number of animal units. IES labor is reduced from .81 hrs/hd to .71

hrs/hd to reflect the change in stocking density. Labor use in the IES burning activities changes from 1.32 hrs/hd to .93 hrs/hd.

Machinery and equipment repair cost also reflect economies of size. Repair costs under SLS decrease from $4.50/hd to $3.60/hd, while repair costs under SLS burning activities change from $10.44/hd to $6.56/hd. IES costs are reduced from $2.24/hd to $1.48/hd. Machinery and equipment repair costs in the IES burning activities decrease from $6.19/hd to $3.17/hd across the five different stocking rates.

The average forage level across the 52 years of data is 3,680 Kg/Ha. This level of forage is non-limiting to animal gain in all four SLS activities at average forage quality levels. The gain for SLS-1 through SLS-4 is 213.64 pounds for the grazing season. Forage availability is marginally limiting in the IES activities, as seasonal gain decreases from 143.32 to 140.38 pounds. Seasonal weight gain in the IES activities is approximately 67 percent of SLS activities.

All burning activities have a higher gain than non-burning due to resulting increases in forage quality. Seasonal gains from SLS used in conjunction with prescribed burning ranged from 230.6 to 241.2 pounds. IES combined with burning results in average gains between 148.1 and 165.6 pounds. The simulation model calculates the effectiveness of a prescribed burn based upon the prior year's residual forage. As stocking rate increases the effectiveness or benefits received from burning decreases because of a smaller residual left at the end of the season. The additional gain from burning declined from a 13 percent increase in SLS activities to an 8 percent increase across stocking rates. The additional gain from burning across the five stocking rates for IES ranged from a 15 percent increase to a 6 percent increase.

Returns above operating costs under average price and forage conditions were greater than $ 10.00 per-acre for each enterprise considered. The SLS-4 and SLS-4B activities ultilize twice the number of head as the SLS recommended practice and had the highest returns for all non-burning and burning activities. SLS-4 has a return of $21.20/acre, and SLS-4B has a return of $26.15/acre. The lowest return was $8.74/ac and occurred under the IES-1 activity.

Mean per-acre net returns increased in each activity as stocking rate was increased; although, the amount of the increase diminished each time. This trend follows that of gain because of less effective burns and increased competition for forage as stocking density is increased. These results represent the net returns at average price, forage quality, and forage production levels and do not consider situations when these factors vary.

Stochastic Simulation Results

This section describes the results from applying the biophysical simulation model to the 18 grazing strategies described earlier. The effects of random forage quality, random prices and simulated forage production and gain are analyzed for each strategy. Distributions for each strategy are generated by running the simulation model simultaneously for the 52 years of available weather data. The distribution of per-acre net returns is reported, and activities are ranked based upon several evaluative criteria.

The mean, standard deviation, highest, lowest, and coefficient of variation of per-acre net returns are reported in Table VI for each strategy. Mean net returns range from -$1.60 per-acre for the IES-5 activity to $15.71 per-acre for the SLS-4B activity. The IES-5 activity is the only strategy with negative mean per-acre net return. All burning strategies have a higher mean net return than activities without burning at the same stocking density. Thus, based strictly on a criterion of profit maximization, producers would implement a prescribed burning program at all stocking densities evaluated. SLS activities have a higher mean net return as stocking rate increases, while IES returns decline after the IES-2 activity.

Considering all activities, the highest and the lowest return per-acre occurs under the IES-5B activity. Years with high per-acre net returns are characterized by favorable prices, forage quality, and high forage production. Alternatively, years with low per-acre net returns are characterized by unfavorable prices, forage quality, and low forage produc-

TABLE VI

SUMMARY OF PER-ACRE NET RETURNS

	mean	std. dev.	high	low	coef var
SLS-1	7.45	15.86	42.27	-21.05	2.13
SLS-1B	8.08	15.33	39.36	-23.49	1.90
SLS-2	9.13	22.22	56.52	-32.77	2.43
SLS-2B	12.76	23.84	64.98	-33.72	1.87
SLS-3	10.40	29.03	70.86	-51.96	2.79
SLS-3B	14.67	30.97	82.15	-53.29	2.11
SLS-4	11.30	36.00	85.28	-62.06	3.19
SLS-4B	15.71	38.27	98.02	-64.00	2.43
IES-1	4.50	21.26	56.67	-36.63	4.72
IES-1B	8.40	22.69	65.87	-39.02	2.70
IES-2	5.20	28.94	75.87	-48.55	5.56
IES-2B	10.31	30.84	88.39	-51.15	2.99
IES-3	5.08	36.77	95.01	-60.50	7.25
IES-3B	10.76	39.07	108.58	-63.19	3.64
IES-4	3.21	44.40	114.32	-72.31	13.89
IES-4B	8.79	47.08	127.81	-75.10	5.35
IES-5	-1.60	52.52	133.55	-84.27	-33.33
IES-5B	3.26	55.36	145.86	-87.99	16.95

tion. This effect becomes more pronounced as stocking density is increased.

The IES-5B activity has the greatest range between net returns and the largest standard deviation. The lowest range between high and low net returns occurs under the SLS-1B activity, with the SLS-1 activity having the second lowest range. IES-5B is characterized by the highest stocking density and the SLS-1B activity the lowest; thus, the trend in the range of net returns across stocking densities is as expected.

The two lowest standard deviations occur under the SLS-1B and SLS-1 activities and are $15.33/acre and $15.86/acre, respectively. These activities represent the base or most conservative of the stocking densities evaluated; therefore, it is expected that the variance of returns would be lower. The next lowest standard deviation moved up to $21.26/acre for the IES-1 activity. The two highest standard deviations were $52.52/acre and $55.36/acre for IES-5 and IES-5B. The ranking according to standard deviation is as expected, since under the larger stocking densities forage becomes limiting more often. In addition, the income benefits associated with years of favorable price and forage quality conditions are more pronounced.

Ranking the strategies according to the coefficient of variation (CV) results in the selection of SLS-2B with a CV of 1.87. The next two strategies chosen are also activities employing prescribed burning (SLS-1B and SLS-3B). The highest

CVs occur under the IES-5 activities. The coefficient of variation is calculated by dividing the standard deviation by the mean; thus, a low CV must have a large mean relative to the standard deviation. Thus, evaluative criteria based solely on return variability provide similar rankings; lower risk SLS activities are preferred over the more heavily stocked IES activities.

Several decision rules that were discussed earlier can be used to rank the strategies without considering probability estimates. Application of the maximin and the maximax rule to rank grazing strategies results in the selection of SLS-1 for the maximin rule and IES-5B for the maximax rule. The SLS-1 activity contains the maximum net return when considering only the lowest values. The IES-5B activity has the largest net return when considering only the highest values. The principle of insufficient reason considers all outcomes as equally likely and selects the action with the highest average outcome. Applying this rule results in the selection of SLS-4B.

Employing the expected return decision rule which considers all outcomes and associated probabilities results in choosing SLS-4B. Utility maximizing risk neutral decision makers would use this rule to select SLS-4B because it has the highest expected monetary value. The expected return and the principle of insufficient reason result in the same strategy in this case because all outcomes are assumed to have an equal probability of occurrence.

The safety-first criterion involves maximizing the expected return subject to a specified probability of returns exceeding a minimum level. Because all of the net return distributions contain negative outcomes, a minimum acceptable net return level of zero cannot be used. Establishing the criteria that 63 percent of returns must exceed zero results in the selection of strategy SLS-3B. Establishing the probability level at 65 percent results in strategy SLS-1B. SLS-1B is the only strategy that would be chosen if the probability of positive net returns must be 67 percent or larger. This result implies that a ranch manager who desired positive net returns at least two-thirds of the time would consistently employ the SLS-1B activity. Thus, optimal stocking densities under safety-first behavior are consistent with those derived under the 25 percent allocation rule.

Stochastic Dominance Analysis

To evaluate the expected value and variability of net returns from employing alternative grazing strategies, stochastic dominance analysis is applied to the distributions of net returns. Specific stochastic dominance criterion included in the analysis are first-degree, second-degree, and generalized stochastic dominance. The stochastic efficiency analysis involves simultaneous comparison of the cumulative distribution functions of net returns summarized in Table XXV.

First and Second Degree Stochastic Dominance

Risk efficient sets of grazing strategies derived from the application of first-degree stochastic dominance (FSD) and second-degree stochastic dominance (SSD) are presented in Table VII. The first degree stochastically efficient set is comprised of 16 of the 18 grazing alternatives. Under the more restrictive assumptions of second-degree stochastic dominance, 10 grazing strategies are eliminated from the risk efficient set leaving six activities.

TABLE VII

RISK EFFICIENT SETS FROM FIRST AND SECOND DEGREE STOCHASTIC DOMINANCE

FSD		SSD
SLS-1	SLS-1B	SLS-1
SLS-2	SLS-2B	SLS-2
SLS-3	SLS-3B	SLS-1B
SLS-4	SLS-4B	SLS-2B
IES-2	IES-2B	SLS-3B
IES-3	IES-3B	SLS-4B
IES-4	IES-4B	
IES-5	IES-5B	

The FSD efficiency set contains all burning and non-burning SLS activities and every IES activity except for IES-

1 and IES-1B. When the number of head per-acre is doubled (from the SCS recommended rate) as in IES-2, the IES activities become part of the risk efficient set. IES activities are designed to take advantage of the higher quality forage produced in the first half of the grazing season, and also any economies of size that may occur due to increasing head/acre. IES-1 and IES-1B contain only 1.5X the SCS recommended rate and do not fully utilize benefits associated with IES; therefore, these activities are not included in the FSD set. Strategies identified as risk efficient under the FSD criteria include both grazing systems having relatively high net returns and large levels of variability, as well as low-risk grazing plans.

The SSD efficiency set contains only SLS activities. The low-risk SLS-1 and SLS-2 activities are chosen as well as all SLS activities used in conjunction with prescribed burning. IES activities are eliminated because of their higher variability of net returns. IES activities do have a greater potential of high net returns, but they also have a larger chance of incurring negative returns because of increased competition for forage. Clearly, neither FSD or SSD are particularly discriminating tools in ranking the efficiency of alternative grazing strategies. Additional restrictions can be placed upon producer risk preferences by the application of generalized stochastic dominance.

Generalized Stochastic Dominance

Generalized stochastic dominance (GSD) can provide a more complete ordering of decision choices by employing risk aversion coefficient intervals. Four different risk interval sets are used to represent decision makers who are risk preferring, risk neutral, slightly risk averse, and strongly risk averse. The four risk interval sets, measured by Pratt/ Arrow risk aversion coefficients, are presented in Table VIII and are based upon findings reported in Cochran et al. Scaling adjustments were necessary to convert net returns to a similar outcome range observed by the Pratt/Arrow coefficients.

