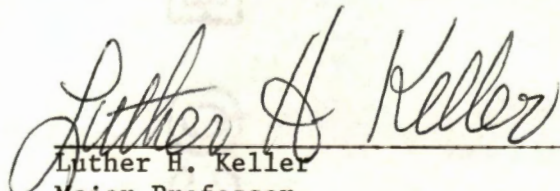
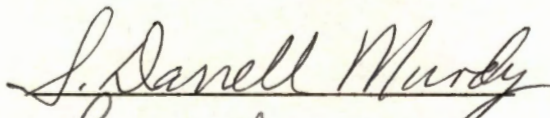
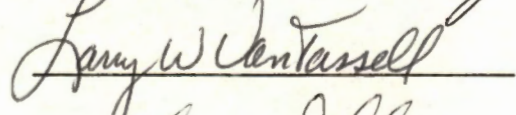
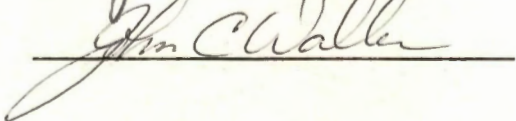


To the Graduate Council:

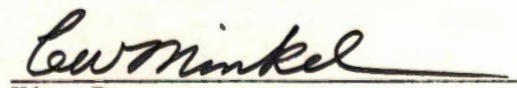
I am submitting herewith a dissertation written by William D. McBride entitled "A Bioeconomic Simulation of Forage-Beef Systems Under Risk Conditions." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Agricultural Economics.


Luther H. Keller
Major Professor

We have read this dissertation
and recommend its acceptance:

Accepted for the Council:


Vice Provost
and Dean of The Graduate School

A BIOECONOMIC SIMULATION OF FORAGE-BEEF SYSTEMS UNDER RISK CONDITIONS

A Dissertation

Presented for the

Doctor of Philosophy

Degree

The University of Tennessee, Knoxville

William D. McBride

August 1989

AD-VET-MED.

Thesis

896

. M232

ACKNOWLEDGEMENTS

The author wishes to express his sincere appreciation to the people who provided ideas, encouragement, and the facilities used in the preparation of this manuscript.

I am indebted to the Agricultural Experiment Station of the University of Tennessee for the time that I held a graduate research assistantship and to the faculty, graduate students, and staff of the Department of Agricultural Economics and Rural Sociology for a most pleasant and rewarding experience.

I am especially grateful to Dr. Luther H. Keller for the guidance, patience, and constructive criticism he contributed throughout the course of my graduate studies. Your guidance as a teacher and a research advisor was invaluable.

Sincere thanks are expressed to Dr. S. Darrell Mundy for the opportunity I had to work with him on other research, in addition to this study. Your kindness and attention to detail has made me a better person and a better researcher.

A study of this kind would not have been possible without the guidance and knowledge I obtained from Dr. Larry W. VanTassell. You vastly improved my abilities in research techniques, and for this I am extremely grateful.

Gratitude is extended to Dr. John C. Waller and Dr. Henry A. Fribourg for their assistance on biological issues of importance in this study, and for much needed data. Thanks are also expressed to Dr. Emmitt L. Rawls for guidance on issues of economic importance.

The cooperation and assistance I obtained from Morgan Gray was invaluable. Without the expertise of computer programming you shared with me, this study would not have been possible. Thanks are also extended to Gina Gwin for her assistance in typing and preparing the final draft of this manuscript.

Finally, I wish to express sincere appreciation to my parents, Mr. and Mrs. Errol J. McBride, and other family members for their inspiration to complete this task. Thank you for your love, patience, and encouragement, and for the knowledge you shared that I could have never obtained from any university.

CRANE & CO

ABSTRACT

Uncertain forage production and price conditions provide much of the business risk facing Tennessee cattle producers. This study focused on the evaluation of pasture improvement and calving strategies in terms of their biological and economic performance in this complex and uncertain environment.

Eight production alternatives were examined. Included were four forage systems, grass pastures of tall fescue and bermudagrass/tall fescue and each grass pasture renovated with red clover and annual lespedesa legumes. Each forage system was evaluated with spring and fall calving beef herds. A cattle operation in the southwestern portion of Tennessee was used as the unit of analysis.

Simulation analysis was the chosen methodology. The simulation model developed in this study was dynamic, stochastic and recursive. Six interrelated components; namely climatic, forage, cattle, managerial, price and cost, and budgetary components comprised the model. Operation of the model involved monthly periods during which accumulated forage and cattle variables were estimated, and then evaluated to determine management decisions. Using Monte Carlo techniques, random climatic conditions, forage production and cattle weights were simulated over a ten-year planning horizon for 100 iterations. Stochastic cattle prices were also developed by projecting the cattle cycle via harmonic functions.

Several output variables, including annual forage, cattle and financial performance measures, were summarized and compared among the

production alternatives. Stochastic dominance was used to determine efficient sets for cattlemen who were risk adverse, risk neutral, and risk loving. Preference ordering of the eight production alternatives was identical for each risk aversion category. Tall fescue pastures with fall calving was most preferred. Renovated bermudagrass/tall fescue pastures with fall calving ranked second. Grass forage pastures were generally preferred to renovated pastures, as was fall to spring calving.

Several limitations of the model were apparent. Among these were difficulties in estimating the annual distribution of forage production and production variability. The analysis of pasture renovation was also restricted. Many of these limitations stem from a lack of primary data necessary to reliably estimate functional relationships over the range of possible outcomes. Caution, therefore, must be exercised when attempting to interpret the results in practical terms.

TABLE OF CONTENTS

CHAPTER	PAGE
I. INTRODUCTION	1
Background	1
Production risk	1
Price risk	5
Problem Statement	6
Objectives	7
Conceptual Framework and Methodological Overview	8
The decision making process	9
Overview of methods	10
Study Area	13
II. TECHNICAL AND METHODOLOGICAL BACKGROUND, AND	
LITERATURE REVIEW	16
Technical Background of Forage-Beef Production	16
Forage species and mixtures	16
Forage intake	20
Annual forage-beef production cycles	22
Review of Studies on the Economics of Forage-Beef Production	26
Profitability studies of forage-beef production	26
Risk studies of forage-beef production	29
Systems Analysis and Simulation	31
Terminology and use	32
Analysis and simulation of forage-beef systems	37
Review of Agricultural Studies Applying Simulation Methods	38
III. UNIT OF ANALYSIS, PRODUCTION ALTERNATIVES AND EXPERIMENTAL	
DESIGN	43
Unit of Analysis	43
Land resources	43
Labor resources	45
Machinery and facility resources	46
Production Alternatives	49
Forage systems	49
Calving systems	55
Forage and cattle financial requirements	58
Experimental Design and Analytical Techniques	63
IV. MODEL DEVELOPMENT AND PARAMETER SPECIFICATION	65
Model Structure	65
Development of COMFABS	68
The climatic component	68
The forage component	70
The managerial component	85
The cattle component	97
The price and cost component	116
The budgetary component	122

CHAPTER	PAGE
V. RESULTS AND DISCUSSION	135
Results and Comparison of the Production Alternatives	136
Forage system performance	137
Cattle system performance	143
Financial characteristics and performance	149
Budgetary Comparison of the Production Alternatives in	
Each Year	157
Peak years (1990 and 1991)	158
Declining phase years (1992, 1993 and 1994)	161
Trough years (1995 and 1996)	161
Rising phase years (1989, 1997 and 1998)	161
Cumulative Probability Distributions of Selected Variables	162
Annual forage yield	162
Annual average calf weight	164
After-tax net present value of income	167
Evaluation by Stochastic Dominance	172
IV. SUMMARY, CONCLUSIONS AND IMPLICATIONS	175
Methodology and Procedures	176
Results	178
Model Limitations and Implications for the Results	184
Conclusions	187
Implications for Further Research	191
REFERENCES	194
APPENDIXES	204
APPENDIX A. TABLES	205
APPENDIX B. FIGURES	216
VITA	219

LIST OF TABLES

TABLE	PAGE
III.1. Inventory of Land Resources on the Representative Cattle Operation.....	45
III.2. Labor Supply, Crop Requirements and Available Labor For Cattle Production in Each Month on the Cattle Operation	47
III.3. Machinery and Facility Complement of the Cattle Operation ...	48
III.4. Sequence and Timing of Operations, and Per Acre Performance Rates, Tall Fescue, Upland Soils, West Tennessee, 1988.....	51
III.5. Sequence and Timing of Operations, and Per Acre Performance Rates, Bermudagrass Interseeded With Tall Fescue (10" Rows), Upland Soils, West Tennessee, 1988.....	53
III.6. Sequence and Timing of Operations, and Per Acre Performance Rates, Perennial Grass Pastures Renovated With Legumes (Red Clover & Annual Lespedeza), Upland Soils, West Tennessee, 1988	54
III.7. Sequence and Timing of Operations, and Per Acre Performance Rates, Hay Harvesting and Feeding (1200 Pound Large Round Bales), Upland Soils, West Tennessee, 1988	56
III.8. Per Head Labor Requirements by Month For Feeder Calf Production in Spring and Fall Calving Herds	59
III.9. Per Acre Expenses Summary For Alternative Forage Systems, Upland Soils, West Tennessee, 1988	61
III.10. Estimated Beef Cow-Calf Expenses Per Cow, 100 Cow Unit, West Tennessee, 1988	62
IV.1. Base Temperatures Used to Calculate Effective Heat Units For Each Forage	69
IV.2. Selected Statistics For the Actual and Simulated Monthly Precipitation and Temperature Levels	71
IV.3. Forage Yield Ordinary Least-Squares Equations For Each Forage	75
IV.4. Monthly Forage Yield Simulated Under Normal Climatic Conditions For Grazing and Hay Production in Each Forage System	82
IV.5. Monthly Forage Quality Simulated Under Normal Climatic Conditions For Grazing and Hay Production in Each Forage System	84

TABLE

PAGE

IV.6.	Estimated Beef Cow-Calf Returns Per Cow Used in the Long-Term Planning (Linear Programming) Model For Spring and Fall Calving Herds	88
IV.7.	Results of the Long-Term Planning Model--Decision Parameters Used in the Simulation Analysis For Each Production Alternative	93
IV.8.	Monthly Net Energy Requirements Per Animal For Maintenance and Growth Used to Determine Short-Term Decisions For Spring and Fall Calving Herds	104
IV.9.	Monthly Lactation Bounds to Specify Milk Production For Spring and Fall Calving Herds Grazing the Grass and Grass-Legume Forage Systems	112
IV.10.	Cattle Price Ordinary Least-Squares Equations For the Cyclical Trend Model	118
IV.11.	Annual Interest and Inflation Rates For 1989-1998	128
IV.12.	Organization and Items of the Budgetary Component	130
V.1.	Selected Forage System Annual Performance Statistics For the Cattle Operation Under Four Forage Systems (TF, BF, TFL, and BFL) With Spring and Fall Calving Systems (SC and FC)	138
V.2.	Selected Cattle System Annual Performance Statistics for the Cattle Operation Under Four Forage Systems (TF, BF, TFL, and BFL) With Spring and Fall Calving Systems (SC and FC)	144
V.3.	Selected Annual Financial Statistics for the Cattle Operation Under Four Forage Systems (TF, BF, TFL, and BFL) With Spring and Fall Calving Systems (SC and FC)	150
V.4.	Mean After-Tax Net Returns and Ranking By Year for the Cattle Operation Under Four Forage Systems (TF, BF, TFL, and BFL) With Spring and Fall Calving Systems (SC and FC)	159
V.5.	Annual Forage Yield By Selected Probabilities of Attainment for the Cattle Operation Under Four Forage Systems (TF, BF, TFL and BFL)	165
V.6.	Annual Average Calf Weight By Selected Probabilities of Attainment for the Cattle Operation Under Four Forage Systems (TF, BF, TFL and BFL) With Spring and Fall Calving Systems (FC and SC)	168

TABLE

PAGE

V.7.	Ten-Year After-Tax Net Present Value of Income By Selected Probabilities of Attainment for the Cattle Operation Under Four Forage Systems (TF, BF, TFL and BFL) With Spring and Fall Calving Systems (SC and FC)	171
V.8.	Preference Ordering by Risk Aversion Intervals for the Eight Production Alternatives on the Representative Cattle Operation	173
A.1.	Estimated Expenses Per Acre, Tall Fescue, Upland Soils, West Tennessee, 1988	206
A.2.	Estimated Expenses Per Acre, Hybrid Bermudagrass Interseeded with Tall Fescue (10" Rows), Upland Soils, West Tennessee, 1988	207
A.3.	Estimated Expenses Per Acre, Perennial Grass Pastures Renovated with Legumes (Red Clover & Annual Lespedeza), Upland Soils, West Tennessee, 1988	208
A.4.	Estimated Expenses Per Acre, Hay Harvesting and Feeding (1200-Pound Large Round Bales), Upland Soils, West Tennessee, 1988	210
A.5.	Tennessee Forage Resources--Percent of Total Annual Production by Month for Selected Forages	211
A.6.	Range of Legume Occurrence in the Grass-Legume Mixtures and Bermudagrass Occurrence in the Bermudagrass/Tall Fescue Mixture, by Month	212
A.7.	Tennessee Forage Resources--Quality by Month for Selected Forages Used in Grazing and Hay Production	213
A.8.	Monthly Net Energy Requirements Per Animal for Maintenance and Growth Used in the Long-Term Planning (Linear Programming) Model for Spring and Fall Calving Herds	214

LIST OF FIGURES

FIGURE	PAGE
I.1.	Location of the Study Area14
II.1.	Influence of Forage Digestibility on Intake23
II.2.	The System Concept and Characteristics of Systems33
III.1.	Timing of Production for Spring and Fall Calving Herds ...57
IV.1.	Schematic of the Comprehensive Forage and Beef Simulator (COMFABS)67
IV.2.	Functional Forms Used to Estimate the Forage-Climate Relationships73
IV.3.	Relationship Between Percent Total Digestible Nutrients and Daily Dry Matter Intake91
IV.4.	Schematic of the Interaction Among Forage, Cattle and Managerial Components to Determine Monthly Ration Parameters and Resulting Animal Performance98
IV.5.	Projected Ten-Year Price Cycles for Steer Calves of Varying Weight Categories, 1989-1998123
IV.6.	Projected Ten-Year Price Cycles for Heifer Calves of Varying Weight Categories, 1989-1998124
IV.7.	Projected Ten-Year Price Cycles for Cow-Calf Pairs and Replacement Bulls, 1989-1998125
IV.8.	Projected Ten-Year Price Cycles for Cull Cows and Bulls, 1989-1998126
IV.9.	Projected Ten-Year Price Cycle for Hay, 1989-1998127
V.1.	Mean After-Tax Net Returns for the Cattle Operation With the Top Three Rated Production Alternatives in Each Year of the Ten-Year Span, 1989-1998160
V.2.	Cumulative Probability Distributions of Annual Forage Yield for the Cattle Operation Under Four Forage Systems.163
V.3.	Cumulative Probability Distributions of Annual Average Calf Weaning Weight for the Cattle Operation Under Four Forage Systems with Spring and Fall Calving166

FIGURE

PAGE

V.4.	Cumulative Probability Distributions of After-Tax Net Present Value of Income for the Cattle Operation Under Four Forage Systems with Spring and Fall Calving	169
B.1.	Schematic of the Design and Specifications of Pastures and Related Equipment on the Cattle Operation	214
B.2.	Schematic of the Design and Specifications of Corral and Related Equipment on the Cattle Operation	215

CRANE & CO. BOND CO.

CHAPTER I

INTRODUCTION

Beef production is an important agricultural activity in Tennessee. Cash receipts from cattle and calves in 1985, at \$425.8 million, ranked first among all farm commodities in the state. Nearly 21 percent of 1985 total farm cash receipts was generated from the sale of cattle and calves (Tennessee Agricultural Statistics Service 1988).