TABLE VIII

PRATT/ARROW RISK AVERSION COEFFICIENTS

	lower bounds	upper bounds
risk preferring	-.0008	-.0001
risk neutral	-.0001	.0001
slightly risk averse	.0001	.0004
strongly risk averse	.0004	.001

The application of GSD reduces the number of grazing strategies comprising the risk efficient set under all four risk intervals. Table IX shows the risk efficient sets for all risk categories.

TABLE IX

RISK EFFICIENT SETS FROM GENERALIZED STOCHASTIC DOMINANCE

risk preferring	risk neutral	slightly risk averse	strongly risk averse
IES-5B	SLS-1	SLS-1	SLS-1
	SLS-1B	SLS-1B	
	SLS-2B		
	SLS-3B		
	SLS-4B		
	IES-2B		
	IES-3B		
	IES-4B		
	IES-5		
	IES-5B		

The risk efficient set identified by the group of risk preferring decision makers consists only of the IES-5B activity. As indicated by the range and standard deviation of net returns (Table VI), this strategy contains the largest return and the largest amount of variability of all alternative grazing systems evaluated. Risk preferrers are willing to accept the chance of low net return outcomes to have the probability of realizing the large net return attainable from stocking at this high density.

Risk neutral decision makers choose the highest returns, regardless of the variability. These decision makers maximize expected utility by adopting all SLS-burning activities, all IES-burning activities except for IES-1B, and non-burning activities SLS-1 and IES-5. These strategies selected under risk neutral preferences are burning activities characterized by higher net returns and larger variability, the very low risk SLS-1 activity, and the high risk IES-5 activity.

Slightly risk averse decision makers adopt the SLS-1 and SLS-1B strategies. The risk efficient set identified under strong risk aversion consists only of the SLS-1 activity. These efficiency sets identified under risk aversion differ considerably from those identified under alternative risk preferences. Grazing strategies comprising efficiency sets derived under the assumption of risk aversion are characterized by low standard deviations and infrequent occurrences of low return. The SLS-1 activities possess these characteristic due to the low stocking rate where forage rarely becomes limiting. Therefore, although higher stocking densities may be preferred based upon a criterion of expected profit maximization; more traditional stocking densities are preferred when risk averse behavior is represented.

Combined Activities

Diversification is a common method of reducing risk and uncertainty (Boehlje and Eidman). Diversification can occur by adding resources or by modifying the existing resources or production activities. This study considers diversified activities by evaluating several SLS and IES combinations.

Ranchers can employ a variety of strategies to deal with risk and uncertainty. Boehlje and Eidman divide these strategies into three broad categories: strategies designed to reduce uncertainty, strategies which shift some of the risk to another firm, and those which rely on reserves in periods of low or negative income. Strategies which shift risk to another firm include purchasing insurance and forward contracting or hedging. Ranchers can shift some risk to insurance companies by purchasing fire, theft and other types of insurance. Price risk can be shifted by forwarding contracting and/or hedging in the commodity futures market. Many ranchers maintain reserves in the form of feed to use during shortage periods. Some ranchers also maintain financial reserves in the form of liquidity and solvency to carry the business through years with low returns.

To consider the possibility of combining stocker-production activities to reduce uncertainty, four diversified grazing activities are evaluated. SLS-1 is combined with IES-2 on a 50/50 percent basis and on a 25/75 percent basis. These combinations are considered with and without prescribed burning. Table X shows a summary of the per-acre net returns of diversified activities.

TABLE X

SUMMARY OF PER-ACRE NET RETURNS
FROM DIVERSIFIED ACTIVITIES

SLS/IES	mean	std. dev.	high	low	coef var
50/50	6.32	22.09	59.04	-34.80	3.50
50/50-B	9.19	22.57	61.22	-37.32	2.50
25/75	5.76	25.47	67.45	-41.67	4.42
25/75-B	9.75	26.63	74.80	-44.24	2.73

The 25/75 diversified activity used in conjunction with prescribed burning (25/75-B) has the highest mean and standard deviation of all diversified activities. The same enterprise combination without prescribed burning (25/75-N) has the lowest mean of the combined activities. The 50/50 activity without burning (50/50-N) contains the lowest standard deviation of diversified activities and the fourth lowest when considering all activities. The 25/75-N activity has the highest coefficient of variation while the 50/50-B activity has the lowest.

When all activities are considered, the diversified activities are ranked neither best nor worst according to mean, standard deviation and coefficient of variation. Not surprisingly, the diversified activities rank between the SLS and IES activities. The profitability of higher net returns is increased, but variation is also increased. Diversified activities did have a lower range of net returns than all other enterprises considered.

Results from stochastic dominance analysis indicate that the 50/50-B, 25/75-N, and 25/75-B activities are included in the FSD efficiency set. The 25/75-B activity is also in the risk neutral efficiency set. Diversified activities are not in any other efficiency set.

Several factors may account for the reason why diversified activities are not included in other efficiency sets. Boehlje and Eidman report that the opportunities to reduce variance of returns by diversification are not significant unless enterprises can be added that are either characterized by less variance per dollar of return or a negative correlation with the included enterprises. The variance of returns for the combined enterprises is the sum of the variance of each enterprise plus the covariance of the two. Because the IES activities have a greater variance of returns than the SLS activities, the combined activities have a higher variance than the SLS activities. The correlation between returns per-acre from IES and SLS activities is .94. The positive correlation between the enterprises results because the activities rely on the same inputs during the same season of the year. The positive correlation affirms the fact that the diversified activities will result in more risk than the SLS activities with low stocking rates.

Combination of IES and SLS activities proves to be an efficient strategy for the risk neutral decision maker but not for the risk averse or risk preferring producer. Risk averse decision makers could reduce their risk by diversifying with activities that are negatively correlated or by stocking with a stocking rate more conservative than the recommended SCS stocking rate to reduce the variance of returns. The opportunity to combine negatively correlated enterprises is small for ranchers because low variance enterprises often have low returns and production activities during the same season tend to be positively correlated. Risk preferrers do not select diversified activities since the probability of high net return outcomes has been reduced below the IES activities.

Forage Prediction

Ranchers and rangeland managers are aware of varying growing conditions and forage production in each season. Ranchers may be better able to make stocking decisions and take advantage of available forage if additional information is available concerning total forage production. A question worthy of consideration is "Can producers improve the profitability of their stocker enterprises by basing stocking densities on projections of annual forage production?".

A forage prediction model was estimated to forecast forage growth using climatic data available prior to the grazing season. The model was then applied to select stocking rates over the 52-year time horizon. A new distribution of net returns was generated based upon flexible stocking densities and compared to the net return distributions generated using a fixed density.

Regression analysis was employed to determine the weather variables which accounted for the greatest percentage of variation in annual forage production. Climatic data used for the analysis is from the National Climatic Center weather station located in Stillwater, Oklahoma. Actual forage production values used as the dependent variable are obtained from a study by Powell et al. The annual forage production data were collected on a tallgrass prairie near Stillwater, Oklahoma. The forage values were determined from annual clipping dates from a Norge loam soil range site. The test site was described as good to excellent range condition and contained the normal species composition for Central Oklahoma.

Several climatic variables were combined to represent the weather effects on annual forage production. Temperature and rainfall data was accumulated from the end of the previous grazing season until the beginning of the grazing season in April. Models were formulated using this span of data because stocking decisions must be made prior to the initiation of the growing season (early April).

Temperature data were characterized on a monthly basis using the lowest temperature recorded in the month (absolute minimum), the highest temperature recorded in the month (absolute maximum), mean minimum, mean maximum, mean daily and the mean monthly. Precipitation values considered were the cumulative precipitation for each calendar month, cumulative precipitation during fall months (September - November), cumulative precipitation for winter months (December - February) and the month of March.

Many combinations of variables are possible, so variables were eliminated according to insignificant t-statistics, very low R^2 values, and poor predictive power. The chosen forecasting equation to predict total forage production (TFP) is:

$$TFP = -8877.9 + \underset{[3.67]}{X_1(164.44)} + \underset{[2.44]}{X_2(109.98)} + \underset{[1.22]}{X_3(46.51)}$$

where, X_1 is the cumulative rainfall since the prior grazing season, X_2 is the mean maximum October temperature, and X_3 is mean February temperature. The R^2 value of the model is .53 and the t-statistics are reported below each coefficient.

These variables explained more of the variation in forage production than most other combination and contained expected signs and possessed the best predictive power. This model is consistent with the findings of Powell et al. who also found that temperature played an important part in forecasting tallgrass prairie production. The predictive power of the model was evaluated using 22 years of actual forage data, and it was found to predict within one standard deviation in 80 percent of the observations.

To evaluate the results of applying the forage prediction model, peak standing crop is divided into four categories which correspond to the four SLS activity stocking densities. Using the forage prediction model, an estimate of peak standing crop was derived for each year of data. The estimate for each year corresponds to one of the categories of forage production ranging from 0-1,500 kg/ha, 1,501-2,250 kg/ha, 2,251-3,000 kg/ha, and yields greater than 3,000 kg/ha. The four forage categories may be labeled as low, medium low, medium high, and high production. The lowest forage production category (1-1,500 kg/ha) corresponds to the lowest stocking rate (SLS-1) and so on; for example, when medium high forage production is predicted then the SLS-3 activity is used.

Employing a new grazing strategy each year, dependent upon the forage prediction, results in a new distribution of net returns which can be compared to distributions generated with a constant stocking rate. The distribution of net returns from applying the forage prediction model has a mean of $12.11, a standard deviation of $33.68, and a coefficient of variation of $2.78. The net returns per-acre range from $-62.06 to $85.28.

The forecasted distribution of returns has a mean which ranks fourth when compared to all other strategies. If the forage prediction model was a perfect predictor, then the forecasted distribution would have the highest mean. Given a situation where forage quality and prices are constant, and a ranch manager is able to accurately predict forage production, then the most profitable grazing system would be selected each year resulting in the highest possible average returns.

Stochastic dominance analysis reveals that the distribution generated using the forage prediction is included in the FSD, SSD, and risk neutral efficiency sets. Risk averse decision makers choose strategies which have a lower standard deviation and a higher mean. The forage prediction model estimated in this study does not change the efficiency set of risk averse decision makers because of its inability to increase the mean value more than the relative increase in variability of returns.

Several factors may account for the reason that risk averse decision makers would not benefit from the use of the forage prediction model. Because the returns from applying the forage prediction model were in the FSD, SSD, and risk neutral sets, we know that producers are provided with some useful information. However, other sources of risk, such as price variability and variability in forage quality may provide the majority of the income variability faced by stocker producers. Since changes in these variables are primarily influenced by market and climatic events occurring during the grazing season, prediction of their values is very difficult.

Revised Biophysical Simulation Model

A problem frequently cited with simulation models is that they do not permit managerial adjustments in response to existing environmental conditions. The application of the simulation model to this point may be subject to similar criticism. The model does not permit the adaption of specified production plans based upon information that comes available through the production year. For example, the model assumes that stockers continue to graze throughout the season without regard to animal performance and/or range productivity. Also, under the range burning option, prescribed burning occurs regardless of the previous year's dry matter residual. The simulation model was revised to account for these factors, and new distributions of net returns were generated for the 18 activities across the 52 years of data.

To eliminate the situation of continuing grazing despite an obvious shortage of available forage, a destocking criterion is incorporated into the simulation model. The criteria used to destock consists of evaluating the relative forage dry matter intake (RFI) on a daily basis. As explained earlier in the Stocker Intake Section of Chapter IV, RFI represents the effect of limiting forage quantities on animal intake. When RFI is below .95 and decreasing for seven consecutive days, the grazing season is terminated and destocking occurs. Operating costs are then adjusted to reflect the shorter time period that cattle are held.

To prevent burning when adequate fuel is not available, a burning criterion is employed which is dependent upon RESID. RESID is found by dividing the previous year's ending dry matter by 2,000 kg/ha. RESID is fully defined in the Stocker Intake/Growth Submodel Section of Chapter IV. The base model did adjust the effectiveness of a prescribed burn by employing RESID, but most range managers would not consider spring burning when fire fuel is not adequate to assure a burn can carry through the pasture. The criterion employed in the revised model accounts for this behavior by allowing prescribed burning to occur only when ending dry matter is greater than 1,200 kg/ha. When dry matter is below this level, benefits received from burning are assumed to be exceeded by the cost of burning.

Table XI reports the mean, standard deviation, range, and the coefficient of variation of net returns generated using the revised model. Activities consist of the same stocking rates and input costs, and are designated by an asterisk.

Due to the higher probability of a low RESID value, the number of times that burning was not allowed to occur increases as stocking density increases. Under the SLS-1B activity, burning was deemed infeasible 13 percent of the time, while under SLS-4B burning was not employed 36 percent of the years. This phenomenon becomes more exaggerated under the IES strategies. Burning is implemented 70 percent of the

TABLE XI

SUMMARY OF PER-ACRE NET RETURNS
FROM THE REVISED MODEL

	mean	std dev	high	low	coef var
*SLS-1	7.63	15.65	42.21	-21.03	2.05
*SLS-1B	10.35	16.72	47.83	-21.02	1.62
*SLS-2	9.87	21.27	56.48	-27.82	2.16
*SLS-2B	13.80	22.66	64.93	-27.82	1.64
*SLS-3	11.89	26.93	70.84	-34.54	2.27
*SLS-3B	16.38	28.34	82.13	-34.54	1.73
*SLS-4	13.94	32.74	85.28	-41.17	2.35
*SLS-4B	18.81	34.44	97.97	-41.17	1.83
*IES-1	4.65	21.05	56.67	-36.63	4.52
*IES-1B	8.76	22.35	65.87	-36.63	2.55
*IES-2	5.54	28.48	75.87	-48.55	5.14
*IES-2B	10.59	29.95	88.45	-48.55	2.83
*IES-3	5.85	35.82	95.01	-60.50	6.12
*IES-3B	11.39	37.68	108.62	-60.50	3.38
*IES-4	4.19	43.26	114.32	-72.31	10.32
*IES-4B	10.01	45.60	127.84	-72.31	4.56
*IES-5	0.12	50.72	133.55	-84.27	410.81
*IES-5B	7.02	54.43	145.53	-84.27	7.75

years under IES-1B, while under the IES-5B activity it is only employed in 52 percent of the years. These numbers suggest that a decision maker employing the base stocking rate (SLS-1), would refrain from prescribed burning at least once every seven years.

Prescribed burning activities become significantly more efficient because of the additional criteria established in the revised model. As explained earlier, burning occurs only if there is adequate fuel to generate benefits greater than the costs. This criterion allows burning activities to have a greater mean net return than the burning activities derived from the base model.

The net returns per-acre from the strategies in the revised model follow with those in the base model by increasing as stocking rate increases and prescribed burning occurs. Returns increase across all four SLS activities but start to decrease under the IES strategy after IES-3.

Mean net returns range from $.12/ac (*IES-5B) to $18.81/ac for *SLS-4B. As in the baseline results, the highest and lowest mean net return per-acre occur under the same activities, but returns are an average of 15.8 percent higher. Returns are increased under the revised model because animals are not forced to remain on pasture when potential gains are very small. The revised model allows animals to graze as long as there is forage available; however, when forage becomes limiting and animal intake starts to decrease, destocking occurs to prevent overgrazing. The previous model held stockers on pasture even though their gain may not be offsetting the cost of holding them.

The new criteria introduced in the revised model increase the mean return in larger amounts as stocking rate is increased and in the prescribed burning activities. Returns increase only by $.18/ac over the baseline result for *SLS-1, but increase by $2.64/ac for *SLS-4. Per-acre net returns for the *SLS-1B activity are $2.27/ac higher than SLS-1B. This increase in returns occurs because of the more complex decision criteria employed in the revised model which results in higher stocking rates and prescribed burning becoming more profitable practices. This adaptive behavior reduces the probability of large income losses and decreases the income variability associated with high stocking rates and prescribed burning.

As in the baseline results, the greatest range in per-acre net returns occurs under the *IES-5B activity. The lowest range in net returns occurs in the *SLS-1 activity which had the second lowest range in the baseline results. The highest and lowest standard deviations occur under the same activities as derived in the baseline, but standard deviations are an average of 3.7 percent lower when using the revised model. These lower standard deviations occur because the stricter criteria employed in the revised model keep returns from dropping to low levels. The average of the minimum returns in the baseline results is -$50.58/ac, while under the revised model it is -$44.93. There are also 10 percent fewer negative net returns under the revised model.

Applying the decision rules that do not use probability estimates results in choosing the same strategies as under the base model. *SLS-1 is chosen for the maximin rule and *IES-5B for the maximax rule. *SLS-4B is chosen using the principle of insufficient reason, as under the base model, due to its highest average outcome. *SLS-4B is also chosen when employing the expected return decision rule because all outcomes are equally likely.

Employing the safety-first criterion results in choosing several different strategies than under the base model. Solutions were significantly affected because of the effect of the adaptive behavior on the magnitude and probability of negative net return outcomes. Using the same criterion that 63 percent of all returns exceed zero results in the selection of *SLS-3B. Establishing the probability at 65 percent also results in selecting *SLS-3B. The *SLS-3B strategy was not in the optimal set when the base model was used. *SLS-2B has the highest expected return when per-acre net returns must be positive 67 percent of the time. *SLS-2B did not have this large probability of positive net returns when adaptive behavior was not represented.

Stochastic Dominance Analysis

Risk efficient sets derived from the application of FSD and SSD to the net returns generated from the revised model are presented in Table XII. The number of activities comprising the efficient sets are considerably lower than in the baseline results. The first-degree stochastically efficient set includes 10 strategies while the set derived using SSD consists of 4 strategies. This compares to the FSD and SSD sets in the baseline results which are comprised of 16 and 6 strategies, respectively. As explained earlier, the difference in the stochastically efficient sets results from the reduction in the number of low net return outcomes in the burning strategies. Eight non-burning strategies were in the FSD risk efficient set from Model 1; however, only one non-burning strategy (IES-5) is included in this same set under the revised model. The new SSD set contains only burning strategies.

TABLE XII

REVISED RISK EFFICIENT SETS FROM FSD AND SSD

FSD		SSD
*SLS-1B	*IES-5	*SLS-1B
*SLS-2B	*IES-1B	*SLS-2B
*SLS-3B	*IES-2B	*SLS-3B
*SLS-4B	*IES-3B	*SLS-4B
	*IES-4B	
	*IES-5B	

Generalized stochastic dominance analysis was performed on the net returns from the revised model using the same risk aversion coefficients described earlier. The results from GSD are shown in Table XIII.

TABLE XIII

REVISED RISK EFFICIENT SETS FROM GENERALIZED STOCHASTIC DOMINANCE

risk preferring	risk neutral	slightly risk averse	strongly risk averse
*IES-5B	*SLS-1B	*SLS-1B	*SLS-1B
	*SLS-2B		
	*SLS-3B		
	*SLS-4B		
	*IES-3B		
	*IES-4B		
	*IES-5B		

The risk efficient set for a risk preferring decision maker contains only *IES-5B and is identical to the risk efficient set derived from Model 1. The efficient set for risk neutral individual, contains all SLS burning activities and *IES-3B, *IES-4B, and *IES-5B. This set differs from the previous risk neutral set by eliminating *SLS-1, *IES-2B, and *IES-5.

Slightly and strongly risk averse decision makers adopt only the SLS-1B activity. These sets differ from the former risk averse sets by excluding SLS-1. The SLS-1 activity contains the lowest stocking density considered and therefore, has the lowest variance of returns but still has a relatively large mean return. The more restrictive criteria employed by the revised model allows burning to increase the mean return without significant increases in variance; thus, the SLS-1 activity was replaced by SLS-1B.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Stocker cattle production is an important part of Oklahoma's economy. Beef cattle are the most valuable commodity produced in the Oklahoma agricultural sector in terms of total cash received by farmers and ranchers and the proportion of farms devoted to beef production. Oklahoma's native rangeland is an important source of feed for these livestock, as evidenced by the 19.7 million acres (46 percent of Oklahoma's land area) grazed annually.

Stocker cattle producers face many decisions where outcomes are uncertain. Producers must seasonally evaluate and select among several alternative production practices, livestock enterprises, and forage activities. Due to the interaction among these components, information is needed to determine the most profitable beef-forage system available. A better understanding of the profitability and risk associated with alternative grazing systems and practices will assist producers in decision making.

The objective of this study is to develop a biophysical simulation model of stocker cattle production on native range, and use the model to identify efficient livestock grazing systems for central Oklahoma stocker operations. Specifically, the study was conducted to determine the distribution of net returns derived from season-long stocking and intensive-early stocking enterprises, at alternative stocking densities and with and without prescribed burning. Based upon the derived distributions, the alternative enterprises may then be ranked based upon their expected return and risk properties.

Method of Analysis

The method of analysis employed in order to fulfill the study objectives includes the modification of an existing forage production model (ERHYM-II) and development of stocker cattle intake/growth and economic submodels. The resulting simulation model is capable of estimating the physical and economic consequences of alternative stocker production practices under a variety of environmental conditions. Net returns are obtained under stochastic forage quantity, forage quality, and output and factor prices.

The ERHYM-II forage submodel estimates annual herbage yield based upon a series of daily simulations of soil evaporation, transpiration, runoff, and soil water routing. The model assumes that transpiration is the principal hydrologic process which affects daily water use and forage production. This submodel assumes that water stress is the only factor preventing the attainment of maximum growth. Annual forage yield is estimated as a function of an accumulated water stress measure derived from daily transpiration deficit measures.