Most of the cattle sold by Tennessee farmers are feeder calves. The foundation for this large feeder cattle industry is the abundance of pastureland and native pasture throughout the state. Roughly 2.6 million acres or 21 percent of farmland in Tennessee was used only for grazing in 1982. Woodland, including woodland pastured, accounted for an additional 26 percent of the farmland (Mundy and Gray 1986). Favorable resource and climatic conditions for forage and pasture production make much of the state conducive to feeder calf production.

Background

Planning is an integral function in operating a successful cattle operation. A manager may possess exceptional cattle management and husbandry skills, but without a design to combine these skills with other available resources, attainment of managerial goals may not be realized.

Several decisions confront the feeder calf producer when planning the operation. How large should the breeding herd be for a given land

resource? When is the best season for cows to calve? What is the best forage system? How should the forage system be managed to provide a year-round feed source for the cattle? How these questions are answered obviously depends on the physical and economic environment and the producer's unique resource endowment. In a static and unchanging environment, many of the answers are easily determined. However, if uncertainty in the decision making environment is considered, the planning process increases in complexity. With uncertain outcomes, planning the cattle operation depends not only upon environmental and resource considerations, but also on the producer's motivation for higher profit as opposed to lower risk.

Tennessee cattle producers operate in a decision making environment that is complex and highly uncertain. Uncertainties surrounding physical and economic conditions complicate the planning process. Characterizing this uncertain environment are considerable business risks. Boehlje and Eidman define business risk as the inherent uncertainty in the operation independent of the way it is financed. Business risk, therefore, includes those sources present regardless of the level of equity or debt financing. Furthermore business risk can be separated into production risk, that variation in production resulting from factors beyond the manager's control, and price risk, that resulting from price fluctuations.

Production Risk

A major management concern of Tennessee cattle producers is the uncertainty associated with forage yield and quality. Both seasonal and year-to-year variability in forage production can be substantial.

Such variability can be attributed to seasonal shifts in climatic conditions and to a great extent, the uncertain and fluctuating temperature and precipitation levels characteristic of the Mid-South. Temperature variation among the annual seasons is a natural occurrence that, when combined with the physiology and growth characteristics of the adapted forage species, creates annual forage production cycles. Much of this natural variation can be anticipated. Wide climatic fluctuations, however, are not as easily predicted. Recent years of severe drought in the Mid-South and the associated problems for cattle producers have highlighted those phenomena (Williams 1986; McCampbell 1988).

Climatic variability has critical implications for planning and managing the cattle operation. Selection of forage systems must include consideration of the natural variation in production and quality of forage species over annual production cycles. Matching annual forage production and quality with seasonal cattle nutrient requirements is essential for obtaining efficient production in a beef herd. Forage-beef systems, therefore, must be planned to take best advantage of periods of increased forage productivity and still be flexible enough to endure seasons of lower production.

While planning for expected seasonal variation in forage productivity is a difficult task in itself, the situation is further complicated by substantial and unpredictable climatic fluctuations. Sustained periods of extreme temperatures inhibit both production and consumption of many forage species. Likewise, extended periods of drought necessitate adjustments in stocking rates and/or buying

additional hay to compensate for reduced quantity and quality of forage. Forage growth and composition is ever changing and continuous periods of unseasonable conditions often result in diminished pasture stands. Moreover, animal performance and grazing efficiency decline. The resulting loss in performance and efficiency of the cattle operation translates into reduced net returns. Consequently, producers need to consider and account for this source of risk when making decisions regarding forage-beef production alternatives.

In an effort to examine variation in forage production, several combinations of forage species have been tested under Tennessee conditions. Results suggest that significant contributions are made to forage production and quality when legumes are incorporated into perennial grasses (Fribourg et al. 1979; Mitchell et al. 1980). Mixes of cool and warm season perennial grasses have been shown to increase forage production and extend the grazing season (McLaren et al. 1983; Mitchell et al. 1986). Maintaining pasture growth and forage composition is essential for realizing benefits from grass-legume combinations (Burns 1975). However, little is known about the economic prospects for these forage systems in the diverse risk environment confronted by commercial feeder calf producers.

Traditional beef cow-calf systems in Tennessee include spring calving, grazing pastures during spring and summer, and selling calves at weaning in the fall. Spring calving has been the preferred choice primarily because of the relative proximity between periods of high cow nutritional requirements and increased forage growth. The fall calving alternative relies on milk from the dam during the winter, and

grazing pastures during the spring and summer until calves are weaned (Forcherio 1986). The production cycle of fall calving cows does not match the forage production cycle as closely as that of spring calving cows. As a result, fall calving cows are under greater nutritional stress and thus, are more susceptible to the risks associated with forage production variability. However, during the spring when forage yield and quality are greatest, the fall-born calf is mature enough to utilize this increased forage growth. Research in other states has reported higher weaning weights and greater profit potential from fall as opposed to spring-born calves (Kartchner et al. 1979; Bagely et al. 1987; Mueller and Harris 1967). Advantages of fall calving, however, are obtained only by exposing the operation to greater forage production risk. Before fall calving can gain a wider acceptance among Tennessee producers more information is needed concerning both the relative profitability and riskiness of fall calving systems as compared to spring calving systems.

Price Risk

Variability in the profitability of a cattle operation can to a considerable extent be attributed to market risk or fluctuations in cattle prices. Short-run price uncertainty presents a serious problem for decision makers who produce feeder cattle. Production and marketing decisions based on erroneous price expectations may lead to less than optimal resource use and reduced income for cattle producers.

Tennessee feeder calf producers have few available options for coping with price risk. Forward price commitments in cattle production have received limited use at the producer level. Public programs

of price support and supply management have never been available. Insurance choices are few. An option less obvious to most producers is fall calving. Fall-born calves are sold in early summer when, historically, feeder cattle prices have been higher than in the fall when spring-born calves are marketed. Results by Bagely et al. (1987) and Mueller and Harris (1967) have identified higher prices for fall-born calves as being an important advantage of the system. From 1981 through 1987 the average price¹ of feeder calves in Tennessee was \$1.50 per hundredweight higher in June than October (Tennessee Agricultural Statistics Service 1988).

Another important source of risk confronting feeder calf producers is the uncertainty associated with purchased feed prices. On many farms hay must be purchased to meet winter feed requirements during years of poor forage production. Consequently, purchased hay requirements tend to be greatest when forage prices are highest. This effectively compounds the risks associated with variable forage yields.

Problem Statement

Planning is a vital management function in a cow-calf operation particularly in an uncertain environment where income and risk goals may conflict. Variable forage production and price uncertainty are major sources of the risk. Forage production variability has serious

¹Average price for medium frame choice, 5-600 pound steer and heifer calves at Tennessee Feeder Calf Auctions.

implications for both long and short-term planning of the cattle operation. Research has focused on improving forage yield and quality, reducing seasonal variation and extending the grazing season through innovative forage combinations and pasture management practices. Results of this research, however, do not describe how these forage systems may fare in a commercial production setting. Fall calving has been shown in some studies to result in higher calf gains and weaning weights as compared to the traditional spring calving alternative. The higher market prices normally received for fall-born calves would be an additional advantage of this system. However, the correspondence between annual forage supply and demand provide production efficiencies in the spring herd not obtained with the fall herd.

Tennessee feeder calf producers require information regarding the economic potential of these technologies in a risky environment. Research examining experimental forage systems in the risky commercial production situation would permit an evaluation of their utility at the producer level. Furthermore, a comparison of fall and spring calving would facilitate an evaluation of their relative production and economic merits, and riskiness. To date, little evidence is available by which to evaluate the potential of these management strategies for coping with the production and price risks inherent with feeder calf production.

Objectives

The general objective of this research was to compare and evaluate production and economic characteristics of experimental forage and

calving systems in the risky commercial feeder calf production situation. Specifically, the objectives were the following:

- 1) To compare and evaluate returns and risks associated with feeder calf production using tall fescue and bermudagrass/tall fescue pasture systems.
- 2) To compare and evaluate returns and risks associated with feeder calf production using perennial grass pasture systems renovated with legumes, namely red clover and annual lespedesa.
- 3) To compare and evaluate returns and risks associated with feeder calf production using each forage system with spring and fall calving systems.

Conceptual Framework and Methodological Overview

To accomplish the objectives the decision making process of a feeder calf producer was specified and incorporated into the uncertain decision environment. Major sources of risk were quantified and combined in such a way as to describe the relationships existing between the uncertain environment and the production and managerial processes of the livestock operation. Furthermore, performance was measured using means suitable for evaluation by producers in terms of their respective goals and preferences.

The focus of this study concerns decision making at the enterprise level by producers operating in a risky environment. Critical steps in the decision making process are the development of long-term plans, implementing these plans, and the evaluation and revision of plans as physical and economic conditions dictate. The framework of analysis, therefore, casts this decision making process into the risky surroundings in a way that is both theoretically and analytically consistent with producer behavior in actual situations.

This section begins by defining the conceptual framework in terms of producer behavior, and then summarizes the methods of analysis used for modeling such behavior.

The Decision Making Process

The process of managing production can be characterized as involving two sets of decisions. Initially, the operator develops a long-term plan guiding resource commitments and flows over a multiple-year horizon. Such plans are based upon expectations about future prices and yields. Because future conditions cannot be fully anticipated, the manager oftentimes must revise plans in response to the changing environment. In the short-term, price and yield fluctuations require that the operator deviate from long-term plans by adjusting to the current situation. Long-term plans, therefore, are formulated primarily to provide for the best possible first move during the current period (Modigliani and Cohen 1961). Both long and short-term plans are developed differently by individual operators according to their unique preferences and goals.

In this study management of forage-beef production was cast into this characterization of the decision making process. Many decisions confronting feeder calf producers take the form of capital investments and thus, were classified as long-term decisions. Besides investment in land, buildings and equipment, other long-term decisions included the selection of perennial forages, herd size and breed, and calving season. Once decisions are made, costs of changing these variables can be substantial and adjustments are typically made slowly. A few decisions, however, are made more frequently in response to

environmental and economic fluctuations. Such short-term decisions included hay production and feeding, hay purchase and sale transactions, and stocking rate adjustments. Climatic variations affect such variables as forage productivity and cattle performance, and thus influence decisions about hay production and stocking rates. Hay purchase and sale transactions depend on reserve levels and feeding requirements. In light of this uncertain decision environment, short-term deviations from long-term plans were necessary to adjust to changing conditions.

Operator preferences and business goals are important behavioral determinants of both long and short-term plans. Factors considered in planning include income potential, riskiness, and financial viability and success possibilities of alternative courses of action. The relative weight planners assign these factors determine which alternatives are selected. As a result, both long-term plans and adjustments in such plans may vary substantially among individual producers.

Overview of Methods

Due to the numerous and interrelated physical and economic relationships characteristic of the forage-beef production setting, a systems approach was adopted in this study. Using the systems approach, alternative components, or subsystems, can be identified and defined, then combined in a manner to describe the operation of the larger system. The forage-beef production system involves several subsystems, such as climatic, biological and economic components, whose interaction gives structure to the larger system. Thus, the

systems perspective provides an appealing framework for approaching and analyzing the complexities involved with forage-beef production.

The methodology chosen to examine these problems of planning and performance of a cattle operation included techniques of simulation analysis. Several advantages are apparent for utilizing simulation in such a study. By representing over time the essential characteristics of the system under study, simulation allows the investigator "to view problems as they exist rather than as some predetermined analytical structure admits" (Johnson and Rausser 1977). Simulation modeling also provides the instrumentality for dealing with dynamic and stochastic processes too complex to be represented by more rigid mathematical models, such as linear and quadratic programming, making simulation "the most flexible and least-confined of symbolic models" (Anderson 1974). These are important considerations because of the complexity of the uncertain physical and economic environment in which Tennessee cattle producers operate.

In this study the forage-beef system was characterized by five critical subsystems; namely, climatic, forage, cattle, managerial, and economic systems. Initially, each system was examined and described as a separate model component, and then linked by specifying important relationships and feedbacks among components. For example, the climatic component specified stochastic environmental conditions to which the forage-beef system was subjected. The forage component utilized this information, along with plant-environment response relations, to describe resulting plant growth characteristics. In turn, the cattle component used the prescribed plant response to

determine the impact on cattle performance. Likewise, other model components were defined and combined in a manner to describe the overall structure and operation of the forage-beef system. Once specified, this larger system provided an experimental laboratory in which the effects of alternative plans, schemes of implementation, and methods of managerial control could be examined.

To accomplish project objectives, production alternatives were specified and performance of a cattle operation was evaluated over a ten-year horizon. The alternatives under examination included systems of fall and spring calving, along with tall fescue and bermudagrass/tall fescue forage systems, with and without renovation with legumes. Eight alternatives, including each combination of the forage and calving systems, were simulated on the cattle operation over the ten-year horizon, subject to stochastic environmental and price conditions. By repeating this technique 100 times for each alternative, performance of the cattle operation was measured via probabilities of outcome variables. Distributions of system performance indicators, including forage, cattle and economic variables, were summarized and compared for the examined alternatives. In addition, cumulative probability distributions for annual forage yield, calf weaning weight and after-tax net present value of income were developed and compared among the production alternatives. Cumulative probability distributions of after-tax net present value of income were ranked according to stochastic dominance criterion for producers expressing risk adverse, risk neutral and risk loving preferences.

Study Area

The area of study included much of the eight most southwestern counties in Tennessee--Shelby, Tipton, Lauderdale, Crockett, Haywood, Fayette, Hardeman and Madison (Figure I-1). This area was delineated on the basis of similarity in topography, types of soils, type of farming and climate. Consequently, the area designated in Figure I-1 includes only portions of some counties.

This eight-county region contained more than 13 percent of total Tennessee farmland in 1982. Much of the farmland is suitable for intensive rowcrop production. Crops were harvested on about 60 percent of the region's farmland in 1982 (U.S. Department of Commerce 1982). Cotton and soybean production were the predominant agricultural activities. During 1987 the counties included in this area accounted for 81 and 35 percent of the state's harvested acreage of cotton and soybeans, respectively (Tennessee Agricultural Statistics Service 1988).

Small cattle operations have characterized the beef industry in this region. Approximately 88 percent of the 1982 beef cow inventory in the area was on farms with 50 cows or less. The average herd consisted of 25 cows (U.S. Department of Commerce 1982). Most cow-calf operations in large crop producing areas are small supplemental enterprises (Gilliam 1984). Many farmers who have other farm enterprises such as crops as the principal farm income source also produce feeder calves as a supplementary enterprise. More than 42 percent of the farms in this area reported an inventory of beef cows in 1982 (U.S. Department of Commerce 1982).

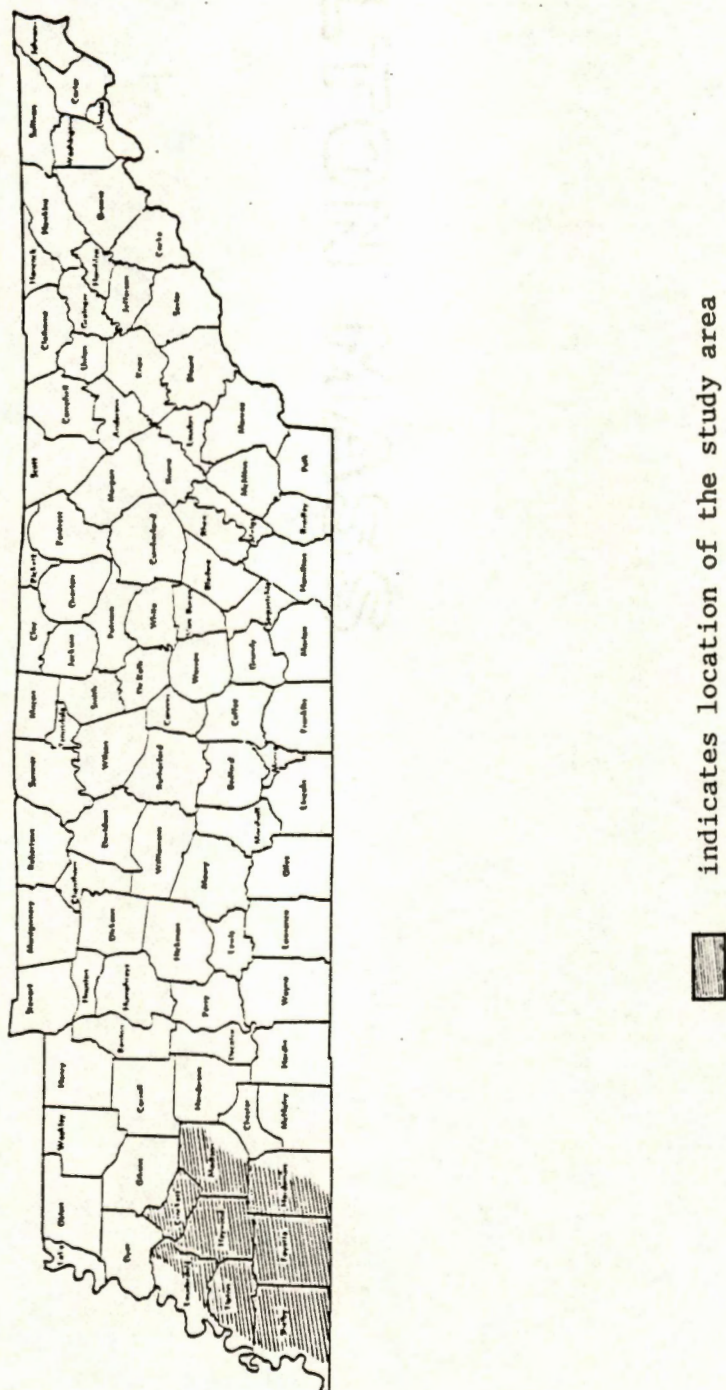


FIGURE I-1

LOCATION OF THE STUDY AREA

Pastureland and woodland pasture comprised roughly 13 percent, or 210 thousand acres, of the farmland in this region during 1982 (U.S. Department of Commerce 1982). Predominant soil associations of these pasture sites included the Memphis, Grenada, Loring and Lexington series. These brown, silty loam soils are the upland soils of this region and are frequently subject to erosion. Many of the pastureland sites were reported as moderate to severely erosive areas in 1982. Dominate cover crops were cool and warm season grass species (U.S. Department of Agriculture/Iowa State University 1982). Tall fescue and bermudagrass are well-adapted to this area of Tennessee and are often used in combination with legumes such as clover.

Climate is highly variable, typically consisting of warm, wet springs and falls, hot and humid summers, and mild winters. Rainfall is varied within and between years with an annual average ranging from 48 inches in the west to 56 inches in the eastern counties. The growing season (freeze-free days) averages between 200 and 220 days annually (Mundy and Gray 1986).

CHAPTER II

TECHNICAL AND METHODOLOGICAL BACKGROUND, AND LITERATURE REVIEW

In this chapter technical aspects of forage-beef production are introduced and described, followed by a review of studies assessing the economic advantages of alternative systems. Also included is a description of systems analysis and simulation methods, and a review of studies applying these techniques to agriculture.

Technical Background of Forage-Beef Production

Several forage-beef production systems have been designed to improve the performance and efficiency of cattle operations. Much of this effort has focused on increasing total forage production and quality, reducing production variability, extending the grazing season, and matching cattle nutrient requirements with forage production and quality. Systems considered in this study include alternative forage species and mixtures, and calving seasons. In this section technical aspects of forage-beef production important to this study are developed.

Forage Species and Mixtures

Forage grasses are quite specific in their temperature adaptation. In the eastern U.S. moisture is adequate for prairie grasslands and temperature is the principal factor affecting grass adaptation (McCloud and Bula 1985). Tennessee lies in the transition zone between a climate that is typically northern and one that is typically southern. As a result wide climatic fluctuations are

observed. Such diversity in temperature has fostered the adaptation of both cool-season grasses, those exhibiting rapid growth during cool moist periods, and warm-season grasses, those whose major growth occurs during the warmer part of the year. Tall fescue is the predominant cool-season perennial, while bermudagrass is the primary warm-season perennial, each grown extensively in the study area.

Tall fescue (Festuca arundinacea Schreb.) is the most widely used pasture grass in Tennessee. Due to its ease of establishment and hardiness under adverse conditions, this perennial grass has become a favorite among beef producers. Tall fescue is tolerant of both poor drainage and droughty conditions, and can provide adequate forage for grazing animals during the annual cool seasons (Buckner 1985). Despite its excellent agronomic characteristics and forage quality, tall fescue has been criticized because of poor animal performance and atypical behavior observed from grazing animals during summer conditions (Hemken et al. 1981; Bond et al. 1984). This phenomena, known as summer syndrome, is believed to be the result of an endophytic fungus resident in the plant (Hoveland et al. 1980; Hemken et al. 1984).

Common bermudagrass (Cynodon dactylon var. dactylon) is the predominant warm-season grass used in Tennessee pastures, especially in the western and southern areas. There are several different ecotypes of bermudagrass that differ in vigor, growth habit and yield. Tifton 44 bermudagrass, a hybrid of Coastal and a winter-hardy common, has gained in producer acceptance due to its improved winter hardiness. Forage production of bermudagrass is highly seasonal. Growth

is rapid during the hot, humid summer conditions and tapers to dormancy in the cooler fall and winter seasons (Burton and Hanna 1985). This characteristic favors the use of bermudagrass pastures to fill the summer production slump of cool-season grass pastures.

The many benefits realized when grass pastures are renovated with legumes have been well documented. Legumes provide nitrogen for perennial grasses. An adequate stand of clover provides as much as 60 to 80 pounds per acre of nitrogen each year, increasing both grass production and protein content of the total forage (Burns 1975). Cattle gains, grazing days and carrying capacity of tall fescue pastures have been shown to improve when legumes were included as a companion crop (High J.W. et al. 1965; High, T.W. et al. 1965; Hobbs et al. 1965). The presence of legumes in tall fescue can dilute the effects of the fungal endophyte, thereby reducing the incidence of summer syndrome (McLaren and Fribourg 1987). High rates of forage growth and cattle gain have been observed when either clover or fescue were incorporated into bermudagrass. Furthermore, these bermudagrass-clover and bermudagrass-fescue mixtures have shown potential for lengthening the grazing season (McLaren et al. 1983). These advantages of grass-legume mixes are obvious to most producers, as well as researchers.

Red clover (Trifolium pratense L.) and annual Lespedeza (Lespedeza striata) are legumes well adapted to Tennessee. Red clover grows best during the annual cool seasons, and in years of favorable moisture. This legume is used extensively in pasture mixes and for renovating old pastures, and is the easiest legume to establish in

closely grazed sods. Red clover persistence in grass pastures, however, can be quite short. Without proper management, clover yield may disappear as soon as the third year (Taylor 1985). Annual lespedesa is usually sown in the early spring in Tennessee. Broadcasting without covering normally gives adequate stands, with volunteer seeding enhancing yields once this legume is established. Kobe lespedesa exhibits large and erect growth habits that make it highly productive and desirable for hay and pasture. Late summer production of this cultivar is higher than any other annual lespedesa (Hoveland and Donnelly 1985). This characteristic favors its use in tall fescue pastures whose productivity declines during the summer.

Pastures change dynamically. Forage composition is variable with season, environmental factors and management. Fribourg et al. (1984) demonstrated the significant influence species composition has on forage growth, consumption and cattle gains. Much difficulty, however, is involved with maintaining productivity and persistence of many forage mixtures. In a three-year study of several legumes growing in fescue sods, Dobson et al. (1976) reported greatly diminished stands of white and red clover in the second and third years. Red clover was essentially non-existent by year three. Fribourg and Overton (1979) tested the persistence of tall fescue seeded into bermudagrass under alternative management systems. Results indicated that fescue stands were less persistent as nitrogen rates or row spacing increased, and the effects of frequent and infrequent clipping varied among seasons. Many studies, such as those cited here, have demonstrated the

importance of management for maintaining productive and high quality forage yields from grass-legume mixtures.

Forage Intake

Holloway (1984) described forage intake of pastured cattle as the point of impingement between two dynamic systems: the grazing animal and the grazed forage. He further emphasized that a detailed study of forage intake by grazing animals reveals that it is not just the connecting link between two dynamic systems, but the focal point of one comprehensive dynamic system. This system can be viewed as being composed of two major components that are intermeshed to the extent that the study of either alone leads to erroneous conclusions (Holloway 1984). Theory and thus technology for feeding cattle under grazing conditions has developed slowly due to the inherent difficulties in measuring feed consumption. Regardless of these problems, understanding the grazing system is very important to the financial success of most beef producers in Tennessee because nearly all beef cows in the state graze pastures most of the year.

Several theories have been proposed to describe the physiology associated with forage intake. One theory, the fill/rate of passage (cell wall content) theory, attempts to explain how certain characteristics of the consumed forage affect digestion and thus intake. According to this theory, the amount an animal can consume is limited by the amount of undigested residue in the rumen. Residue can leave the rumen by either of two avenues, digestion or passage. Rate of passage apparently has a much greater influence on reticulo-rumen fill, and thus intake, than does rate of digestion (Van Soest 1982).

The fill/rate of passage theory assumes the rumen can stretch. Hunger pangs occur when the rumen is relatively empty and the animal eats until the rumen stretches to cause discomfort, eating then ceases. Consequently, the forage characteristic that determines the amount of fill and rate of passage also determines the amount of possible intake. That characteristic has been identified as bulk and is determined by plant cell structure. Plant cells are given structure, or bulk, by their cell walls. Besides giving plant tissue volume, cell walls also prevent ruminal microbial attack of the soluble cell contents. Digestion is the process by which this structure is collapsed, exposing the digestible cell contents to the fermentative medium.

Although the extent of digestion for perennial grasses and legumes has been reported to be similar, the rate of digestion and passage is faster for legumes. Legumes have greater collapsibility early in the digestive process and undigested residues leave the rumen faster, giving rise to greater effective capacity for intake (Thorton and Minson 1973). The faster digestibility of legumes may explain the improved cattle performance observed on grass-legume pastures than on grass pastures. Holloway et al. (1979) reported increased cattle intake and weight gain for cows and calves grazing fescue-legume pastures as opposed to pure fescue stands.

Other theories describing the physiology of forage intake include the chemostatic, thermostatic and lipostatic theories. The chemostatic theory maintains that the products of ruminal digestion, possibly acetic and propionic acid, appear in the blood and through

feedback mechanisms, signal the animal that it is satisfied. In the thermostatic theory the principal notion is that the animal eats to maintain a comfortable body temperature. Eating results in a rise in temperature through specific dynamic action and heat of digestion, and feeds a satiety signal back to the animal. The lipostatic theory is that, over the long term, animals eat to maintain a certain percentage of body fat (Holloway 1984).

Montgomery and Baumgardt have proposed a concept that explains the relative importance and relationship of these theories of feed intake control. They have reported evidence that the intake of ruminants is controlled by physical factors (bulkiness of the diet) if the ration is less than 67 percent digestible. For rations greater than 67 percent digestible, intake is controlled by the animal's energy requirements (chemostatic, thermostatic or lipostatic feedback mechanisms) (Figure II-1). The point of demarcation has been defined as the "set point".

Annual Forage-Beef Production Cycles

The production of cool and warm-season perennial forages follows a seasonal cycle (Matches et al. 1977; Fribourg 1983). In the Mid-South cool-season forages have little growth during the freezing temperatures of December and January. Primary growth of these grass species initiates during the early spring and production reaches peak levels in April and May. Production of cool-season forages declines during the hot summer months, but increases slightly in the fall. The cooler fall conditions promote growth before freezing temperatures

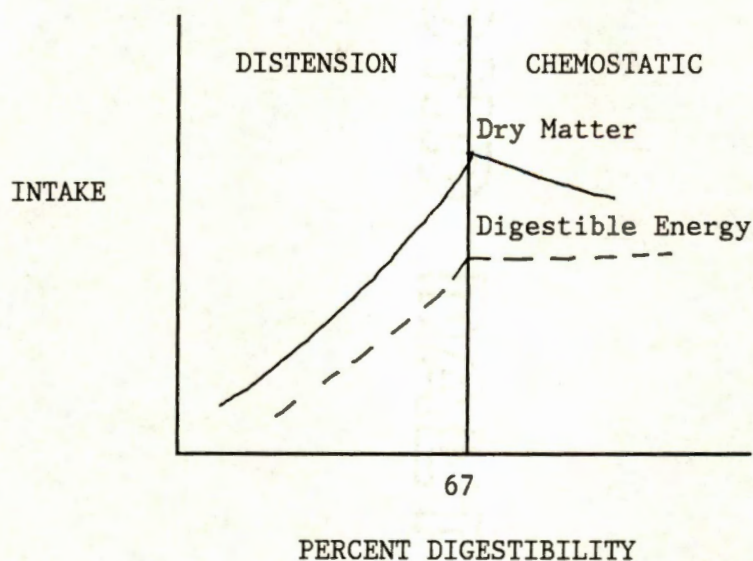


FIGURE II-1

INFLUENCE OF FORAGE DIGESTIBILITY ON INTAKE

Source: Adapted from Montgomery and Baumgardt (1965), and Holloway (1984)

return. Warm-season perennials usually begin production around April, grow vigorously during the hot summer months, and cease production in October.

The annual production cycle of a mature beef cow can be divided into four periods. Period 1 initiates following calf weaning and lasts up to between 30 and 45 days prior to calving. During this last one-third of gestation nutrient requirements are lowest and poorer quality forages may be fed without affecting performance. Period 2 includes the final 30 to 45 days of pregnancy when approximately 70 percent of fetal growth occurs. Underfeeding at this time can result in small, weak calves at parturition and reduced milk production. Period 3 is the 90-day period following calving. At this time nutritional requirements of the cow are greatest. Lactation is at the highest level and adequate nutrition is necessary to prepare the

reproductive tract for breeding and conception. Period 4 lasts from the beginning of the breeding season to weaning. Much of the nutrients consumed at this time are required for milk production. Milk production, however, is declining throughout the period and at weaning, nutrient requirements of the cow are at the lowest level of the production cycle (Byers 1986).

Matching the annual production cycles of beef cows and forage production is important for providing adequate nutrition for the beef herd at the lowest cost. Nutritional requirements of spring calving cows and the relative forage production of cool-season forages appear to be closely matched throughout the annual production cycles. Nutritional requirements of spring calving cows are greatest in March to May. This corresponds with high levels of forage production by cool-season grasses during the spring. Nutrient requirements decline during the summer and increase in late fall and early winter, while forage production decreases in the summer, increases in the fall and decreases in the late fall and winter. The forage supply, however, does not correspond to higher nutrient needs of spring calving cows in late fall and winter months. December and January appear to be high deficit months for forage supply. When the greatest amount of forage is available (March to May), the reticulo-rumen of the spring-born calf is just becoming functional and the calf will not benefit from the lush growth in early spring. The spring-born calf would benefit from the increased forage growth in late summer and early fall, just before weaning. Because of this relative proximity of forage supply

and demand, the majority of feeder calves produced in Tennessee are from spring calving herds.