The basis for the data and equations used in the forage submodel were results from a composite of related agronomic research projects. Vegetation parameters and soil water characteristics developed from these projects were incorporated into the ERHYM-II model. Soil and watershed parameters were based upon SCS data for compatible range sites of similar production potential.

Total forage production determined by the forage submodel was estimated by employing accumulated transpiration values and an equation derived from a 20 year study conducted to estimate annual forage growth. Historical weather data and model-generated solar radiation values were used to determine the daily transpiration values.

The stocker intake/growth submodel was constructed by employing NRC equations and results from related animal science studies. The animal's energy requirements for maintenance and gain were based upon the California Net Energy System. The actual intake of steers was assumed to be dependent upon voluntary intake, forage availability, and an adjustment for actual daily air temperatures.

Voluntary intake was defined as a function of random forage quality and metabolic weight. Forage quality estimates were derived from a random forage quality model based upon the covariance of monthly protein values. Forage availability was considered to be the amount of forage available for consumption and was expressed as a function of available dry matter, cumulative animal weight, and stocking density. Actual intake was reduced below voluntary intake estimates using an exponential function relating relative intake to forage availability. The stocker submodel increases gain when feeding protein supplement by adjusting the digestibility of the composite feed.

The economic submodel was constructed to calculate net returns and uses data based upon existing enterprise budgets and budgets from similar studies. Price and cost data used for the economic inputs were based upon average prices for these inputs in the study area. Input and output prices, as well as protein supplement and hay prices, were assumed to be random, and were generated using a procedure for estimating correlated random outcomes. Labor and machinery and equipment operating costs were assumed to change as stocking density is increased to reflect economies of size.

Summary of Results

Total acreage in the model was constrained at 1,000 hectares (2,471 acres). Annual net returns were estimated by the simulation model for each activity over a period of 52 years. The historical weather data was obtained from the National Climatic Center weather station located in Stillwater, Oklahoma. All grazing activities employed a 14 day receiving program in which two pounds of protein supplement and ten pounds of hay were fed to each head per day. Protein supplement was also fed at the rate of one pound per head per day for strategies staying on pasture after July 1. SLS strategies permitted a maximum of a 150 day grazing season, and IES strategies involved grazing durations of 80 days.

Base Model

The biophysical simulation model was employed to generate a distribution of net returns for eight SLS and ten IES grazing activities. The highest average net return from these activities consisted of employing annual prescribed burning in conjunction with grazing stockers at a density of .61 hd/ac from April 15 through September 15 (SLS-4B). All activities were assumed to graze the maximum of 150 days for SLS and 80 days for IES. Burning strategies involved prescribed burning each year.

Stochastic dominance analysis indicated that all producers characterized by positive marginal utility of income (first-degree stochastic dominance) could select 16 out of the 18 available strategies. The second-degree stochastic dominance set contained all SLS burning activities and the two lowest stocked SLS activities without burning. These results imply that as decision criteria becomes more discriminating, SLS is preferred over IES and burning over non-burning.

By employing generalized stochastic dominance, it is shown that as risk is reduced, decision makers choose SLS activities over IES. Risk averse producers choose only the conservative SCS recommended season-long stocking rate. This activity involves grazing .3 hd/ac without prescribed burning. Risk preferring individuals choose the IES strategy with the highest stocking density. This activity involves grazing 1.06 hd/ac for 80 days. Risk neutral individuals indicate no preference on the stocking rate or length of the grazing period, but do prefer prescribed burning over non-burning at equivalent stocking densities.

Combined Enterprises

IES and SLS activities were combined to determine if diversification opportunities exist that might be preferred by decision makers over single enterprise activities. The SLS-1 activity with a stocking density of .3 hd/ac was combined with the .6 hd/ac IES-2 activity on a 50/50 and 25/75 percent basis respectively. These combinations were considered with and without prescribed burning.

Stochastic dominance analysis indicates three of the combined activities are included in the first-degree stochastic dominance set. The only efficiency set which contained a combined enterprise was the risk neutral set which added the one-fourth SLS-1B three-fourths IES-2B activity. As the degree of risk aversion increases, diversified activities are not included in the risk efficient sets, since combining IES and SLS does not reduce the variance per dollar of return and the enterprises are positively correlated.

Forage Prediction

A forage prediction model was estimated to determine if more efficient strategies could be developed by modifying stocking densities annually to reflect expected forage conditions. The variables in the model chosen to forecast peak standing crop consisted cumulative rainfall, and October and February temperatures.

To evaluate the additional information, the four SLS activities were implemented as higher forage was predicted. Thus, expected forage production increased as the stocking density was increased. The purpose of employing the forage prediction was to allow the producer to graze heavily in years of high forage and use more conservative enterprises in years of projected low production.

The distribution of net returns generated using the prediction model has a mean value of $12.11/ac, which ranks fourth among the distributions estimated using a single stocking rate. Unfortunately, the distribution generated using the prediction model also has a relatively large standard deviation. This result reflects the large income losses that may occur when forage production is overestimated and stocking rates are adjusted accordingly. When stochastic dominance analysis was performed, the predicted distribution was in the risk efficient sets derived using first and second-degree stochastic dominance. However, the distribution generated using the forage prediction model was not included in efficiency sets reflecting risk averse preferences.

Several factors may account for the reason that risk averse decision makers did not adopt the forage prediction model and change their efficiency sets. Because the returns from applying the forage prediction model were in the FSD, SSD, and risk neutral sets, we know that producers were provided with some useful information. Other sources of risk such as price risk may be the majority of the risk that risk averse individuals face.

Revised Biophysical Simulation Model

The baseline results were generated assuming that the same strategy was employed annually regardless of the specific production conditions. Thus, decision makers could not adjust their stocking rates to the current availability of forage and practiced prescribed burning regardless of the quantity of fire fuel available. The simulation model was revised so that grazing under conditions of limited forage availability was minimized and prescribed burning was practiced only in years when sufficient fuel was available. The revised model minimized overgrazing to a minimum by allowing animals to be destocked when sufficient dry matter was not available for consumption. Prescribed burning was not followed when the previous years residual dry matter was less than 1,200 kg/ha.

The mean returns from the revised model were all greater then the previous estimates because losses were minimized in low production years, and burning was only practiced when its benefits exceeded the associated costs. Average returns from the revised model were 15.8 percent higher than the returns from the previous model.

Comparing the risk efficient sets of net returns from the revised model with the baseline results demonstrated that prescribed burning and higher stocking densities became more efficient strategies as a result of the added decision criteria employed in the revised model. The revised efficiency sets from stochastic dominance analysis show that the burning and heavier stocked activities were more efficient.

General Conclusions

The biophysical simulation model was employed as an analytical tool to simultaneously determine forage production, animal performance, and expected levels of net returns for summer stocker grazing programs. The model also allows a wide range of production practices and management strategies to be analyzed. Through the use of this model, distributions of returns can be derived and analyzed for decision makers with alternative risk preferences.

Results from this analysis indicate that efficient grazing strategies are sensitive to the producers degree of risk aversion. Studies which ignore risk when attempting to identify efficient summer grazing programs may result in erroneous recommendations. The derived risk efficient sets in this study illustrate that burning strategies are preferred over non-burning and season-long stocking programs are preferred over intensive-early stocking for the risk averse decision maker. Though, as more complex decision criteria are incorporated into the model to represent seasonal adjustments available to the producer, intensive-early stocking becomes more favorable.

The specific results derived from this study are specific to north central Oklahoma, due to the site specifity of the data employed. However, the simulation model does provide a method of more accurately representing the relationship between forage production, stocker cattle performance on native range, and economic returns. In addition, the risk efficient sets derived from the model are applicable to stocker cattle grazing systems in other regions.

Limitations and Need for Further Research

In the process of conducting this research various difficulties were encountered. These problems provide several opportunities for future research and can be summarized as follows:

a) The biophysical simulation model describes a production response surface and can be used to analyze decision alternatives; though, the model lacks the ability to derive optimal input levels.

b) The forage production submodel assumes that water stress is the only factor preventing attainment of maximum growth. Thus, yield losses resulting from nutrient deficiencies, plant disease, etc. are ignored. More complete data on these factors and their effect upon growth and animal performance would aid in more closely representing the dynamic process.

c) Monthly forage protein estimates were generated on a random basis to represent changing forage quality. A forage quality model which relates the specific relationship between digestibility values and the basic process of forage production (e.g., soil moisture, transpiration, etc.) would increase the accuracy and validity of the model.

d) Due to a lack of data, several of the relationships underlying the stocker submodel were developed based upon research findings from areas outside the study region. Additional data and modeling efforts are needed to validate and/or modify intake functions, energy relationships, and gain equations included in the model.

e) Labor cost, machinery operating costs, and equipment operating costs are assumed to reflect economies of size by decreasing, on a per head basis, as stocking density increases. Actual information on the change in costs as stocking density changes would provide a more realistic portrayal of this relationship.

f) This study assumes that when destocking occurs, all cattle are removed that specific day. In actual practice, some percentage of the total herd may be left to graze for the rest of the season. More sophisticated destocking strategies could be incorporated into the model.

g) Buy price, sell price, hay price, and supplemental feed price are assumed to be independent of the physical parameters of forage production. Actual information on the correlation between these prices and seasonal forage production would provide a more accurate price relationship.

h) Further research is needed in the area of livestock price forecasting. Because the majority of risk faced by producers results from price fluctuations, an accurate price prediction model might aid in identifying optimal grazing strategies.