An alternative to the spring calving system would have calves born in the fall, rely on milk from the dam during the winter, and graze pastures during the spring and summer until weaned (Forcherio 1986). The production cycle of fall calving cows does not match the forage production cycle as closely as spring calving cows. Fall calves are born September to November when cool-season grass pastures are increasing growth. This increase in growth corresponds to greater nutritional needs of the lactating cow. Greatest nutritional requirements occur November to January. In this period the decreased forage production implies that some type of forage supplementation is necessary to meet lactation requirements. Decreasing nutritional needs of fall calving cows during April and May correspond with peak levels of forage production. However, the fall-born calf should be old enough to benefit from this increase in forage production during the spring. When nutrient needs of cows are increasing during the summer to meet pregnancy requirements, forage production of cool-season pastures will be declining. The increasing production from warm-season grass pastures may be utilized at this time to meet the greater cow requirements.

While it is obvious that spring calving is superior to fall calving in terms of matching forage production with cow requirements, the latter is not without certain advantages. The most prominent advantage occurs during the spring when forage production is increasing. The fall-born calf is old enough at this time to utilize the

high quality forage. Kartchner et al. (1979) have reported greater average daily gains of fall-born as opposed to spring-born calves. In another study comparing fall and spring calving herds, Bagley et al. (1987) reported higher weaning weights for the fall-born calves. Other reported advantages include lower death losses for calves born in the fall and higher prices received for spring marketed calves (Mueller and Harris 1967).

Review of Studies on the Economics of Forage-Beef Production

Several studies have assessed the economic advantages of alternative forage-beef production systems. Much of this work differs in direction of focus and methods of analysis. Most often the emphasis of these studies was related to the location under analysis and the problems and peculiarities associated with this area. For example a sharp contrast can be drawn between systems of forage-beef production suitable for the more arid range conditions of the west, and those of the more humid eastern U.S.. Consequently, problems studied in various research studies tend to be very location specific. This section will emphasize findings of research pertaining to the selection of alternative forage systems and calving seasons. The review of studies is grouped into those primarily concerned with profitability of forage-beef production, and those whose major focus is on the risks.

Profitability Studies of Forage-Beef Production

Petritz et al. (1980) undertook a study to determine the economic advantage, if any, for the use of tall fescue overseeded with legumes

rather than orchardgrass or tall fescue in southern Indiana pastures. Data from a physical experiment comparing each sward were utilized in the economic analysis. The relative economic value of each pasture species was determined by deducting from gross receipts only those costs that varied due to differences in pasture management. These included nitrogen fertilization, legume seeding in the established pasture and hay harvest. Tall fescue-legume pastures produced \$106/ha greater net returns than tall fescue pastures, and \$8/ha greater net returns than orchardgrass pastures. Most of the difference in net returns was due to poor calf gains and conception rates when animals were grazing tall fescue pastures.

Carpenter et al. (1979) used standard budgetary techniques to evaluate the economic implications of producing beef calves in western Louisiana with four pasture management systems. Comparisons were made of each pasture system for fall and spring calving herds. Each system consisted of 30 acres. Bermudagrass overseeded with clovers and annual ryegrass was the primary forage source in all systems with varying acreage of wheat-rye-ryegrass followed by millet. None of the systems yielded positive net returns when all costs, including land rent, were deducted from gross receipts. Only one of the systems, 20 acres of the bermudagrass-clover-ryegrass mixture along with 10 acres of wheat-rye-ryegrass followed by millet, provided positive net returns to land and management. Utilizing results from this same experiment, Bagley et al. (1987) conducted a cost and return analysis for systems of fall and spring calving. On the average, per acre variable costs were much higher for the fall calving herd primarily

because of greater supplemental feed requirements of lactating cows during the winter. Net returns per acre, however, were greater for the fall herd. The higher net returns resulted from lower calf death losses, greater weaning weights and higher calf prices in the spring.

Mueller and Harris (1967) developed budgets for a 170 cow herd calving at alternative dates on the range of northern Washington. Calving dates considered in the analysis included the early spring (February-March), fall (September-October) and late spring (April-May). The traditional early spring calving date was shown to generate the least amount of net returns to land and management. Fall and late spring calving yielded much higher net returns even as total cost/cow was greater for these systems. The economic advantages of the later calving dates resulted from heavier weaning weights of fall-born calves, and lower death losses and higher prices received for calves in both the fall and late spring systems.

The economic implications of beef production in West Tennessee were evaluated by Williams (1975). Budgetary and linear programming techniques were utilized to examine the competitiveness of various beef production alternatives for representative farm situations. Several systems of forage production, including bermudagrass pastures, permanent pastures (tall fescue-clover) and hay production, were also considered in the analysis. Results implied that beef production was not as profitable as hog production in this area of Tennessee. Of the beef enterprises, stocker steers grazing bermudagrass and permanent pastures appeared as the most profitable alternative. Cow-calf enterprises did provide additional farm income, but generally were

included in the optimal enterprise mix at relatively low levels. In situations where the farm was limited to beef and associated crop enterprises only, beef feeding and stocker enterprises were the most profitable livestock alternatives. The cow-calf enterprises competed with these alternatives at economical levels only in situations of high efficiency in the production of feeder calves (i.e. high calf crop and weaning weight).

Risk Studies of Forage-Beef Production

Pope and Shumway (1984) analyzed the implications of forage yield uncertainty for planning forage-beef production in east Texas. Using four years of historical forage yields to represent possible states of nature, linear programming was utilized to determine optimal management strategies (i.e. herd size, forage system and hay transactions) for each state of nature. The LP model was then executed for each management plan under the conditions of each state of nature. Preferred management plans were selected from the resulting payoff matrix of net returns according to alternative decision criteria. Optimal production plans included much larger cow herds in plans where high yields of forage were anticipated as opposed to those of low expected yields. Bermudagrass and bermudagrass-clover-ryegrass pastures were included in all production plans. At lower expected forage yields, the forage program became much more diversified. Planning for poor weather conditions and forage production was the preferred strategy according to 4 of the 5 considered decision criteria. This approach was the least risky and, on the average, the most profitable strategy for planning forage-beef production. Only for decision makers using

the maximax criterion for choice was planning for high forage yields appropriate.

The effects of both price and yield risk on planning forage-beef production were considered by Gebremeskel and Shumway (1979) in a study of Texas Gulf Coast cattle producers. Risk-constrained linear programming (MOTAD) was used to develop long-run forage-beef plans for a fall and a spring calving herd. The MOTAD model was designed to incorporate forage yield variability into the decision process of a cattle producer. Hay purchase and sale were permitted in variable years to convert seasonal and yearly variations in forage production into dollar values. This source of risk was added to historical cattle and supplemental feed price variations to account for the major sources of risk confronting feeder cattle producers. Resulting E-A efficient sets for both calving seasons showed the herd calving in early spring to dominate the fall calving option at all risk levels. Estimated E-A frontiers were very steep for both calving options indicating little trade-off between risk and net returns. Given this situation, the authors concluded that it is unlikely a producer would choose any plan other than the least risky alternative. The optimal forage system was relatively stable across the different risk levels and included a bermudagrass-clover mixture fertilized at varying rates.

Angirasa et al. (1981) employed a combination of biological simulation and MOTAD programming to examine the effects of risk on an east Texas cow-calf operation. The biological simulation model was used to develop input-output coefficients for beef production under

alternative physical and managerial conditions. Results of this model, combined with forage yield and quality data, provided input parameters for a short-run MOTAD analysis. Bermudagrass and a bermudagrass- clover-ryegrass mixture were the forage systems used at every risk level. Fall calving was the preferred choice in plans that marketed calves at weaning. The value of the extra weight gain of fall-born calves more than offset the extra cost of winter feed. Spring calving was chosen in the plans that retained calves past weaning.

Saez et al. (1981) evaluated profit potential and risks associated with alternative management choices of an east Texas cow-calf producer using a MOTAD model very similar to the one developed by Gebremeskel and Shumway (1979). In this study fall-calving farm organizations provided the highest expected net returns at alternative risk levels. Regardless of the risk level the optimal plans included a diversified forage system. The forage system varied with degree of risk aversion only slightly in relative proportions of species. An important impact of the high degree of risk aversion was that a large amount of the hay produced in the average year was stored for feeding in low-yield years. In this way, on-farm hay storage was used as a method of risk reduction.

Systems Analysis and Simulation

Systems analysis and simulation have had a recent but marked influence on research in many applied sciences including agricultural

economics. Recent history reveals a gravitation toward greater use of these concepts and methods for analyses of applied issues. Factors identified as accounting for this trend are about as numerous as the individuals who have commented on the subject. Two factors particularly applicable to agricultural economics are the pragmatic nature of the research and the increasingly eclectic nature of the problems studied (Leontief 1971).

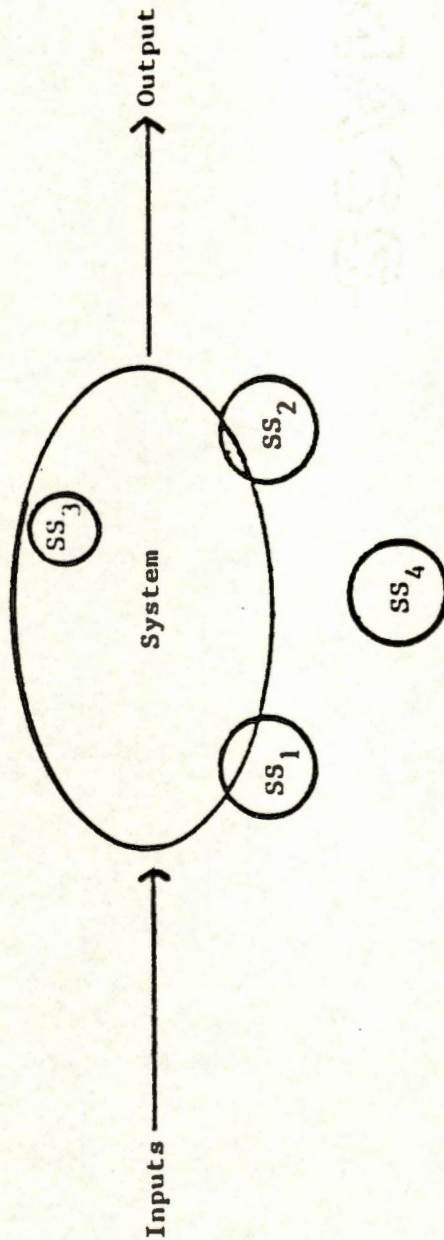
Terminology and Use

A number of terms common to systems concepts and simulation have specialized meaning. These terms will be identified, therefore, before discussing the approach and/or methods.

The most basic concept of systems analysis is that of a system. A "system" may be simply defined as a collection of interrelated components or elements with a purpose (Johnson and Rausser 1977). Due to the high degree of interrelationships among components of most systems, knowledge about parts of a system is typically insufficient for understanding the complete system. Systems can be characterized as being complex, dynamic and affected by stochastic variables (Figure II-2). Most systems vary widely in terms of specific characteristics but typically have these basic features (Keller 1987):

- 1) Systems include a set of identifiable components and complex interconnections.
- 2) Systems involve a hierarchical structure of subsystems which operate independently in some respects but retain important features that link them to a larger system. Subsystems may be completely embedded, partially related or largely or wholly

The System Concept



CHARACTERISTICS

- | | |
|---------------------|--------------|
| *Complex | *Stochastic |
| *Interrelationships | *Feedback |
| *Dynamic | *Environment |

Source: Keller (1987)

FIGURE II-2

THE SYSTEM CONCEPT AND CHARACTERISTICS OF SYSTEMS

outside the current focus of a particular system (SS1, SS2, SS3 and SS4 in Figure II-2).

- 3) Systems can be visualized in terms of processes and many of the component relationships emerge over time. Thus, proper specification of the system must give explicit consideration to time and rates of change. Delays or lags exist between inputs and resulting outputs, and feedback information produces the basis for monitoring and modifying the behavior of the system.
- 4) The environment is critical to how systems operate. Environment includes sets of objects outside of the system that impact on system operation. The operation of the system in turn may impact on the environment.

The system perspective provides a mental framework for approaching and visualizing real world problems in a more meaningful way. In comments on the value of the systems perspective for research, Boulding (1956) stated that, "... it prevents us from accepting as final a level of theoretical analysis which is below the level of the empirical world we are investigating."

A "model" can be described as a synthetic representation of a system. Constructing a model of a system may be viewed as a developmental process. Activities of this process have been identified as analysis, synthesis and design. "Systems analysis" is the purposeful study of systems. "Systems synthesis" is the act of characterizing a system, including the identification, classification and specification of components or elements and the relationships giving the model cohesive structure. "Systems design" is the process of investigating and selecting modes for studying systems (Johnson and Rausser 1977). Collectively, analysis, synthesis and, for most problems, design may be viewed as steps in the process of developing a sufficient understanding of a system for the construction of a model.

Once the system has been analyzed and a model has been synthesized and designed, model construction may proceed. Model construction can be viewed as involving five principal steps. These are model specification, parameter estimation, verification, validation and revision (Johnson and Rausser 1977). At each step decisions are made which are crucial to the modeling endeavor. Model specification involves choosing how general or specific of a model is needed. Decisions at this point are to a great extent based on the research questions at hand. For example, results of the modeling endeavor will have wider applicability when the model is based on primitive and generally accepted normative and physical concepts. Conversely, if the modeling effort attempts to closely describe each component of the actual system, the range over which the results apply will narrow. Parameter estimation refers to how parameters of the model are estimated. Typically, data used in developing model parameters come from different sources, and thus, the framework for considering estimation must reconcile the use of alternative data sources. After the model is conceptualized and constructed, the process by which the investigator determines whether or not it performs in accordance with the intended objectives is called verification. Primary concerns at this step are with completeness, the existence of solutions and internal functioning of the model. Next the model is compared with the system it is designed to represent. This process, called validation, is employed to evaluate the ability of the model to duplicate required characteristics of the system and in fulfilling modeling objectives. Finally, assessments are made as to whether or

not the model should be altered to make it more suitable for the intended objectives. Information on which revisions are based may come from observing the system, on the basis of implications of the model outputs, and a refinement of modeling objectives or the model itself.

"Simulation" is the process of experimenting with models or systems. This context implies a view of simulation as a method and not as a substitute for a model (Naylor 1971). Monte Carlo methods are commonly used in combination with simulation to model the performance of complex stochastic systems. Consequently, these procedures are particularly applicable for the analysis of problems involving choice in risky situations. Under this approach, numerical procedures are employed to generate sample observations from decision maker's subjective probability distributions or empirically observed probability distributions for input variables (King 1979). A set of variants drawn from variables is used for the statistical parameters in the problem. The probability distributions of output variables are obtained by repeating the process. Monte Carlo sampling techniques for estimating the distributions of net present value, internal rate of return, ending net worth and net cash flow have been developed and examined for use in whole-farm/ranch planning (Richardson and Condra 1981; Mapp et al. 1979; VanTassell 1987).

King (1979) noted one of the distinct advantages of simulation is that it is a remarkably flexible procedure which allows complex processes, such as whole-farm planning, to be represented realistically. Such flexibility in model design is, however, both an

advantage and disadvantage (Mapp and Helmers 1984). The system and design of the model are determined by the researcher. Consequently, simulation models rarely have a pre-existing structure as occurs with the coefficients, constraints and objective functions of linear and quadratic programming. Each problem is uniquely modeled. Once a firm is simulated, the model can sometimes be adapted to solve or analyze other problems. However, few simulation models in agricultural economics have been generalized and documented for modification and reuse. The most noteworthy exception is a model known as FLIPSIM, developed by Richardson and Nixon (1986).