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APPENDICES

APPENDIX A

BULK DENSITY, AIR-DRY, FIELD CAPACITY AND PERMANENT WILTING VALUES AS RELATED TO SOIL TEXTURE

TABLE XV

BULK DENSITY AND AIR-DRY VALUES
AS RELATED TO SOIL TEXTURE

Texture	Bulk Density (g/cm^3)	Air-Dry[2] (inches)
sand	1.49	0.34
loamy sand	1.49	.40
sandy loam	1.45	.49
loam	1.42	.52
silt loam	1.32	.56
sandy clay loam	1.60	.60
clay loam	1.42	.80
silty clay loam	1.40	.83
sandy clay	1.51	.92
silty clay	1.38	1.00
clay	1.39	1.00

adapted from Wight

TABLE III

FIELD CAPACITY AND PERMANENT WILTING VALUES AS RELATED TO SOIL TEXTURE

Texture	Field Capacity volu-metric (g/cm^3)	Field Capacity gravi-metric (g/g)	Permanent Wilting volu-metric (g/cm^3)	Permanent Wilting gravi-metric (g/g)
sand	0.091	0.061	0.033	0.022
loamy sand	.125	.084	.055	.037
sandy loam	.207	.143	.095	.066
loam	.270	.190	.117	.082
silt loam	.330	.250	.133	.101
sandy clay loam	.255	.159	.148	.092
clay loam	.318	.224	.197	.139
silty clay loam	.366	.261	.208	.149
sandy clay	.337	.223	.239	.158
silty clay	.387	.280	.250	.181
clay	.396	.285	.262	.196

adapted from Wight

APPENDIX B

BUDGETS AT AVERAGE LEVELS

TABLE XVI

SCS RECOMMENDED STOCKING DENSITY BUDGET

BUY PRICE 0.8957 $/lb	SELL PRICE 0.7978 $/lb
BUY WEIGHT 449.64 lbs	TOTAL GAIN 213.64 lbs
NUMBER HEAD 750	NUMBER ACRES 2471
DAYS ON PASTURE 150	DEATH LOSS 2 %
NUMBER OF TIMES FED HAY 14	LBS OF HAY FED 10 lbs/hd
NUMBER OF TIMES FED SUPPLEMENT 14	LBS OF SUPPL FED 2 lbs/hd
SUPPLEMENT COST 13.99 $/cwt	HAY COST 62.86 $/ton
SALT & MIN CONSUMED 2 lbs/hd/mo	SALT & MIN COST .09 $/lb
HAULING CHARGE .35 $/cwt	MARKETING CHARGE 1.72 $/cwt
NEW CATTLE TREATED 25 %	SICKPEN COST 12 $/hd
NEW CATTLE PROCESSING 6.01 $/hd	VET MED SUPPLIES $ 2.08
INTEREST RATE 14 %	LABOR CHARGE 4.65 $/hour

SELL WEIGHT 650.01 lbs	STOCKING RATE 45.53 hd/days/ac
DAILY GAIN 1.42 lbs/day	STOCKING DENSITY 0.30 hd/ac

OPERATING INPUTS:	PRICE	QUANTITY	VALUE
STEER CALVES	.8957	449.64	402.73
SUPPLEMENTAL FEED	.1399	108.00	15.11
HAY	62.86	0.0700	4.40
SALT AND MINERALS	.09	10.00	0.90
CUSTOM HAULING	.35	11.00	3.85
VET. MED EXPENSES	9.01	1	9.01
VET. MED SUPPLIES	2.08	1	2.08
MARKETING CHARGE	1.72	6.50	11.18
LABOR	4.65	1.43	6.64
MACH. REPAIR	3.50	1	3.50
EQUIP. REPAIR	1.00	1	1.00
OPERATING INTEREST	.14	175.75	24.61
TOTAL COSTS			484.99
TOTAL RECEIPTS	.798	650.01	518.58
RETURNS PER HEAD			33.59
RETURNS PER ACRE			10.08
BREAKEVEN PRICE			.74

TABLE XVII

SCS RECOMMENDED STOCKING DENSITY BUDGET
WITH PRESCRIBED BURNING

BUY PRICE 0.8957 $/lb	SELL PRICE 0.7978 $/lb
BUY WEIGHT 449.64 lbs	TOTAL GAIN 241.22 lbs
NUMBER HEAD 750	NUMBER ACRES 2471
DAYS ON PASTURE 150	DEATH LOSS 2 %
NUMBER OF TIMES FED HAY 14	LBS OF HAY FED 10 lbs/hd
NUMBER OF TIMES FED SUPPLEMENT 14	LBS OF SUPPL FED 2 lbs/hd
SUPPLEMENT COST 13.99 $/cwt	HAY COST 62.86 $/ton
SALT & MIN CONSUMED 2 lbs/hd/mo	SALT & MIN COST .09 $/lb
HAULING CHARGE .35 $/cwt	MARKETING CHARGE 1.72 $/cwt
NEW CATTLE TREATED 25 %	SICKPEN COST 12 $/hd
NEW CATTLE PROCESSING 6.01 $/hd	VET MED SUPPLIES $ 2.08
INTEREST RATE 14 %	LABOR CHARGE 4.65 $/hour

SELL WEIGHT 677.04 lbs	STOCKING RATE 45.53 hd/days/ac
DAILY GAIN 1.61 lbs/day	STOCKING DENSITY 0.30 hd/ac

OPERATING INPUTS:	PRICE	QUANTITY	VALUE
STEER CALVES	.8957	449.64	402.73
SUPPLEMENTAL FEED	.1399	108.00	15.11
HAY	62.86	0.0700	4.40
SALT AND MINERALS	.09	10.00	0.90
CUSTOM HAULING	.35	11.27	3.94
VET. MED EXPENSES	9.01	1	9.01
VET. MED SUPPLIES	2.08	1	2.08
MARKETING CHARGE	1.72	6.77	11.65
LABOR	4.65	2.19	10.20
MACH. REPAIR	6.47	1	6.47
EQUIP. REPAIR	3.97	1	3.97
OPERATING INTEREST	.14	175.96	24.63
TOTAL COSTS			495.06
TOTAL RECEIPTS	.798	677.04	540.15
RETURNS PER HEAD			45.09
RETURNS PER ACRE			13.53
BREAKEVEN PRICE			.73

TABLE XVIII

INTENSIVE-EARLY STOCKING BUDGET
.46 HEAD/ACRE

BUY PRICE 0.8957 $/lb
BUY WEIGHT 449.64 lbs
NUMBER HEAD 1125
DAYS ON PASTURE 80
NUMBER OF TIMES FED HAY 14
NUMBER OF TIMES FED SUPPLEMENT 14
SUPPLEMENT COST 13.99 $/cwt
SALT & MIN CONSUMED 2 lbs/hd/mo
HAULING CHARGE .35 $/cwt
NEW CATTLE TREATED 25 %
NEW CATTLE PROCESSING 4.67 $/hd
INTEREST RATE 14 %

SELL PRICE 0.8138 $/lb
TOTAL GAIN 143.32 lbs
NUMBER ACRES 2471
DEATH LOSS 2 %
LBS OF HAY FED 10 lbs/hd
LBS OF SUPPL FED 2 lbs/hd
HAY COST 62.86 $/ton
SALT & MIN COST .09 $/lb
MARKETING CHARGE 1.72 $/cwt
SICKPEN COST 10.53 $/hd
VET MED SUPPLIES $ 1.88
LABOR CHARGE 4.65 $/hour

SELL WEIGHT 581.09 lbs
DAILY GAIN 1.79 lbs/day

STOCKING RATE 36.42 hd/days/ac
STOCKING DENSITY 0.46 hd/ac

OPERATING INPUTS:	PRICE	QUANTITY	VALUE
STEER CALVES	.8957	449.64	402.73
SUPPLEMENTAL FEED	.1399	28.00	3.92
HAY	62.86	0.0700	4.40
SALT AND MINERALS	.09	5.33	0.48
CUSTOM HAULING	.35	10.31	3.61
VET. MED EXPENSES	7.67	1	7.67
VET. MED SUPPLIES	1.88	1	1.88
MARKETING CHARGE	1.72	5.81	9.99
LABOR	4.65	0.81	3.77
MACH. REPAIR	1.73	1	1.73
EQUIP. REPAIR	0.51	1	0.51
OPERATING INTEREST	.14	92.80	12.99
TOTAL COSTS			453.68
TOTAL RECEIPTS	.814	581.09	472.87
RETURNS PER HEAD			19.19
RETURNS PER ACRE			8.74
BREAKEVEN PRICE			.78

TABLE XIX

INTENSIVE-EARLY STOCKING BUDGET
WITH PRESCRIBED BURNING
.46 HEAD/ACRE

BUY PRICE 0.8957 $/lb	SELL PRICE 0.8138 $/lb
BUY WEIGHT 449.64 lbs	TOTAL GAIN 165.60 lbs
NUMBER HEAD 1125	NUMBER ACRES 2471
DAYS ON PASTURE 80	DEATH LOSS 2 %
NUMBER OF TIMES FED HAY 14	LBS OF HAY FED 10 lbs/hd
NUMBER OF TIMES FED SUPPLEMENT 14	LBS OF SUPPL FED 2 lbs/hd
SUPPLEMENT COST 13.99 $/cwt	HAY COST 62.86 $/ton
SALT & MIN CONSUMED 2 lbs/hd/mo	SALT & MIN COST .09 $/lb
HAULING CHARGE .35 $/cwt	MARKETING CHARGE 1.72 $/cwt
NEW CATTLE TREATED 25 %	SICKPEN COST 10.53 $/hd
NEW CATTLE PROCESSING 4.67 $/hd	VET MED SUPPLIES $ 1.88
INTEREST RATE 14 %	LABOR CHARGE 4.65 $/hour

SELL WEIGHT 602.93 lbs	STOCKING RATE 36.42 hd/days/ac
DAILY GAIN 2.07 lbs/day	STOCKING DENSITY 0.46 hd/ac

OPERATING INPUTS:	PRICE	QUANTITY	VALUE
STEER CALVES	.8957	449.64	402.73
SUPPLEMENTAL FEED	.1399	28.00	3.92
HAY	62.86	0.0700	4.40
SALT AND MINERALS	.09	5.33	0.48
CUSTOM HAULING	.35	10.53	3.68
VET. MED EXPENSES	7.67	1	7.67
VET. MED SUPPLIES	1.88	1	1.88
MARKETING CHARGE	1.72	6.03	10.37
LABOR	4.65	1.32	6.14
MACH. REPAIR	3.71	1	3.71
EQUIP. REPAIR	2.48	1	2.48
OPERATING INTEREST	.14	92.94	13.01
TOTAL COSTS			460.48
TOTAL RECEIPTS	.814	602.93	490.64
RETURNS PER HEAD			30.16
RETURNS PER ACRE			13.73
BREAKEVEN PRICE			.76

TABLE XX

SEASON-LONG STOCKING BUDGET
.4 HEAD/ACRE

BUY PRICE 0.8957 $/lb	SELL PRICE 0.7978 $/lb
BUY WEIGHT 449.64 lbs	TOTAL GAIN 213.64 lbs
NUMBER HEAD 1000	NUMBER ACRES 2471
DAYS ON PASTURE 150	DEATH LOSS 2 %
NUMBER OF TIMES FED HAY 14	LBS OF HAY FED 10 lbs/hd
NUMBER OF TIMES FED SUPPLEMENT 14	LBS OF SUPPL FED 2 lbs/hd
SUPPLEMENT COST 13.99 $/cwt	HAY COST 62.86 $/ton
SALT & MIN CONSUMED 2 lbs/hd/mo	SALT & MIN COST .09 $/lb
HAULING CHARGE .35 $/cwt	MARKETING CHARGE 1.72 $/cwt
NEW CATTLE TREATED 25 %	SICKPEN COST 12 $/hd
NEW CATTLE PROCESSING 6.01 $/hd	VET MED SUPPLIES $ 2.08
INTEREST RATE 14 %	LABOR CHARGE 4.65 $/hour

SELL WEIGHT 650.01 lbs	STOCKING RATE 60.70 hd/days/ac
DAILY GAIN 1.42 lbs/day	STOCKING DENSITY 0.40 hd/ac

OPERATING INPUTS:	PRICE	QUANTITY	VALUE
STEER CALVES	.8957	449.64	402.73
SUPPLEMENTAL FEED	.1399	108.00	15.11
HAY	62.86	0.0700	4.40
SALT AND MINERALS	.09	10.00	0.90
CUSTOM HAULING	.35	11.00	3.85
VET. MED EXPENSES	9.01	1	9.01
VET. MED SUPPLIES	2.08	1	2.08
MARKETING CHARGE	1.72	6.50	11.18
LABOR	4.65	1.43	6.64
MACH. REPAIR	3.25	1	3.25
EQUIP. REPAIR	0.95	1	0.95
OPERATING INTEREST	.14	176.39	24.69
TOTAL COSTS			484.58
TOTAL RECEIPTS	.798	650.01	518.58
RETURNS PER HEAD			34.00
RETURNS PER ACRE			13.76
BREAKEVEN PRICE			.75

TABLE XXI

SEASON-LONG STOCKING BUDGET
WITH PRESCRIBED BURNING
.4 HEAD/ACRE

BUY PRICE 0.8957 $/lb	SELL PRICE 0.7978 $/lb
BUY WEIGHT 449.64 lbs	TOTAL GAIN 240.64 lbs
NUMBER HEAD 1000	NUMBER ACRES 2471
DAYS ON PASTURE 150	DEATH LOSS 2 %
NUMBER OF TIMES FED HAY 14	LBS OF HAY FED 10 lbs/hd
NUMBER OF TIMES FED SUPPLEMENT 14	LBS OF SUPPL FED 2 lbs/hd
SUPPLEMENT COST 13.99 $/cwt	HAY COST 62.86 $/ton
SALT & MIN CONSUMED 2 lbs/hd/mo	SALT & MIN COST .09 $/lb
HAULING CHARGE .35 $/cwt	MARKETING CHARGE 1.72 $/cwt
NEW CATTLE TREATED 25 %	SICKPEN COST 12 $/hd
NEW CATTLE PROCESSING 6.01 $/hd	VET MED SUPPLIES $ 2.08
INTEREST RATE 14 %	LABOR CHARGE 4.65 $/hour

SELL WEIGHT 676.47 lbs	STOCKING RATE 60.70 hd/days/ac
DAILY GAIN 1.60 lbs/day	STOCKING DENSITY 0.40 hd/ac

OPERATING INPUTS:	PRICE	QUANTITY	VALUE
STEER CALVES	.8957	449.64	402.73
SUPPLEMENTAL FEED	.1399	108.00	15.11
HAY	62.86	0.0700	4.40
SALT AND MINERALS	.09	10.00	0.90
CUSTOM HAULING	.35	11.26	3.94
VET. MED EXPENSES	9.01	1	9.01
VET. MED SUPPLIES	2.08	1	2.08
MARKETING CHARGE	1.72	6.76	11.64
LABOR	4.65	1.96	9.11
MACH. REPAIR	5.47	1	5.47
EQUIP. REPAIR	3.17	1	3.17
OPERATING INTEREST	.14	176.53	24.71
TOTAL COSTS			492.27
TOTAL RECEIPTS	.798	676.47	539.69
RETURNS PER HEAD			47.42
RETURNS PER ACRE			19.19
BREAKEVEN PRICE			.73

TABLE XXII

INTENSIVE-EARLY STOCKING BUDGET
.61 HEAD/ACRE

BUY PRICE 0.8957 $/lb	SELL PRICE 0.8138 $/lb
BUY WEIGHT 449.64 lbs	TOTAL GAIN 143.31 lbs
NUMBER HEAD 1500	NUMBER ACRES 2471
DAYS ON PASTURE 80	DEATH LOSS 2 %
NUMBER OF TIMES FED HAY 14	LBS OF HAY FED 10 lbs/hd
NUMBER OF TIMES FED SUPPLEMENT 14	LBS OF SUPPL FED 2 lbs/hd
SUPPLEMENT COST 13.99 $/cwt	HAY COST 62.86 $/ton
SALT & MIN CONSUMED 2 lbs/hd/mo	SALT & MIN COST .09 $/lb
HAULING CHARGE .35 $/cwt	MARKETING CHARGE 1.72 $/cwt
NEW CATTLE TREATED 25 %	SICKPEN COST 10.53 $/hd
NEW CATTLE PROCESSING 4.67 $/hd	VET MED SUPPLIES $ 1.88
INTEREST RATE 14 %	LABOR CHARGE 4.65 $/hour

SELL WEIGHT 581.09 lbs	STOCKING RATE 48.56 hd/days/ac
DAILY GAIN 1.79 lbs/day	STOCKING DENSITY 0.61 hd/ac

OPERATING INPUTS:	PRICE	QUANTITY	VALUE
STEER CALVES	.8957	449.64	402.73
SUPPLEMENTAL FEED	.1399	28.00	3.92
HAY	62.86	0.0700	4.40
SALT AND MINERALS	.09	5.33	0.48
CUSTOM HAULING	.35	10.31	3.61
VET. MED EXPENSES	7.67	1	7.67
VET. MED SUPPLIES	1.88	1	1.88
MARKETING CHARGE	1.72	5.81	9.99
LABOR	4.65	0.77	3.60
MACH. REPAIR	1.47	1	1.47
EQUIP. REPAIR	0.45	1	0.45
OPERATING INTEREST	.14	92.79	12.99
TOTAL COSTS			453.19
TOTAL RECEIPTS	.814	581.09	472.87
RETURNS PER HEAD			19.68
RETURNS PER ACRE			11.95
BREAKEVEN PRICE			.78

TABLE XXIII

INTENSIVE-EARLY STOCKING BUDGET
WITH PRESCRIBED BURNING
.61 HEAD/ACRE

BUY PRICE 0.8957 $/lb	SELL PRICE 0.8138 $/lb
BUY WEIGHT 449.64 lbs	TOTAL GAIN 162.03 lbs
NUMBER HEAD 1500	NUMBER ACRES 2471
DAYS ON PASTURE 80	DEATH LOSS 2 %
NUMBER OF TIMES FED HAY 14	LBS OF HAY FED 10 lbs/hd
NUMBER OF TIMES FED SUPPLEMENT 14	LBS OF SUPPL FED 2 lbs/hd
SUPPLEMENT COST 13.99 $/cwt	HAY COST 62.86 $/ton
SALT & MIN CONSUMED 2 lbs/hd/mo	SALT & MIN COST .09 $/lb
HAULING CHARGE .35 $/cwt	MARKETING CHARGE 1.72 $/cwt
NEW CATTLE TREATED 25 %	SICKPEN COST 10.53 $/hd
NEW CATTLE PROCESSING 4.67 $/hd	VET MED SUPPLIES $ 1.88
INTEREST RATE 14 %	LABOR CHARGE 4.65 $/hour

SELL WEIGHT 599.43 lbs	STOCKING RATE 48.56 hd/days/ac
DAILY GAIN 2.03 lbs/day	STOCKING DENSITY 0.61 hd/ac

OPERATING INPUTS:	PRICE	QUANTITY	VALUE
STEER CALVES	.8957	449.64	402.73
SUPPLEMENTAL FEED	.1399	28.00	3.92
HAY	62.86	0.0700	4.40
SALT AND MINERALS	.09	5.33	0.48
CUSTOM HAULING	.35	10.49	3.67
VET. MED EXPENSES	7.67	1	7.67
VET. MED SUPPLIES	1.88	1	1.88
MARKETING CHARGE	1.72	5.99	10.31
LABOR	4.65	1.16	5.38
MACH. REPAIR	2.95	1	2.95
EQUIP. REPAIR	1.94	1	1.94
OPERATING INTEREST	.14	92.90	13.01
TOTAL COSTS			458.32
TOTAL RECEIPTS	.814	599.43	487.79
RETURNS PER HEAD			29.47
RETURNS PER ACRE			17.89
BREAKEVEN PRICE			.76

TABLE XXIV

SEASON-LONG STOCKING BUDGET
.51 HEAD/ACRE

BUY PRICE 0.8957 $/lb
BUY WEIGHT 449.64 lbs
NUMBER HEAD 1250
DAYS ON PASTURE 150
NUMBER OF TIMES FED HAY 14
NUMBER OF TIMES FED SUPPLEMENT 14
SUPPLEMENT COST 13.99 $/cwt
SALT & MIN CONSUMED 2 lbs/hd/mo
HAULING CHARGE .35 $/cwt
NEW CATTLE TREATED 25 %
NEW CATTLE PROCESSING 6.01 $/hd
INTEREST RATE 14 %

SELL PRICE 0.7978 $/lb
TOTAL GAIN 213.64 lbs
NUMBER ACRES 2471
DEATH LOSS 2 %
LBS OF HAY FED 10 lbs/hd
LBS OF SUPPL FED 2 lbs/hd
HAY COST 62.86 $/ton
SALT & MIN COST .09 $/lb
MARKETING CHARGE 1.72 $/cwt
SICKPEN COST 12 $/hd
VET MED SUPPLIES $ 2.08
LABOR CHARGE 4.65 $/hour

SELL WEIGHT 650.01 lbs
DAILY GAIN 1.42 lbs/day

STOCKING RATE 75.88 hd/days/ac
STOCKING DENSITY 0.51 hd/ac

OPERATING INPUTS:	PRICE	QUANTITY	VALUE
STEER CALVES	.8957	449.64	402.73
SUPPLEMENTAL FEED	.1399	108.00	15.11
HAY	62.86	0.0700	4.40
SALT AND MINERALS	.09	10.00	0.90
CUSTOM HAULING	.35	11.00	3.85
VET. MED EXPENSES	9.01	1	9.01
VET. MED SUPPLIES	2.08	1	2.08
MARKETING CHARGE	1.72	6.50	11.18
LABOR	4.65	1.35	6.27
MACH. REPAIR	3.00	1	3.00
EQUIP. REPAIR	0.90	1	0.90
OPERATING INTEREST	.14	176.37	24.69
TOTAL COSTS			484.12
TOTAL RECEIPTS	.798	650.01	518.58
RETURNS PER HEAD			34.47
RETURNS PER ACRE			17.43
BREAKEVEN PRICE			.74