Analysis and Simulation of Forage-Beef Systems

The forage-beef setting fits very well into the systems framework and, thus, lends itself to systems analysis and simulation. Forage-beef systems involve a hierarchy of subsystems whose components are highly interrelated and interact in a way as to give the overall system its structure. For example, the grazing animal and the grazed forage may be regarded as two subsystems that are highly interconnected in their component relationships. The interaction of these components give structure to a higher level system, the grazing system. In turn, the grazing system interacts with other systems, such as forage and hay production systems, calving systems and financial systems, among others, to define the overall forage-beef system. Environmental factors including climatic, resource, price and cost conditions play a critical role in how these systems operate. Consequently, forage-beef systems can be characterized as being highly complex, dynamic and affected by numerous stochastic variables.

The systems approach and simulation techniques are well suited to the analysis of forage-beef systems and will be used in this study. Utilizing the systems approach provides a framework for analysis that is highly structured and thus, facilitates conceptualization, visualization and understanding of the complexities involved with forage-beef production. Simulation methods are sufficiently flexible as to consider these complexities, along with the dynamic and stochastic characteristics of forage-beef systems.

Review of Agricultural Studies Applying Simulation Methods

One of the earliest studies in Agricultural Economics involving whole-farm simulation analysis was applied to a large scale range-feedlot operation by Halter and Dean (1965). The general objective was to find improved management policies to deal with the uncertain environment in which decisions were made about buying feeders, transferring them between the range and feedlot, and selling finished cattle. To consider the major sources of risk confronting cattle producers, namely price and weather fluctuations, price and range conditions were treated as stochastic variables. Historical indexed monthly range conditions were specified as either uniform or normal distributions. Successive months were correlated by assigning the previous months index as the mean of the current months distribution, plus a given constant to account for seasonal changes. Future price expectations were formulated using alternative forecasting models that combined average prices in various preceding months minus specified uncertainty margins. An important conclusion

from this early study was that simulation offered a promising tool of analysis in situations involving decision making where numerous stochastic and time related relationships among variables exist.

In a much more recent effort to evaluate ranchers decisions in a risky environment, VanTassell (1987) developed and applied a simulation model to examine range improvement and management alternatives. Nine scenarios, including combinations of three grazing strategies along with three schemes of brush control, were investigated. Under each scenario, the financial performance of a cow-calf ranch was determined by simulating the risky environment and managerial responses to environmental fluctuations for a 20-year planning horizon. Random climatic variables were drawn from empirical distributions and used to determine stocking rates, supplementation rates, cattle weights and success of brush control at four annual decision dates. Relevant managerial decisions were made at each specified date based upon the cumulative environmental conditions and assigned range and cattle production parameters. Stochastic cattle prices were also developed by projecting the cattle cycle via harmonic functions. Monte Carlo methods were used to develop success and survival probabilities for each scenario. Cumulative probability distributions of income were ranked according to stochastic dominance criteria.

Other studies have conducted economic analyses by utilizing the purely technical relations provided by a biological simulation model. One such study was undertaken by Stokes et al. (1981) to evaluate alternative beef feeder cattle genotypes and management/marketing systems. To account for basic production relationships, a

comprehensive biological model (Sanders and Cartwright 1979 a,b) was used to simulate pre- and postweaning performance of nine different beef cattle genotypes under alternative production and marketing systems. This biological model was developed with the philosophy that each equation should be biologically interpretable (Sanders and Cartwright 1979a). The authors viewed this as an important advantage over bioeconomic simulators that use equations giving the best fit to some particular data set.

A number of recent studies have incorporated optimizing routines into the simulation framework. Richardson and Condra (1981) used a programming-simulation model to examine the effects of size on farm survival and success. A linear programming model was linked to a dynamic simulation model to determine farm crop mix at the beginning of each year, permitting the mix to change over time. Expected price vectors used in the LP component were generated randomly by the simulation and adjusted to reflect a farmer's adaptive expectations. Annual production, marketing, financial and income tax activities on farms of varying size were simulated. Projected chances of success and survival were derived using Monte Carlo procedures to simulate a ten-year planning horizon recursively 100 times for each situation.

Chien and Bradford (1976) integrated multiperiod linear programming (MLP) and computer simulation techniques into a single recursive-sequential model of the farm firm growth process. Operation of the model proceeded in three phases. Initially, a distributed lag model (Nerlove 1958) was used to quantify the entrepreneur's price and yield expectations. Next the MLP submodel approximated

entrepreneurial long-run planning behavior. The resulting plans for each period provided input data for the simulation submodel. Enterprise levels for the current period were determined in the decision-operation process of the simulator by comparing the optimal enterprise level obtained from MLP with specified decision criteria. Once the modified current plan was developed, the simulator implemented operation of the plan and executed decisions regarding the addition of durable assets. Finally, a report writer recorded results of the current period on resource inventories, the enterprise organization, a financial summary, and model generated prices and yields. An outstanding feature of this modeling framework was how well it corresponded to theories of dynamic decision making by the firm as put forth by Hicks (1946), and later Modigliani and Cohen (1961). In accordance with Hicks theory, the modeling effort stressed that decision makers revise plans when information becomes available. Long-run plans are, therefore, not necessarily made up in order to be implemented, but mostly to provide for the best possible move during the current period (Modigliani and Cohen 1961).

Few studies in agricultural economics have used both risk programming and simulation methods in the same analysis. Mapp et al. (1979) combined the methods to evaluate risk efficient farm plans in a simulation framework. A MOTAD model was used to develop production and marketing strategies designed to minimize variability of net farm income subject to receiving a specified level of income. For selected plans generated by MOTAD, the simulation model traced the operation of the firm thru a 20-year planning horizon under stochastic prices and

yields. Cash flow data were generated and used in present value and feasibility analyses of the firm. Balance sheet information determined if equity was sufficient to maintain financial viability of the farm during the planning horizon.

CHAPTER III

UNIT OF ANALYSIS, PRODUCTION ALTERNATIVES AND EXPERIMENTAL DESIGN

The unit of analysis in this study is a cattle operation specified in terms of available physical and economic resources. Forage production and calving alternatives are described by management characteristics and annual resource and financial requirements. The experimental design and analytical techniques involve the use of a dynamic, stochastic, and recursive simulation model designed to develop production and economic characteristics of the cattle operation under each alternative.

Unit of Analysis

A cattle operation representative of southwestern Tennessee was designated as the unit of analysis in this study. Most cattle operations in this area are supplemental enterprises found primarily on rowcrop farms. Attention was therefore given to describing farm physical and financial resources available to the cattle operation as a supplemental enterprise on a rowcrop farm. An assumption of this study was, however, that resources used in feeder cattle production could be identified and considered separately from resources used in other enterprises. Thus, planning and performance of the cattle operation was examined independent of the whole-farm business.

Land Resources

The cattle operation included a fixed inventory of land resources which could be allocated between grazing and hay production during a

year. The land resource was assumed large enough to justify the operator possessing the expertise and capital base necessary to invest in and manage the production practices under examination. In this respect, a land resource judged sufficient to support a cattle operation including at least 100 cows was specified. The representative operation was defined to consist of 200 acres of land suitable for pasture and hay production. According to finding from a 1985 extension survey¹, a unit of at least this size was characteristic of the largest 25 to 35 percent of beef producers in West Tennessee (Kimery 1987).

A meaningful depiction of the land resource includes the specification of variables describing characteristics that impact on forage productivity. Both level and variation in yield of various forage species have been shown to be quite different among the different soil series of West Tennessee (Fribourg 1988a.). Soil series classifications and the assumed proportions of each soil on the representative operation are shown in Table III-1. These parameters were developed using 1982 National Resource Inventory data (U.S. Department of Agriculture/Iowa State University 1982) for southwest Tennessee. Proportions of land in each soil series group were based on the distributions of the inventory acreage used primarily for pastureland. The upland soils, including the Memphis, Grenada, Loring, Lexington,

¹This survey includes a sample of West Tennessee beef producers whose herd included at least 25 cows of breeding age.

Calloway and Henry series, comprised more than 95 percent of the pasture sites. Percentage of each soil was derived from the number

TABLE III-1

INVENTORY OF LAND RESOURCES ON THE REPRESENTATIVE CATTLE OPERATION

Soil Series	Soil Mix of Acreage
	percent of acreage
Memphis	33
Grenada	29
Loring	22
Lexington	9
Calloway	4
Henry	3
Total	100

Source: Analysis of 1982 National Resource Inventory Data for Selected Counties in West Tennessee

of acres of pastureland in the study area classified in each of the soil groups.

Labor Resources

The operator and his family were assumed to supply 80 hours of labor per week--50 hours of operator labor and 30 hours of family labor. Since the cattle operation was assumed to be a supplemental enterprise on a diversified farming operation, the available labor supply was divided between labor used in cattle production and labor used in rowcrop production. The amount of available labor for cattle was determined by deducting from monthly supply the amount required in rowcrop enterprises. The farm was assumed to produce cotton and soybeans, the two major crops of the study area, in addition to

cattle. According to survey findings (Kimery 1987), beef producers in West Tennessee obtained approximately 40 percent of annual gross income from beef production. Thus, the acreage of cotton and soybeans (110 and 250 acres, respectively) produced on the farm was set to provide approximately 60 percent of annual gross income. Given the supplemental nature of the cattle enterprise, monthly available labor for cattle production included the remaining supply after crop production requirements were met. The assumed labor supply, estimated crop labor requirements and the residual amount of available labor for cattle production in each month are shown in Table III-2. Separating labor into monthly periods facilitated a comparison of fall and spring calving systems in terms of how well available labor and needs compare in each month.

Any additional required labor was available for hire at the time and in amounts needed with an initial hourly charge of \$8.00. In the analytical model the wage rate was inflated annually according to the assumed economic environment. No full-time employees were available for hire.

Machinery and Facility Resources

Required machinery complements and livestock facilities of the cattle operation were considered as intermediate-term assets. The list of assumed items required along with purchase price, salvage value and expected life are shown in Table III-3. Most items were necessary for feeder cattle production regardless of the system utilized, although usage rates varied by production system. Each item

TABLE III-2

LABOR SUPPLY, CROP REQUIREMENTS AND AVAILABLE LABOR FOR CATTLE
PRODUCTION IN EACH MONTH ON THE CATTLE OPERATION

Month	Labor ¹ Supply	Crop Labor Requirements ²		Available Labor for Cattle
		Cotton	Soybeans	
-----hours-----				
January	333.3	0.0	0.0	333.0
February	333.3	0.0	0.0	333.0
March	333.3	42.9	22.5	267.6
April	333.3	68.2	87.5	177.3
May	333.3	68.2	175.0	89.8
June	333.3	85.4	115.0	132.6
July	333.3	100.1	112.5	120.4
August	333.3	0.0	47.5	285.5
September	333.3	0.0	72.5	260.5
October	333.3	11.0	72.5	249.5
November	333.3	0.0	47.5	285.5
December	333.3	0.0	0.0	333.0
Total	4000	375.8	725.5	2867.7

¹Labor supply was based upon 50 hours per week of operator labor and 30 hours per week of family labor for 50 weeks per year. Hours are spread evenly among the months.

²Crop Labor Requirements are based upon 110 acres of cotton and 250 acres of soybeans. Cotton was assumed to be custom harvested. Estimates were determined using budgetary estimates for Tennessee (Johnson 1987a).

TABLE III-3

MACHINERY AND FACILITY COMPLEMENT OF THE CATTLE OPERATION

Item	Purchase ¹ Price	Salvage Value	Economic Life
	dollars	dollars	dollars
Permanent Fencing ² (2.6 miles)	2087.00	0.00	20
Temporary Fencing ³	356.00	0.00	20
Corral Materials ⁴	1027.00	0.00	20
Headgate (manual)	225.00	0.00	10
Salt/Mineral Feeders			
5 Feeders	330.00	0.00	10
Large Bale Feeders			
5 Feeders ⁵	390.00	0.00	8
Water System	774.00	0.00	10
Shade Shelters (3) ⁶	1602.00	0.00	20
Pickup Truck	9070.00	1500.00	7
Gooseneck Trailer	3200.00	700.00	8
Tractor (50 HP)	15000.00	4500.00	10
Plow (4-14")	2377.00	400.00	10
Disk (12')	3589.00	600.00	10
Harrow (14')	1365.00	200.00	10
Fertilizer Spreader (8')	1542.00	400.00	6
Cultipacker Seeder (8' 7/4")	2927.00	500.00	10
Manure Spreader (13')	3858.00	400.00	10
Rotary Mower (10')	3255.00	500.00	8
Mower Conditioner (7')	6244.00	1000.00	8
Large Round Baler	11108.00	2200.00	10
Rake (side delivery)	1904.00	300.00	10
Large Bale Mover	310.00	50.00	10

¹ Purchase price of each item is that prior to the beginning of the planning horizon (1988).

² Permanent fencing includes barbed wire, steel posts, corner and gate posts, and gates.

³ Temporary fencing includes electric wire, charger, posts and connectors.

⁴ Corral materials include lumber, posts, gates and nails.

⁵ Water system includes 3 tanks and pipe from well.

⁶ Shade shelters are permanent structures made of wood with open sides and a covered top. Included are materials needed for construction (e.g. lumber, posts, etc.)

⁷ The manure spreader was used only in the bermudagrass systems to scatter sprigs at establishment.

was valued at its estimated purchase price in 1988 and assumed to be replaced at the end of its economic (useful) life.

Cattle facility and equipment items were constructed according to recommended technical specifications (Midwest Plan Service 1977), utilization of 200 acres of land for pasture, and a projected herd size of 100 cows (see Appendix Figures 1 and 2 for facility design). The cattle operation was assumed to include the equipment necessary to establish, renovate and maintain pastures, and to prepare, bale and handle hay production in the form of large round bales. Truck, tractor and other machinery were charged to the cattle operation based on expected annual use estimates in the operation (Gilliam 1984; Johnson 1987a.). A straight-line schedule was used to recover machinery and other depreciable assets.

Production Alternatives

Eight production alternatives were evaluated in this study.

Alternatives included each combination of the four forage systems;

- 1) Tall Fescue
- 2) Bermudagrass/Tall Fescue
- 3) Tall Fescue + Legumes
- 4) Bermudagrass/Tall Fescue + Legumes

with the two calving systems.

- 1) Spring Calving
- 2) Fall Calving

Forage Systems

The perennial grass species of tall fescue and bermudagrass provided the base source of forage for all cattle grazing systems. Once established, each species was assumed to have a productive life

of ten years before reestablishment was necessary. Each year of the ten-year span one-tenth of the pastureland, or twenty acres, were reestablished. This assumption minimized the amount of acreage idled for reestablishment in any year, while spreading costs of establishment evenly over the years.

Acreage reestablished in the tall fescue systems was idled in July and not grazed until the next year. Seedbed preparation and fertilization occurred in July through August, with fescue seed sown in late August. Such practices allow the young fescue seedlings to become established during the fall season (Buckner 1985). Annual maintenance included nitrogen applications at a rate of 30 pounds per acre in March and September, and summer mowing for weed control. Operational sequence, timing and performance rates for establishing and maintaining tall fescue stands are presented in Table III-4.

Bermudagrass/tall fescue systems require much more management than pure tall fescue systems. Hybrid bermudagrass must be established from sprigs (Burton and Hanna 1985), increasing both machinery and labor time. Acreage reestablished in this system was idled in March and April for seedbed preparation and fertilization. In April, bermudagrass sprigs were purchased and scattered using a manure spreader. A light disking was used to incorporate sprigs and herbicide into the soil. Once established, bermudagrass was not grazed during the summer, but was available for hay production. The bermudagrass stand was lightly disked in the fall before drilling fescue seed in ten-inch rows. Pastures were idled until the following year to allow the fescue seedlings to become firmly established.

TABLE III-4

SEQUENCE AND TIMING OF OPERATIONS, AND PER ACRE PERFORMANCE RATES,
TALL FESCUE, UPLAND SOILS, WEST TENNESSEE, 1988

Operation	Equipment	Date	Times Over	Machine Hours	Labor Hours
Establishment					
Plow	4-14"	July	1.00	0.59	0.74
Disk & Harrow	12' Disk 14' Harrow	July-Aug	2.00	0.72	0.90
Fertilize & Lime	Fert. & Lime Spreader, 8'	Aug	2.00	0.68	0.86
Seed	Cultipacker- Seeder, 8'4"	Aug	1.00	0.25	0.31
Total					2.81
Protated over Ten Years					0.28
Annual					
Fertilize	Fert. & Lime Spreader, 8'	Mar & Sept	2.00	0.68	0.86
Mow	Rotary Mower, 10'	June-Aug	1.00	0.36	0.45
Total					1.31

Source: Synthesized from Halbrook et al. (1988) and Johnson (1987b.).

Nitrogen was applied in March and September at an annual rate of 45 pounds per acre. Pastures were mowed each summer for weed control. The operational sequence, timing and performance rates for establishing and maintaining bermudagrass/tall fescue pasture stands are shown in Table III-5.

Each grass pasture system was also evaluated with the incorporation and maintenance of legume stands. Legumes used included red clover and annual lespedesa. Grass pastures were renovated with legumes every five years to maintain a viable stand of the companion crop. Thus for this season, one-fifth, or forty acres, of grass-legume systems were renovated each year. The renovation process involved disking twice in the December-February period, and spreading seed in March. During this time pastures were idled to allow germination and establishment of the legume seedlings. Nitrogen was withheld at renovation to minimize competition between the established grass species and legume seedlings. Lime, phosphorous and potassium were applied as required to promote growth of the companion crop (Buckner 1985; Burton and Hanna 1985). Red clover, a biennial species, was overseeded every two years, while lespedesa was overseeded annually. Other yearly practices included nitrogen fertilization, 15 pounds per acre in March and September, and summer mowing for weed control. Operational sequence, timing and performance rates for pasture renovation and maintenance of legume stands are shown in Table III-6.

During summer months acreage was set-aside for hay production to overwinter the beef herd. Two cuttings of hay were possible. The

TABLE III-5

SEQUENCE AND TIMING OF OPERATIONS, AND PER ACRE PERFORMANCE RATES,
BERMUDAGRASS INTERSEEDED WITH TALL FESCUE (10" ROWS),
UPLAND SOILS, WEST TENNESSEE, 1988

Operation	Equipment	Date	Times Over	Machine Hours	Labor Hours
Establishment					
Plow	4-14"	March	1.00	0.59	0.74
Disk & Harrow	12' Disk 14' Harrow	March-April	2.00	0.72	0.90
Fertilize & Lime	Fert. & Lime Spreader, 8'	April	2.00	0.68	0.86
Sprig	Manure Spreader, 130 BU	April	1.00	0.20	0.25
Herbicide	Fert. & Lime Spreader, 8'	April	1.00	0.34	0.43
Disk ¹	12' Disk	April	1.00	0.18	0.22
Disk ²	12' Disk	Sept	1.00	0.18	0.22
Seed	Grain Drill 14 X 7"	Sept	1.00	0.23	0.29
Total					3.91
Prorated Over Ten Years					0.39
Annual					
Fertilize	Fert. & Lime Spreader, 8'	Mar & Sept	2.00	0.68	0.86
Mow	Rotary Mower, 10'	June-Aug	1.00	0.36	0.45
Total					1.31

¹Light disking to incorporate sprigs and herbicide into soil.

²Light disking to loosen soil before drilling fescue seed.

Source: Synthesized from Halbrook et al. and Johnson (1987b.).

TABLE III-6

SEQUENCE AND TIMING OF OPERATIONS, AND PER ACRE PERFORMANCE RATES,
PERENNIAL GRASS PASTURES RENOVATED WITH LEGUMES (RED CLOVER &
ANNUAL LESPEDESA), UPLAND SOILS, WEST TENNESSEE, 1988

Operation	Equipment	Date	Times Over	Machine Hours	Labor Hours
Renovation					
Disk & Harrow	12' Disk 14' Harrow	Dec-Feb	2.00	0.72	0.90
Fertilize & Lime	Fert. & Lime Spreader, 8'	Feb-March	1.00	0.34	0.43
Seed	Cultipacker- Seeder, 8'4"	March	1.00	0.25	0.31
Total					1.64
Prorated Over Five Years					0.33
Annual					
Fertilize	Fert. & Lime Spreader, 8'	Mar & Sept	2.00	0.68	0.86
Seed	Cultipacker- Seeder, 8'4"	March	1.00	0.25	0.31
Mow	Rotary Mower, 10'	June-Aug	1.00	0.36	0.45
Total					1.62

Source: Synthesized from Halbrook et al. (1986) and Johnson (1987b.).

first cutting would occur in June and would consist of accumulated forage growth during April, May and June. Second cutting hay would include accumulated growth in July, August and September. Hay was prepared and handled in the form of large round bales (1200 pounds), and stored on the ground with plastic covering. During normal years hay would be fed in December through February. The operational sequence, timing and performance rates for hay harvesting and feeding at each cutting are presented in Table III-7.

Calving Systems

Beef herds in each calving system were divided into five animal classifications; cows, calves, weaned heifers, replacement heifers and bulls (Waller 1988). Forage requirements of each class varied during the year with the production cycle of each calving system, and age and weight of animals. Cows utilized forage for lactation, gestation and maintenance of a 1000-pound average weight. Calves required forage, as well as dams milk for growth. At weaning, 20 percent of cow numbers were retained in the weaned heifer class as potential breeding stock. Once bred, 17 percent of cow numbers comprised the replacement heifer category. Each heifer class utilized forage for growth. The cow to bull ratio was 25 to one, or 0.04 percent of cow numbers. Bulls required forage to maintain an average weight of 1200 pounds. Breeding, birth and weaning dates, and months during a year in which each cattle classification resided in the operation for both spring and fall calving herds are illustrated in Figure III-1.

Spring calving cows were bred in May, calved in February, and grazed spring, summer and early fall pastures while lactating until

TABLE III-7

SEQUENCE AND TIMING OF OPERATIONS, AND PER ACRE PERFORMANCE RATES,
HAY HARVESTING AND FEEDING (1200 POUND LARGE ROUND BALES),
UPLAND SOILS, WEST TENNESSEE, 1988

Operation	Equipment	Date	Times Over	Machine Hours	Labor Hours
First Cutting					
Mow & Condition	Mower- Conditioner, 7'	June	1.00	0.52	0.65
Rake	Side Delivery	June	1.00	0.32	0.40
Bale	Round Baler, PTO, Large	June	1.00	0.41	0.51
Store Bales	Bale Carrier, 3PT Hitch	June	--	0.50	0.55
Feed Bales	Bale Carrier, 3PT Hitch	Dec-Feb	--	0.50	0.55
Total					2.66
Second Cutting					
Mow & Condition	Mower- Conditioner, 7'	Sept	1.00	0.52	0.65
Rake	Side Delivery	Sept	1.00	0.32	0.40
Bale	Round Baler, PTO, Large	Sept	1.00	0.41	0.51
Store Bales	Bale Carrier, 3PT Hitch	Sept	--	0.50	0.55
Feed Bales	Bale Carrier, 3PT Hitch	Dec-Feb	--	0.50	0.55
Total					2.66

Source: Synthesized from Halbrook et al. (1986) and Johnson (1987b.).

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
<u>Spring Herd</u>												
	calf born				cows bred				calf weaned			
Cows	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
	Feb 15				May 16				Oct 31			
Calves		*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
Weaned Heifers					heifers bred				heifers weaned			
	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
					May 16				Oct 31			
Replacement Heifers		heifers calf										
	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
	Feb 15											
Bulls	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****

Fall Herd

	cows bred				calf weaned				calf born			
Cows	*	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
	Jan 14				June 30				Oct 15			
Calves		*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
Weaned Heifers		heifers bred			heifers weaned							
	*	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
	Jan 14				June 30							
Replacement Heifers									heifers calf			
		*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
									Oct 15			
Bulls	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****

*** Indicates portion of year in which each class of cattle is retained in the operation.

FIGURE III-1

TIMING OF PRODUCTION FOR SPRING AND FALL CALVING HERDS

the end of October. In contrast, fall calving cows were bred in January, calved in October and relied heavily on supplemental winter forage in addition to spring and early summer pastures while lactating through June. Likewise, late spring, summer and early fall pastures were available for spring-born calves, while fall-born calves had little available grazing in winter months, but improved grazing conditions in spring and early summer. Heifers retained in each calving system also had unique grazing periods.

Cow herds in each system were culled annually at weaning (spring herd-October; fall herd-June). The annual 17 percent culling rate included nonpregnant cows, dry cows or cows which had reached the end of their economic life. Heifer calves saved at weaning were bred at 15 months of age. After breeding, heifers were pregnancy checked and 15 percent (or 3 percent of cow numbers) were sold as nonbreeders. Replacement heifers calved as two-year olds. Bulls were purchased at two-years of age and sold after they reached eight.

Labor requirements by month for fall and spring calving herds are shown in Table III-8. Requirements indicate the number of hours needed in each month for herd observation and performance of managerial tasks. Labor needs varied throughout the year with the production cycle of each herd and seasonal management priorities.

Forage and Cattle Financial Requirements

Estimated expenses incurred with the forage and calving systems were developed using procedures described in the Oklahoma State budget generator (Kletke 1979). Production data and prices were specified to reflect 1988 production practices and costs. These expenses,

TABLE III-8

PER HEAD¹ LABOR REQUIREMENTS BY MONTH FOR FEEDER CALF PRODUCTION
IN SPRING AND FALL CALVING HERDS

Month	Spring Herd	Fall Herd
----- hours per head ² -----		
January	1.00	1.10
February	1.25	0.90
March	0.90	0.50
April	0.65	0.65
May	0.85	0.50
June	0.60	1.10
July	0.60	0.75
August	0.60	0.60
September	0.65	0.75
October	1.00	1.00
November	0.65	0.75
December	0.75	0.90
Total	9.50	9.50

¹ Per head requirements were for a cow-calf unit comprised of 1.0 cows, 0.88 calves, 0.2 weaned heifers, 0.17 replacement heifers and 0.04 bulls.

² Requirements were developed using 0.50 hours per head as the minimum amount of labor needed each month for herd observation. Labor needed above this minimum was for additional observation and routine management of the beef herd as follows:

calving--1.00 hr/hd: 0.25 in month prior to calving
0.50 in month of calving
0.25 in month preceeding calving

breeding--0.35 hr/hd

wintering--0.25 hr/hd

calf marketing--0.35 hr/hd

vaccinations, pregnancy check and castration--0.15 hr/hd

parasite control (summer)--0.10 hr/hd

Source: Synthesized from Williams (1976) and Taylor (1984).

therefore, represent expected costs incurred as the planning horizon begins. Since prices and costs are dynamic variables in the simulation analysis, these parameters changed from year-to-year according to the assumed economic conditions.

Per acre expenses for each forage system are summarized in Table III-9. Specific input expenses and use rates for the forage systems and hay production are shown in Appendix Tables 1 through 4. Sources for the production data and costs used in the expense budgets were Johnson (1987b.), Halbrook et al. (1986), and the Tennessee Agricultural Statistics Service 1988.

Per acre expenses for the perennial grass species, tall fescue and bermudagrass/tall fescue, were divided into those expenses incurred during establishment, and those for annual maintenance. Annual expenses were higher for the bermudagrass/tall fescue system than the tall fescue system. The higher expenses resulted from greater establishment costs and more nitrogen applied each year for bermudagrass. Expenses attributed to the renovation of grass pastures included those incurred during renovation and annual maintenance. Renovation and higher annual maintenance charges for the grass-legume systems caused total annual expenses to be much greater than in the grass systems. Per acre expenses associated with harvesting and feeding hay were identical at both cuttings, June and September.

Per cow expenses for beef cow-calf production are presented in Table III-10. Expenses are for both spring and fall calving systems since little difference existed between the two for the listed items. Pasture and hay requirements and costs were omitted due to their variation with forage and calving system.

TABLE III-9

PER ACRE EXPENSES SUMMARY FOR ALTERNATIVE FORAGE SYSTEMS,
UPLAND SOILS, WEST TENNESSEE, 1988

Item	Tall Fescue	Bermudagrass/ Tall Fescue	Tall Fescue + Legumes	Bermudagrass/ Tall Fescue + Legumes
Establishment Expenses				
Total	121.05	176.38	121.05	176.38
Prorated over ten years	12.11	17.64	12.11	17.64
Rennovation Expenses				
Total	- ¹	-	67.79	67.79
Prorated over five years	-	-	13.56	13.56
Annual Expenses				
Variable	29.86	36.46	43.76	43.76
Fixed ²	21.10	26.63	39.06	44.59
Total	50.96	63.09	82.82	88.35
Hay Harvesting and Feeding ³				
Variable	15.76	15.76	15.76	15.76
Fixed	36.62	36.62	36.62	36.62
Total	52.38	52.38	52.38	52.38

¹Dashes indicate system not rennovated with legumes.

²Annual fixed expenses include prorated establishment and rennovation expenses, and fixed machinery expenses.

³Expenses are identical for first and second cutting hay.

TABLE III-10

ESTIMATED BEEF COW-CALF EXPENSES PER COW,
100 COW UNIT, WEST TENNESSEE, 1988

Item	Weight Each	Unit	Unit Cost	Quantity	Total Cost
Variable Expenses					
Feed ¹					
Pasture		AC	--	--	0.00
Hay		TON	--	--	0.00
Salt & Mineral ²		COW	4.42	1.00	4.42
Vet & Medicine ³		COW	13.12	1.00	13.12
Marketing ⁴		COW	6.15	1.00	6.15
Herd Bulls	8.0	CWT	100.00	0.01	8.00
Machinery		COW	11.44	1.00	11.44
Equipment		COW	1.02	1.00	1.02
Total Variable Expenses					44.15
Fixed Expenses					
Machinery		COW	24.86	1.00	24.86
Equipment		COW	9.06	1.00	9.06
Livestock		COW	70.98	1.00	70.98
Total Fixed Expenses					104.90

¹ Pasture and hay prices and quantities vary by forage and calving systems and, thus, are not included in this budget.

² Assumes 1 ounce per head per day of a salt-dicalcium phosphate mineral mixture at a cost of \$0.01 per ounce.

³ Costs consist of four-way Clostridia (Blackleg, etc.) vaccination, five-way Leptospirosis vaccination, vaccination of replacement heifers for bangs, pregnancy check, grub and lice control, face fly control and internal parasite control.

⁴ Auction charge of \$7.50 per head sold.

Experimental Design and Analytical Techniques

Production and economic characteristics of a West Tennessee cow-calf operation utilizing each production alternative were examined. The representative cattle operation was simulated recursively over a ten-year planning horizon for 100 iterations for each alternative. Assumptions outlined in this chapter, as well as others specified in Chapter IV, were constant across evaluated alternatives. The planning horizon included the period of 1989 through 1998. After each of the 100 iterations, the cattle operation was reinitialized to the 1989 financial, environmental and production base situation of the alternative under analysis. A new set of stochastic parameters were then developed for the planning span of each iteration. These procedures provided an experimental laboratory with which to evaluate the performance of the cattle operation in the risky environment.

Because the simulation model replicated the multiple-year planning horizon a large number of times, several summary statistics were developed. To facilitate a comparison of the production alternatives under evaluation, summary statistics for the cattle operation under each strategy were grouped into three categories; forage and cattle physical performance variables, and budgetary performance variables. Means, standard deviations, minimums and maximums were summarized for variables in each category. Forage variables included annual yield, quality, and hay production and management variables. Summarized cattle variables were annual herd size, number of steer and heifer calves sold, animal weights and cow milk production. Budgetary variables chosen for comparison included

annual prices paid and received, gross receipts, operating and fixed expenses, and net incomes above specified costs.