TABLE XXV

SEASON-LONG STOCKING BUDGET
WITH PRESCRIBED BURNING
.51 HEAD/ACRE

BUY PRICE 0.8957 $/lb	SELL PRICE 0.7978 $/lb
BUY WEIGHT 449.64 lbs	TOTAL GAIN 235.63 lbs
NUMBER HEAD 1250	NUMBER ACRES 2471
DAYS ON PASTURE 150	DEATH LOSS 2 %
NUMBER OF TIMES FED HAY 14	LBS OF HAY FED 10 lbs/hd
NUMBER OF TIMES FED SUPPLEMENT 14	LBS OF SUPPL FED 2 lbs/hd
SUPPLEMENT COST 13.99 $/cwt	HAY COST 62.86 $/ton
SALT & MIN CONSUMED 2 lbs/hd/mo	SALT & MIN COST .09 $/lb
HAULING CHARGE .35 $/cwt	MARKETING CHARGE 1.72 $/cwt
NEW CATTLE TREATED 25 %	SICKPEN COST 12 $/hd
NEW CATTLE PROCESSING 6.01 $/hd	VET MED SUPPLIES $ 2.08
INTEREST RATE 14 %	LABOR CHARGE 4.65 $/hour

SELL WEIGHT 671.56 lbs	STOCKING RATE 75.88 hd/days/ac
DAILY GAIN 1.57 lbs/day	STOCKING DENSITY 0.51 hd/ac

OPERATING INPUTS:	PRICE	QUANTITY	VALUE
STEER CALVES	.8957	449.64	402.73
SUPPLEMENTAL FEED	.1399	108.00	15.11
HAY	62.86	0.0700	4.40
SALT AND MINERALS	.09	10.00	0.90
CUSTOM HAULING	.35	11.21	3.92
VET. MED EXPENSES	9.01	1	9.01
VET. MED SUPPLIES	2.08	1	2.08
MARKETING CHARGE	1.72	6.72	11.55
LABOR	4.65	1.81	8.40
MACH. REPAIR	4.78	1	4.78
EQUIP. REPAIR	2.68	1	2.68
OPERATING INTEREST	.14	176.49	24.71
TOTAL COSTS			490.27
TOTAL RECEIPTS	.798	671.56	535.77
RETURNS PER HEAD			45.50
RETURNS PER ACRE			23.02
BREAKEVEN PRICE			.73

TABLE XXVI

INTENSIVE-EARLY STOCKING BUDGET
.76 HEAD/ACRE

BUY PRICE 0.8957 $/lb
BUY WEIGHT 449.64 lbs
NUMBER HEAD 1875
DAYS ON PASTURE 80
NUMBER OF TIMES FED HAY 14
NUMBER OF TIMES FED SUPPLEMENT 14
SUPPLEMENT COST 13.99 $/cwt
SALT & MIN CONSUMED 2 lbs/hd/mo
HAULING CHARGE .35 $/cwt
NEW CATTLE TREATED 25 %
NEW CATTLE PROCESSING 4.67 $/hd
INTEREST RATE 14 %

SELL PRICE 0.8138 $/lb
TOTAL GAIN 143.28 lbs
NUMBER ACRES 2471
DEATH LOSS 2 %
LBS OF HAY FED 10 lbs/hd
LBS OF SUPPL FED 2 lbs/hd
HAY COST 62.86 $/ton
SALT & MIN COST .09 $/lb
MARKETING CHARGE 1.72 $/cwt
SICKPEN COST 10.53 $/hd
VET MED SUPPLIES $ 1.88
LABOR CHARGE 4.65 $/hour

SELL WEIGHT 581.06 lbs
DAILY GAIN 1.79 lbs/day

STOCKING RATE 60.70 hd/days/ac
STOCKING DENSITY 0.76 hd/ac

OPERATING INPUTS:	PRICE	QUANTITY	VALUE
STEER CALVES	.8957	449.64	402.73
SUPPLEMENTAL FEED	.1399	28.00	3.92
HAY	62.86	0.0700	4.40
SALT AND MINERALS	.09	5.33	0.48
CUSTOM HAULING	.35	10.31	3.61
VET. MED EXPENSES	7.67	1	7.67
VET. MED SUPPLIES	1.88	1	1.88
MARKETING CHARGE	1.72	5.81	9.99
LABOR	4.65	0.76	3.52
MACH. REPAIR	1.33	1	1.33
EQUIP. REPAIR	0.43	1	0.43
OPERATING INTEREST	.14	92.79	12.99
TOTAL COSTS			452.95
TOTAL RECEIPTS	.814	581.06	472.84
RETURNS PER HEAD			19.89
RETURNS PER ACRE			15.09
BREAKEVEN PRICE			.78

TABLE XXVII

INTENSIVE-EARLY STOCKING BUDGET
WITH PRESCRIBED BURNING
.76 HEAD/ACRE

BUY PRICE 0.8957 $/lb	SELL PRICE 0.8138 $/lb
BUY WEIGHT 449.64 lbs	TOTAL GAIN 158.39 lbs
NUMBER HEAD 1875	NUMBFR ACRES 2471
DAYS ON PASTURE 80	DEATH LOSS 2 %
NUMBER OF TIMES FED HAY 14	LBS OF HAY FED 10 lbs/hd
NUMBER OF TIMES FED SUPPLEMENT 14	LBS OF SUPPL FED 2 lbs/hd
SUPPLEMENT COST 13.99 $/cwt	HAY COST 62.86 $/ton
SALT & MIN CONSUMED 2 lbs/hd/mo	SALT & MIN COST .09 $/lb
HAULING CHARGE .35 $/cwt	MARKETING CHARGE 1.72 $/cwt
NEW CATTLE TREATED 25 %	SICKPEN COST 10.53 $/hd
NEW CATTLE PROCESSING 4.67 $/hd	VET MED SUPPLIES $ 1.88
INTEREST RATE 14 %	LABOR CHARGE 4.65 $/hour

SELL WEIGHT 595.86 lbs	STOCKING RATE 60.70 hd/days/ac
DAILY GAIN 1.98 lbs/day	STOCKING DENSITY 0.76 hd/ac

OPERATING INPUTS:	PRICE	QUANTITY	VALUE
STEER CALVES	.8957	449.64	402.73
SUPPLEMENTAL FEED	.1399	28.00	3.92
HAY	62.86	0.0700	4.40
SALT AND MINERALS	.09	5.33	0.48
CUSTOM HAULING	.35	10.45	3.66
VET. MED EXPENSES	7.67	1	7.67
VET. MED SUPPLIES	1.88	1	1.88
MARKETING CHARGE	1.72	5.96	10.25
LABOR	4.65	1.06	4.95
MACH. REPAIR	2.52	1	2.52
EQUIP. REPAIR	1.61	1	1.61
OPERATING INTEREST	.14	92.87	13.00
TOTAL COSTS			457.06
TOTAL RECEIPTS	.814	595.86	484.89
RETURNS PER HEAD			27.82
RETURNS PER ACRE			21.11
BREAKEVEN PRICE			.77

TABLE XXVIII

SEASON-LONG STOCKING BUDGET
.61 HEAD/ACRE

BUY PRICE 0.8957 $/lb	SELL PRICE 0.7978 $/lb
BUY WEIGHT 449.64 lbs	TOTAL GAIN 213.64 lbs
NUMBER HEAD 1500	NUMBER ACRES 2471
DAYS ON PASTURE 150	DEATH LOSS 2 %
NUMBER OF TIMES FED HAY 14	LBS OF HAY FED 10 lbs/hd
NUMBER OF TIMES FED SUPPLEMENT 14	LBS OF SUPPL FED 2 lbs/hd
SUPPLEMENT COST 13.99 $/cwt	HAY COST 62.86 $/ton
SALT & MIN CONSUMED 2 lbs/hd/mo	SALT & MIN COST .09 $/lb
HAULING CHARGE .35 $/cwt	MARKETING CHARGE 1.72 $/cwt
NEW CATTLE TREATED 25 %	SICKPEN COST 12 $/hd
NEW CATTLE PROCESSING 6.01 $/hd	VET MED SUPPLIES $ 2.08
INTEREST RATE 14 %	LABOR CHARGE 4.65 $/hour

SELL WEIGHT 650.01 lbs	STOCKING RATE 91.06 hd/days/ac
DAILY GAIN 1.42 lbs/day	STOCKING DENSITY 0.61 hd/ac

OPERATING INPUTS:	PRICE	QUANTITY	VALUE
STEER CALVES	.8957	449.64	402.73
SUPPLEMENTAL FEED	.1399	108.00	15.11
HAY	62.86	0.0700	4.40
SALT AND MINERALS	.09	10.00	0.90
CUSTOM HAULING	.35	11.00	3.85
VET. MED EXPENSES	9.01	1	9.01
VET. MED SUPPLIES	2.08	1	2.08
MARKETING CHARGE	1.72	6.50	11.18
LABOR	4.65	1.32	6.12
MACH. REPAIR	2.75	1	2.75
EQUIP. REPAIR	0.85	1	0.85
OPERATING INTEREST	.14	176.36	24.69
TOTAL COSTS			483.66
TOTAL RECEIPTS	.798	650.01	518.58
RETURNS PER HEAD			34.92
RETURNS PER ACRE			21.20
BREAKEVEN PRICE			.74

TABLE XXIX

SEASON-LONG STOCKING BUDGET
WITH PRESCRIBED BURNING
.61 HEAD/ACRE

BUY PRICE 0.8957 $/lb	SELL PRICE 0.7978 $/lb
BUY WEIGHT 449.64 lbs	TOTAL GAIN 230.58 lbs
NUMBER HEAD 1500	NUMBER ACRES 2471
DAYS ON PASTURE 150	DEATH LOSS 2 %
NUMBER OF TIMES FED HAY 14	LBS OF HAY FED 10 lbs/hd
NUMBER OF TIMES FED SUPPLEMENT 14	LBS OF SUPPL FED 2 lbs/hd
SUPPLEMENT COST 13.99 $/cwt	HAY COST 62.86 $/ton
SALT & MIN CONSUMED 2 lbs/hd/mo	SALT & MIN COST .09 $/lb
HAULING CHARGE .35 $/cwt	MARKETING CHARGE 1.72 $/cwt
NEW CATTLE TREATED 25 %	SICKPEN COST 12 $/hd
NEW CATTLE PROCESSING 6.01 $/hd	VET MED SUPPLIES $ 2.08
INTEREST RATE 14 %	LABOR CHARGE 4.65 $/hour

SELL WEIGHT 666.61 lbs	STOCKING RATE 91.06 hd/days/ac
DAILY GAIN 1.54 lbs/day	STOCKING DENSITY 0.61 hd/ac