Another summary statistic chosen to compare the production alternatives was the cumulative probability distribution (CPD) of specified performance variables. The CPD of a variable is a convenient statistic for determining the probability of obtaining specific levels of the variable. In this study, CPDs were developed for per acre forage yield, calf weaning weight and after-tax net present value of income variables, and compared for each production alternative. Finally, after-tax net present value of income CPDs were ranked according to the criterion of stochastic dominance with respect to a function. This procedure permitted a ranking of alternatives by expected returns and riskiness for producers who are risk adverse, risk neutral and risk loving.

CHAPTER IV

MODEL DEVELOPMENT AND PARAMETER SPECIFICATION

The purpose of this chapter is to specify model structure and components used to analyze the forage-beef production alternatives. Model structure is designed to be consistent with the biological and economic nature of forage-beef production, and the decision process used by cattle producers. Once the general model structure is specified, operational characteristics of the component parts are identified.

Model Structure

Each production alternative was evaluated in terms of its impact on the financial performance of the cattle operation using a bio-economic simulation model which is dynamic, stochastic and recursive. The simulation model determined physical and financial performance of the cattle operation over a ten-year planning horizon. To illustrate and explain model structure and operation, six component parts were specified; namely, forage, cattle, managerial, and budgetary operational components, and climatic, and price and cost input components. Interactions and feedbacks among these components gave the simulator its operating structure. Operation of the model involved monthly periods during which accumulated forage and cattle variables were evaluated and used to determine management decisions made in each month. Since much attention was given to describing the detailed production, managerial and economic characteristics of the

forage-beef system, the simulation model was named COMFABS (a COMprehensive Forage And Beef Simulator). Organization of COMFABS, parameters developed by each component, and relationships and feedbacks among components are illustrated in Figure VI-1.

The climatic component specified stochastic environmental conditions each month. Climatic variables were used in the forage component to describe the resultant forage yield and quality. The managerial component was divided into two parts. Long-term decisions, including stocking rate, grazing and hay acreage specifications, were set according to normal environmental conditions. In the short-term, adjustments were made as changes in environmental conditions warranted. The resulting monthly ration fed cattle was passed to the cattle component for performance and weight determination. Cattle and forage variables were used in the price and cost component, and stochastic cattle and hay prices were assigned. Ultimately, financial performance variables were summarized and evaluated in the budgetary component.

This simulation cycle was repeated for each year of the ten-year planning horizon. Afterward, a report of system variables was prepared and the model proceeded to the next planning horizon (or iteration). Once the planning horizon had been simulated 100 times for a production alternative, means, variances and probability statistics were summarized. The entire procedure was then repeated for each of the eight alternatives under examination.

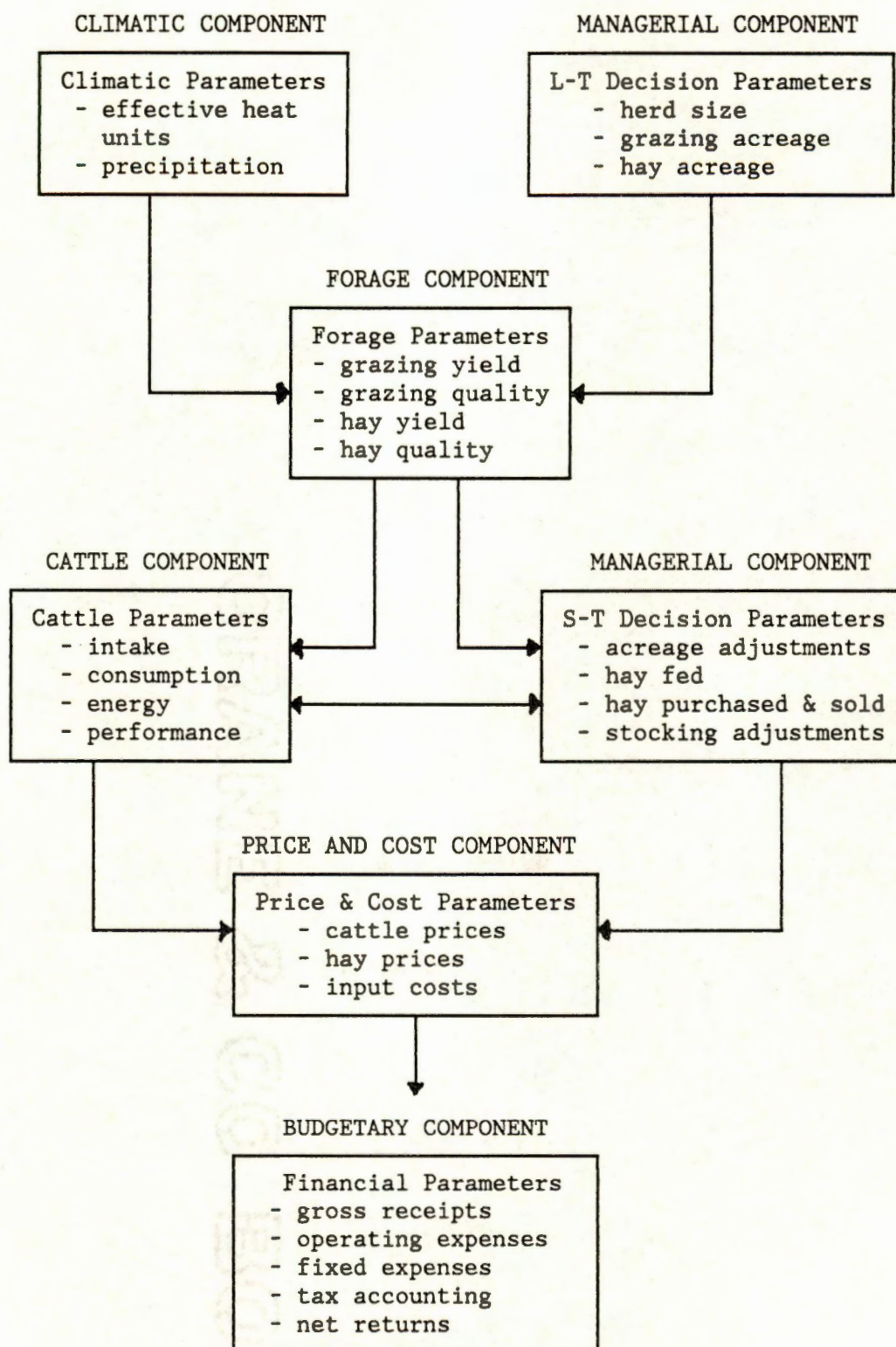


FIGURE IV-1

SCHEMATIC OF THE COMPREHENSIVE FORAGE AND BEEF SIMULATOR (COMFABS)

Development of COMFABS

Development of the simulation model, COMFABS, involved a series of steps. First, the forage-beef system was separated into the primary components. Critical variables of each component were identified and coordinated to describe the characteristics and operation of the component. Finally, interactions among the components were specified by expressing the important relationships and feedbacks among components.

The Climatic Component

Weather variability induces a significant amount of uncertainty in pasture forage yields. Because irrigated pastures are virtually nonexistent in the West Tennessee area, livestock producers rely upon climatic conditions for the amount and quality of forage available to produce cattle. Monthly temperature and precipitation were deemed as most crucial in developing production relationships.

Forage species are quite specific in their response to temperature. Therefore, a measure of temperature in terms of ranges tolerated by each species was determined as being valuable in assessing forage productivity. Owens and Moore (1974) used a variety of heat-unit models for predicting the number of days required from seeding to six stages of growth for tomatoes. Their most precise method of determining rate of maturity can be generalized with the following formulation:

$$(IV.1) \quad EHU = [(T+t/2) - (T-MAXT)] - MINT$$

where:

EHU = effective heat units, °days
 T = maximum daily temperature, °F
 t = minimum daily temperature, °F
 MAXT = "maximum" base temperature above which temperatures do not
 contribute to plant growth, °F
 MINT = "minimum" base temperature below which plant growth is
 minimal, °F

Because growth of cool and warm season forage species is influenced by
 temperature fluctuations, this procedure was adapted for this study.
 Specification of the base temperatures, "maximum" and "minimum", for
 each forage species are shown in Table IV-1. These temperatures were
 derived through consultation with Dr. H. Fribourg (1988b.), along with
 temperatures reported by Buckner (1985); Burton and Hanna (1985);
 Taylor (1985); and Hoveland and Donnelly (1985).

TABLE IV-1

BASE TEMPERATURES USED TO CALCULATE EFFECTIVE HEAT UNITS
 FOR EACH FORAGE

Forage Species	Maximum ¹	Minimum ²
	----- °F -----	-----
Tall Fescue	90	50
Bermudagrass/Tall Fescue	100	50
Bermudagrass	100	65
Red Clover	90	50
Annual Lespedeza	90	60

¹Maximum temperature above which forage growth is minimal.

²Minimum temperature below which forage growth is minimal.

Monthly precipitation and temperature data were obtained from the
 National Oceanic and Atmospheric Administration, Brownsville Weather
 Station for the years 1951 through 1987. The past thirty-seven years
 were assumed to provide a valid representation of precipitation and

temperature distributions which could occur over the planning horizon. To generate stochastically possible sequences of monthly climatic data, multivariate empirical probability density functions (pdf's) were developed for monthly precipitation, and maximum and minimum temperatures. A process for obtaining correlated random normal deviates, discussed by Clements et al. (1971), and Richardson and Condra (1978), was used to select climatic variables from the empirical pdf's. This method works well for maintaining the correlation between months within a year.

Means, standard deviations and ranges are given in Table IV-2 for the historical and the generated climatic variables simulated over the ten-year span for 100 iterations. Ranges are identical since the simulated data were distributed empirically, with remaining statistics coinciding closely with the historical data.

The Forage Component

The simulated climatic variables were used to determine forage yield and quality each month. Forage production in a month is not solely related to climatic conditions in that month. Rather, climatic effects on forage productivity are cumulative in nature. This relationship, therefore, was specified by relating forage yield accumulated through each month to accumulated climatic variables, using January 1st as the beginning of each forage production year.

Forage Yield Estimation. The relationship between accumulated forage yield (lbs. dry matter per acre) and accumulated climatic variables was estimated using experimental data obtained from the Ames

TABLE IV-2

SELECTED STATISTICS FOR THE ACTUAL AND SIMULATED
MONTHLY PRECIPITATION AND TEMPERATURE LEVELS

Month	Mean		Standard Deviation		Minimum ¹	Maximum
	Actual	Simulated	Actual	Simulated		
Precipitation	----- inches -----					
January	4.25	4.27	2.79	2.83	0.61	11.49
February	4.39	4.46	2.30	2.37	1.20	10.67
March	5.22	5.27	2.53	2.61	0.64	12.18
April	5.56	5.64	2.40	2.43	1.25	10.55
May	5.35	5.54	3.28	3.52	0.67	18.01
June	3.52	3.68	1.82	1.89	0.53	8.09
July	4.08	4.05	2.23	2.21	0.25	9.22
August	3.02	3.00	2.39	2.46	0.05	10.42
September	3.57	3.65	2.03	2.04	0.00	7.67
October	2.67	2.73	1.71	1.72	0.00	7.54
November	4.49	4.60	2.46	2.58	1.14	11.06
December	4.94	4.97	3.07	3.15	0.53	13.23
Maximum Temperature	----- °F -----					
January	47.49	47.26	5.50	5.66	33.48	55.65
February	52.86	52.74	5.47	5.71	37.57	61.48
March	62.00	61.95	4.97	5.17	49.35	71.26
April	73.14	73.12	3.66	3.59	63.40	78.33
May	81.09	81.05	3.32	3.44	74.13	90.06
June	88.47	88.30	2.53	2.61	83.40	95.15
July	91.50	91.51	2.40	2.55	86.42	97.97
August	90.69	90.76	2.98	3.13	85.58	98.67
September	84.93	84.97	3.58	3.81	76.93	93.00
October	74.97	74.86	3.67	3.69	68.06	85.81
November	62.00	61.84	3.36	3.37	52.87	67.60
December	51.83	51.69	4.33	4.58	39.26	59.90
Minimum Temperature	----- °F -----					
January	28.25	28.00	5.34	5.39	16.10	38.42
February	32.18	32.12	4.69	4.92	20.32	39.96
March	40.37	40.42	3.95	4.07	29.35	48.06
April	50.18	50.19	2.97	2.92	43.73	55.80
May	58.50	58.40	2.91	3.02	52.48	63.90
June	66.14	66.05	2.40	2.41	61.13	72.93
July	69.74	69.75	1.80	1.92	66.29	73.71
August	67.82	67.69	2.02	2.13	63.45	71.37
September	60.88	61.04	2.83	2.85	56.00	66.37
October	48.71	48.58	3.74	3.92	41.77	57.65
November	39.73	39.78	3.31	3.32	30.67	47.03
December	32.47	32.31	4.54	4.61	23.03	41.32

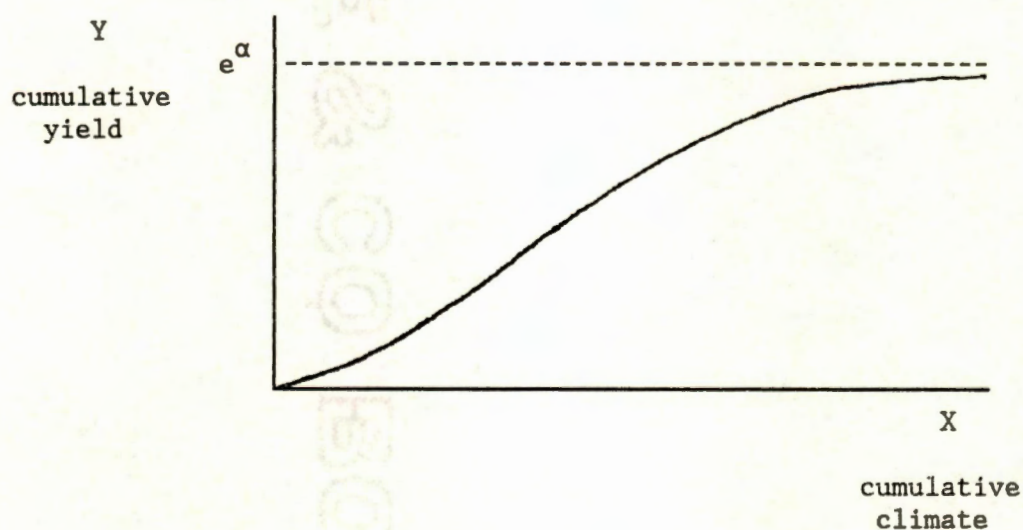
¹Maximums and minimums are identical for the actual and simulated data.

Plantation Experiment Station in Southwest Tennessee. Forage data were collected from experimental plots of tall fescue, bermudagrass/tall fescue, bermudagrass, red clover and annual lespedesa, maintained through the four years of 1980-1983. Experimental design included plots on six soils; Lexington, Grenada, Memphis, Loring, Calloway and Henry, with three replications for each forage (Fribourg 1988a.). Growth on each plot was cut, bagged and weighed at various times during each year. Forage production was measured as that accumulated from last collection. Forage yield variables were measured as the cumulative annual yield to each cutting date. Climatic variables, also measured at the Ames Plantation, were used to relate forage yield response to environmental conditions. Cumulative climatic variables were measured as the amounts of annual precipitation and effective heat units accumulated to each cutting date. Ordinary least-squares was used to estimate the growth-climate relationship of each forage evaluated in this study.