OPERATING INPUTS:	PRICE	QUANTITY	VALUE
STEER CALVES	.8957	449.64	402.73
SUPPLEMENTAL FEED	.1399	108.00	15.11
HAY	62.86	0.0700	4.40
SALT AND MINERALS	.09	10.00	0.90
CUSTOM HAULING	.35	11.16	3.91
VET. MED EXPENSES	9.01	1	9.01
VET. MED SUPPLIES	2.08	1	2.08
MARKETING CHARGE	1.72	6.67	11.47
LABOR	4.65	1.70	7.90
MACH. REPAIR	4.23	1	4.23
EQUIP. REPAIR	2.33	1	2.33
OPERATING INTEREST	.14	176.46	24.70
TOTAL COSTS			488.76
TOTAL RECEIPTS	.798	666.61	531.82
RETURNS PER HEAD			43.06
RETURNS PER ACRE			26.14
BREAKEVEN PRICE			.73

TABLE XXX

INTENSIVE-EARLY STOCKING BUDGET
.91 HEAD/ACRE

BUY PRICE 0.8957 $/lb	SELL PRICE 0.8138 $/lb
BUY WEIGHT 449.64 lbs	TOTAL GAIN 142.88 lbs
NUMBER HEAD 2250	NUMBER ACRES 2471
DAYS ON PASTURE 80	DEATH LOSS 2 %
NUMBER OF TIMES FED HAY 14	LBS OF HAY FED 10 lbs/hd
NUMBER OF TIMES FED SUPPLEMENT 14	LBS OF SUPPL FED 2 lbs/hd
SUPPLEMENT COST 13.99 $/cwt	HAY COST 62.86 $/ton
SALT & MIN CONSUMED 2 lbs/hd/mo	SALT & MIN COST .09 $/lb
HAULING CHARGE .35 $/cwt	MARKETING CHARGE 1.72 $/cwt
NEW CATTLE TREATED 25 %	SICKPEN COST 10.53 $/hd
NEW CATTLE PROCESSING 4.67 $/hd	VET MED SUPPLIES $ 1.88
INTEREST RATE 14 %	LABOR CHARGE 4.65 $/hour

SELL WEIGHT 580.67 lbs	STOCKING RATE 72.85 hd/days/ac
DAILY GAIN 1.79 lbs/day	STOCKING DENSITY 0.91 hd/ac

OPERATING INPUTS:	PRICE	QUANTITY	VALUE
STEER CALVES	.8957	449.64	402.73
SUPPLEMENTAL FEED	.1399	28.00	3.92
HAY	62.86	0.0700	4.40
SALT AND MINERALS	.09	5.33	0.48
CUSTOM HAULING	.35	10.30	3.61
VET. MED EXPENSES	7.67	1	7.67
VET. MED SUPPLIES	1.88	1	1.88
MARKETING CHARGE	1.72	5.81	9.99
LABOR	4.65	0.73	3.38
MACH. REPAIR	1.20	1	1.20
EQUIP. REPAIR	0.37	1	0.37
OPERATING INTEREST	.14	92.78	12.99
TOTAL COSTS			452.61
TOTAL RECEIPTS	.814	580.67	472.52
RETURNS PER HEAD			19.91
RETURNS PER ACRE			18.13
BREAKEVEN PRICE			.78

TABLE XXXI

INTENSIVE-EARLY STOCKING BUDGET
WITH PRESCRIBED BURNING
.91 HEAD/ACRE

BUY PRICE 0.8957 $/lb
BUY WEIGHT 449.64 lbs
NUMBER HEAD 2250
DAYS ON PASTURE 80
NUMBER OF TIMES FED HAY 14
NUMBER OF TIMES FED SUPPLEMENT 14
SUPPLEMENT COST 13.99 $/cwt
SALT & MIN CONSUMED 2 lbs/hd/mo
HAULING CHARGE .35 $/cwt
NEW CATTLE TREATED 25 %
NEW CATTLE PROCESSING 4.67 $/hd
INTEREST RATE 14 %

SELL PRICE 0.8138 $/lb
TOTAL GAIN 154.31 lbs
NUMBER ACRES 2471
DEATH LOSS 2 %
LBS OF HAY FED 10 lbs/hd
LBS OF SUPPL FED 2 lbs/hd
HAY COST 62.86 $/ton
SALT & MIN COST .09 $/lb
MARKETING CHARGE 1.72 $/cwt
SICKPEN COST 10.53 $/hd
VET MED SUPPLIES $ 1.88
LABOR CHARGE 4.65 $/hour

SELL WEIGHT 591.87 lbs
DAILY GAIN 1.93 lbs/day

STOCKING RATE 72.85 hd/days/ac
STOCKING DENSITY 0.91 hd/ac

OPERATING INPUTS:	PRICE	QUANTITY	VALUE
STEER CALVES	.8957	449.64	402.73
SUPPLEMENTAL FEED	.1399	28.00	3.92
HAY	62.86	0.0700	4.40
SALT AND MINERALS	.09	5.33	0.48
CUSTOM HAULING	.35	10.42	3.65
VET. MED EXPENSES	7.67	1	7.67
VET. MED SUPPLIES	1.88	1	1.88
MARKETING CHARGE	1.72	5.92	10.18
LABOR	4.65	0.98	4.56
MACH. REPAIR	2.19	1	2.19
EQUIP. REPAIR	1.36	1	1.36
OPERATING INTEREST	.14	92.85	13.00
TOTAL COSTS			456.01
TOTAL RECEIPTS	.814	591.87	481.63
RETURNS PER HEAD			25.62
RETURNS PER ACRE			23.33
BREAKEVEN PRICE			.77

TABLE XXXII

INTENSIVE-EARLY STOCKING BUDGET
1.06 HEAD/ACRE

BUY PRICE 0.8957 $/lb
BUY WEIGHT 449.64 lbs
NUMBER HEAD 2625
DAYS ON PASTURE 80
NUMBER OF TIMES FED HAY 14
NUMBER OF TIMES FED SUPPLEMENT 14
SUPPLEMENT COST 13.99 $/cwt
SALT & MIN CONSUMED 2 lbs/hd/mo
HAULING CHARGE .35 $/cwt
NEW CATTLE TREATED 25 %
NEW CATTLE PROCESSING 4.67 $/hd
INTEREST RATE 14 %

SELL PRICE 0.8138 $/lb
TOTAL GAIN 140.38 lbs
NUMBER ACRES 2471
DEATH LOSS 2 %
LBS OF HAY FED 10 lbs/hd
LBS OF SUPPL FED 2 lbs/hd
HAY COST 62.86 $/ton
SALT & MIN COST .09 $/lb
MARKETING CHARGE 1.72 $/cwt
SICKPEN COST 10.53 $/hd
VET MED SUPPLIES $ 1.88
LABOR CHARGE 4.65 $/hour

SELL WEIGHT 578.22 lbs
DAILY GAIN 1.75 lbs/day

STOCKING RATE 84.99 hd/days/ac
STOCKING DENSITY 1.06 hd/ac

OPERATING INPUTS:	PRICE	QUANTITY	VALUE
STEER CALVES	.8957	449.64	402.73
SUPPLEMENTAL FEED	.1399	28.00	3.92
HAY	62.86	0.0700	4.40
SALT AND MINERALS	.09	5.33	0.48
CUSTOM HAULING	.35	10.28	3.60
VET. MED EXPENSES	7.67	1	7.67
VET. MED SUPPLIES	1.88	1	1.88
MARKETING CHARGE	1.72	5.78	9.95
LABOR	4.65	0.71	3.30
MACH. REPAIR	1.13	1	1.13
EQUIP. REPAIR	0.35	1	0.35
OPERATING INTEREST	.14	92.78	12.99
TOTAL COSTS			452.39
TOTAL RECEIPTS	.814	578.22	470.53
RETURNS PER HEAD			18.14
RETURNS PER ACRE			19.27
BREAKEVEN PRICE			.78

TABLE XXXIII

INTENSIVE-EARLY STOCKING BUDGET
WITH PRESCRIBED BURNING
1.06 HEAD/ACRE

BUY PRICE 0.8957 $/lb
BUY WEIGHT 449.64 lbs
NUMBER HEAD 2625
DAYS ON PASTURE 80
NUMBER OF TIMES FED HAY 14
NUMBER OF TIMES FED SUPPLEMENT 14
SUPPLEMENT COST 13.99 $/cwt
SALT & MIN CONSUMED 2 lbs/hd/mo
HAULING CHARGE .35 $/cwt
NEW CATTLE TREATED 25 %
NEW CATTLE PROCESSING 4.67 $/hd
INTEREST RATE 14 %

SELL PRICE 0.8138 $/lb
TOTAL GAIN 148.06 lbs
NUMBER ACRES 2471
DEATH LOSS 2 %
LBS OF HAY FED 10 lbs/hd
LBS OF SUPPL FED 2 lbs/hd
HAY COST 62.86 $/ton
SALT & MIN COST .09 $/lb
MARKETING CHARGE 1.72 $/cwt
SICKPEN COST 10.53 $/hd
VET MED SUPPLIES $ 1.88
LABOR CHARGE 4.65 $/hour

SELL WEIGHT 585.74 lbs
DAILY GAIN 1.85 lbs/day

STOCKING RATE 84.99 hd/days/ac
STOCKING DENSITY 1.06 hd/ac

OPERATING INPUTS:	PRICE	QUANTITY	VALUE
STEER CALVES	.8957	449.64	402.73
SUPPLEMENTAL FEED	.1399	28.00	3.92
HAY	62.86	0.0700	4.40
SALT AND MINERALS	.09	5.33	0.48
CUSTOM HAULING	.35	10.35	3.62
VET. MED EXPENSES	7.67	1	7.67
VET. MED SUPPLIES	1.88	1	1.88
MARKETING CHARGE	1.72	5.86	10.07
LABOR	4.65	0.93	4.32
MACH. REPAIR	1.98	1	1.98
EQUIP. REPAIR	1.19	1	1.19
OPERATING INTEREST	.14	92.84	13.00
TOTAL COSTS			455.26
TOTAL RECEIPTS	.814	585.74	476.65
RETURNS PER HEAD			21.38
RETURNS PER ACRE			22.72
BREAKEVEN PRICE			.78

VITA

Dennis Wayne Roddy

Candidate for the Degree of

Master of Science

Thesis: AN ECONOMIC ANALYSIS OF STOCKER CATTLE GRAZING SYSTEMS ON OKLAHOMA NATIVE RANGE

Major Field: Agricultural Economics

Biographical:

Personal Data: Born on November 6, 1963, the son of Donald H. and Betty L. Roddy.

Education: Graduated from Clovis High School, Clovis, New Mexico, in May 1982; received Bachelor of Science Degree in Agricultural Economics from Oklahoma State University in December, 1986; completed requirements for the Master of Science Degree at Oklahoma State University in December, 1989.

Professional Experience: Program and Field Assistant, Caddo County Agriculture Stabilization and Conservation Service, Anadarko, Oklahoma, December, 1986 to August, 1987; Graduate Research Assistant, Department of Agricultural Economics, Oklahoma State University, August, 1987 to December, 1989.