Two functional forms were used to specify the equations. A log-reciprocal form (Figure VI-2, a.) was specified for the tall fescue, bermudagrass/tall fescue and red clover equations. This form was chosen because of inherent properties which characterize the forage-climate relationship of these forages. Firstly, this form is restricted to emanate from the origin. Thus, at the beginning of the year, climatic variables have yet to accumulate and forage production is nil. Secondly, the shape exhibited by this function generally follows that of accumulated forage growth. Annual growth begins slowly in late winter months, becomes rapid during the spring and early summer, and tapers as the year progresses.

- a. Functional form used in the Tall Fescue, Bermduagrass/Tall Fescue and Red Clover Equations.

Log-Reciprocal Form: $\ln Y = \alpha + \beta (1/X)$



- b. Functional form used in the Bermudagrass and Annual Lespedesa Equations.

Reciprocal Form: $Y = \alpha + \beta (1/X)$

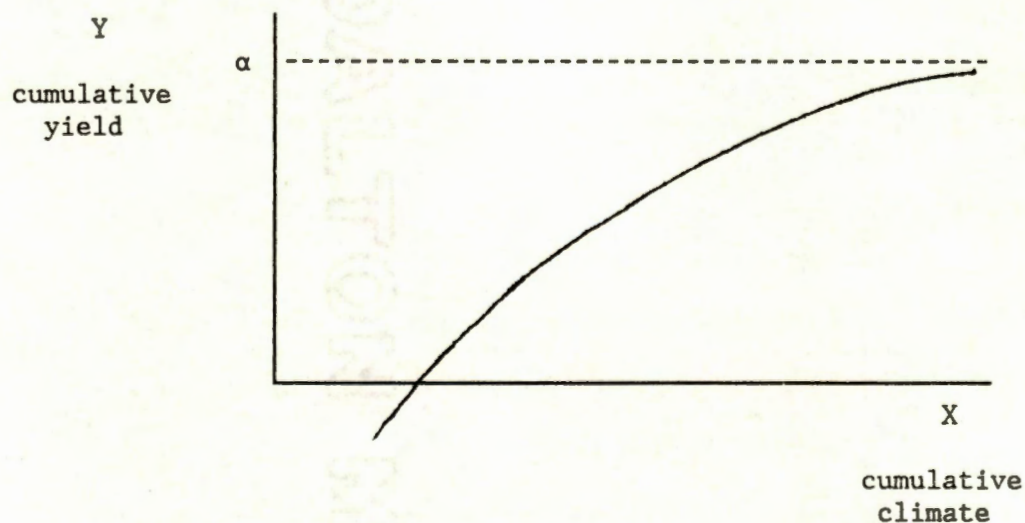


FIGURE IV-2

FUNCTIONAL FORMS USED TO ESTIMATE THE FORAGE-CLIMATE RELATIONSHIPS

A reciprocal form (Figure IV-2, b.) was specified for the bermudagrass and annual lespedesa equations. An important consideration for this form was the warm-season nature of these species. Consequently, forage growth does not initiate until the warmer conditions of April and May are encountered. With this form the onset of annual production was indicated by accumulated climatic conditions. Both the log-reciprocal and reciprocal forms approach a maximum. One would expect that a biological maximum exists for each forage species, albeit unknown.

The forage yield equations used in this study, along with their accompanying statistics are shown in Table IV-3. The equations relate accumulated forage yield (lbs. dry matter per acre) to accumulated climatic variables at common days during each year. In all equations effective heat units were significant at the 95-percent level with correct sign. Negative estimates resulted from the reciprocal specification of these variables. Precipitation variables were specified as interaction terms with the discrete soil variables. Accumulated precipitation was highly correlated with the heat unit variables. Thus, the climate-soil specification reduced the impacts of the inherent collinearity, while including the explanatory power of yield variation due to the moisture retaining capability of each soil. The Calloway soil was deleted in each equation. Parameter estimates, therefore, measure yield difference between the Calloway-precipitation interaction and the other soil-precipitation interactions.

Year effects were also included as discrete variables (YR2 & RYRS) in each equation. The establishment year was deleted to examine patterns of forage growth in post-establishment years. Thus, parame-

TABLE IV-3
FORAGE YIELD ORDINARY LEAST-SQUARES EQUATIONS¹
FOR EACH FORAGE

Tall Fescue

$$\begin{aligned} \text{TFY} = & 9.30^{(2)} - 8041.54 \text{ TFHU} - 10392.37 \text{ PXLEX}^{(3)} - 507.29 \text{ PXGREN} \\ & (117.7)** \quad (-30.8)** \quad (-8.2)** \quad (-0.4) \\ & - 5234.29 \text{ PXMEM} - 3778.53 \text{ PXLOR} + 12103.29 \text{ PXHEN} + 0.50 \text{ YR2} \\ & (-4.9)** \quad (-3.1)** \quad (7.9)** \quad (7.2)** \\ & + 0.15 \text{ RYRS} + \epsilon \\ & (2.1)** \end{aligned}$$

$$R^2 = 0.84 \quad \text{STD DEV} = 0.54 \quad N = 525$$

Bermdagrass/Tall Fescue

$$\begin{aligned} \text{BFY} = & 8.55 - 11479.73 \text{ BFHU} - 4840.32 \text{ PXLEX} - 1063.42 \text{ PXGREN} \\ & (66.6)** \quad (-21.3)** \quad (-2.4)** \quad (-0.5) \\ & - 2122.26 \text{ PXMEM} - 2501.12 \text{ PXLOR} + 10334.95 \text{ PXHEN} + 1.58 \text{ YR2} \\ & (-1.2) \quad (-1.2) \quad (4.8)** \quad (9.5)** \\ & + 1.05 \text{ RYRS} + \epsilon \\ & (8.2)** \end{aligned}$$

$$R^2 = 0.77 \quad \text{STD DEV} = 0.69 \quad N = 393$$

Bermudagrass

$$\begin{aligned} \text{BGY} = & 8860.78 - 36948317.36 \text{ BGHU} + 10227552.97 \text{ PXLEX} \\ & (15.6)** \quad (-13.7)** \quad (0.96) \\ & + 30798082.40 \text{ PXGREN} + 14914250.79 \text{ PXMEM} + 16101885.06 \text{ PXLOR} \\ & (2.8)** \quad (1.4) \quad (1.3) \\ & + 88282003.22 \text{ PXHEN} + 3941.96 \text{ YR2} + 2806.90 \text{ RYRS} + \epsilon \\ & (5.5)** \quad (8.8)** \quad (8.8)** \end{aligned}$$

$$R^2 = 0.62 \quad \text{STD DEV} = 1606.49 \quad N = 232$$

TABLE IV-3 (continued)

Red Clover

$$\begin{aligned}
 \text{RCY} = & 9.91 - 8908.17 \text{ RCHU} + 12876.98 \text{ PXLEX} - 6265.05 \text{ PXGREN} \\
 & (54.0)** \quad (-9.4)** \quad (3.7)** \quad (-1.8)* \\
 & + 10645.95 \text{ PXMEM} + 6842.88 \text{ PXLOR} - 5238.16 \text{ PXHEN} - 0.46 \text{ YR2} \\
 & (3.8)** \quad (2.0)** \quad (-1.2) \quad (-4.1)** \\
 & - 0.27 \text{ RYRS} + \epsilon \\
 & (-3.6)**
 \end{aligned}$$

$$R^2 = 0.45 \quad \text{STD DEV} = 0.45 \quad N = 200$$

Annual Lespedeza

$$\begin{aligned}
 \text{ALY} = & 4764.38 - 10616940.62 \text{ ALHU} - 13532223.18 \text{ PXLEX} \\
 & (5.7)** \quad (-3.5)** \quad (-1.4) \\
 & - 771242.44 \text{ PXGREN} + 8614334.43 \text{ PXMEM} - 6534809.24 \text{ PXLOR} \\
 & (-0.1) \quad (1.0) \quad (-0.6) \\
 & + 14411959.84 \text{ PXHEN} + 1484.70 \text{ YR2} + 813.36 \text{ RYRS} + \epsilon \\
 & (1.2) \quad (3.8) \quad (3.8)**
 \end{aligned}$$

$$R^2 = 0.45 \quad \text{STD DEV} = 915.97 \quad N = 123$$

¹ A log-reciprocal form was fitted for the tall fescue, bermudagrass/tall fescue and red clover equations, while a reciprocal form was fitted for the bermudagrass and annual lespedesa equations.

² t-values for each parameter are in parenthesis below parameter estimates.

³ Accumulated precipitation was specified as an interaction term with soil dummy variables (0,1). Thus the values of interaction terms are determined by accumulated precipitation times, 1 if soil type, 0 otherwise.

*Significant at the 90 percent level.

**Significant at the 95 percent level.

where:

STD DEV = standard deviation

N = number of observations

TFY = log of accumulated tall fescue yield (lbs. DM per acre)

BFY = log of accumulated bermudagrass/tall fescue yield (lbs. DM per acre)

BGY = accumulated bermudagrass yield (lbs. DM per acre)

RCY = log of accumulated red clover yield (lbs. DM per acre)

TABLE IV-3 (continued)

ALY = accumulated annual lespedesa yield (lbs. DM per acre)
TFHU = reciprocal of accumulated tall fescue heat units ($^{\circ}$ days)
BFHU = reciprocal of accumulated bermudagrass/tall fescue heat units ($^{\circ}$ days)
BGHU = reciprocal of accumulated bermudagrass heat units ($^{\circ}$ days)
RCHU = reciprocal of accumulated red clover heat units ($^{\circ}$ days)
ALHU = reciprocal of accumulated annual lespedesa heat units ($^{\circ}$ days)
PXLEX = reciprocal interaction between accumulated precipitation (hundreds of inches) and the Lexington soil series
PXGREN = reciprocal interaction between accumulated precipitation (hundreds of inches) and the Grenada soil series
PXMEM = reciprocal interaction between accumulated precipitation (hundreds of inches) and the Memphis soil series
PXLOR = reciprocal interaction between accumulated precipitation (hundreds of inches) and the Loring soil series
PXHEN = reciprocal interaction between accumulated precipitation (hundreds of inches) and the Henry soil series
YR2 = year following establishment (1981)
RYRS = years following second year (1982 & 1983)
 ϵ = residual error term

ter estimates indicate yield differences associated with time from establishment. In all equations year variables were significant at the 95-percent level. For each perennial grass forage (tall fescue, bermudagrass/tall fescue and bermudagrass) prominent year effects were observed. Forage production was lowest in the establishment year, followed by highest production in year two. After year two, average production diminished. This pattern¹ also prevailed in the lespedesa equation. Lespedesa was reseeded annually so that year effects are likely due to volunteer seeding from year-to-year. Unlike the other forages, red clover exhibited a decline in yield from the establishment year. This observation concurs with the biennial nature of red clover. In year three red clover was overseeded, accounting for the rise in average yield for years three and four. Unfortunately, more years of data were unavailable so that persistence of forages could not be fully specified over their useful life.

Each acre of land on the cattle operation included a fixed percentage of soils (refer to Table III-1). Further, the land resource was divided into ten tracts of twenty acres. Monthly yields were projected for each forage-soil-year combination. Per acre yields were calculated using the assigned percentage of soils on each acre. Next, tracts were assigned a specific year according to assumed date of establishment, renovation and reseeding. For example, the tall fescue system consisted of twenty acres in establishment, twenty acres

¹one might suspect that the observed year effects were due to annual climatic differences. Climatic conditions, however, were poorest in year two (1981), coinciding with greatest annual forage growth as indicated by the year effects.

in year two, and other acreage (160 acres) in the remaining years. Finally, per acre yield estimates were specified for each tract according to its assumed year of productive life.

Limited data and restrictions imposed by the functional form specified in each equation resulted in monthly yield estimates that were contradictory, in some months, to general contention. Production data on several forages were unavailable for much of the winter season, and oftentimes were not collected at regular intervals during the grazing season. Rigidity in functional form precluded estimates exhibiting typical forage production peaks and slumps, such as the summer slump exhibited by tall fescue. Consequently, procedures were developed to circumvent these shortcomings. First, yield estimates were aggregated into three-month intervals, or seasons, beginning January 1st. Monthly yields within each season were specified using secondary data on the annual production distribution of forages in Tennessee (Fribourg 1983, Appendix Table 5). Seasonal estimates were disaggregated into monthly yields according to the percentage of seasonal yield that normally occurs in each month. Thus monthly yields within a season exhibit production patterns which typically characterize the season. Seasonal yield differences, however, are the consequence of climatic variability.

Finally, yield estimates were needed for the grass-legume mixtures. Unfortunately, yield measurements were unavailable for legumes growing with the grass species. Monthly yield estimates for the grass and legume forages were therefore combined. The relative yield of

grass and legume forages was used to estimate monthly production for the grass-legume systems. Relative yields were specified in each month with the equation:

$$(IV.2) \quad G-LY = (\%G)(GY) + (\%L)(LY)$$

with:

$$(IV.3) \quad LY = (\%RC)(RCY) + (\%AL)(ALY)$$

where:

G-LY = monthly grass/legume yield
 GY = monthly grass yield
 LY = monthly legume yield
 RCY = monthly red clover yield
 ALY = monthly lespedesa yield
 %G = percent grass yield of total yield
 %L = percent legume yield of total yield
 %RC = percent red clover yield of total legume yield
 %AL = percent lespedesa yield of total legume yield

Percentages of grass and legumes (%G & %L) were determined from the proportion each comprised of their sum. Due to the competition among forages for plant nutrients, monthly limits were placed on the percentages of grass and legumes in the mixture. Secondary data (Fribourg 1988b., Appendix Table 6) were used to specify monthly ranges of occurrence for legumes growing in the grass pastures. Specification of the monthly percentage of legumes in the grass-legume mixtures was as follows. If the monthly legume occurrence estimated by the relative yields was within the monthly bounds, this percentage was used as that of legumes in the mix. Else if the upper bound was exceeded, the upper bound was used as %L in equation IV.2. Likewise, the lower bound was used if estimated legume occurrence was below the range. Once these monthly percentages were specified, equations IV.2

& 3 were used to estimate grass-legume yields in each month. This procedure considers competition among forages in a narrow sense, and assumes cattlemen can manage pastures to obtain forage composition within these ranges. It does, however, provide a method of specifying the dynamic nature of forage composition, given the limited data available for this study.

Monthly grazing and hay yields for each forage system simulated under normal climatic conditions are shown in Table IV-4. Per acre yields are presented for both grazing and hay production. Grazing yields included a 10-percent loss in forage due to cattle damage of the pasture stand while grazing. Two cuttings of hay were possible in each year. Hay yields included forage accumulated during each season designated for hay production and were specified for the months in which hay would be harvested. A 10 percent yield loss was assumed for hay harvesting (Fribourg 1988b.).

Forage Quality Estimation. Both forage yield and quality in each month were needed to determine cattle production parameters. Since the forage data did not include measurements of quality, secondary data were employed to specify quality (percent total digestible nutrients) of the forages in each month (Appendix Table 7). Stage of maturity and length between grazings (or cuttings) were deemed most critical in developing forage quality parameters. Thus, quality was estimated in each month for grazing and in each of the two hay production seasons. Monthly quality estimates were generated using grazing and hay estimates for forages in different stages of maturity (National Academy of Sciences), along with expert consultation (Fribourg 1988b.).

TABLE IV-4

MONTHLY FORAGE YIELD SIMULATED UNDER NORMAL CLIMATIC CONDITIONS
FOR GRAZING AND HAY PRODUCTION IN EACH FORAGE SYSTEM

Month	Tall Fescue	Bermudagrass/ Tall Fescue	Tall Fescue + Legumes	Bermudagrass/ Tall Fescue + Legumes
----- pounds of dry matter per acre ¹ -----				
Grazing Yield				
January	23.74	23.54	27.56	27.56
February	85.45	84.74	91.23	91.25
March	365.53	362.51	449.26	450.91
April	689.48	518.89	819.62	750.99
May	614.94	730.28	630.19	715.27
June	559.04	672.63	615.47	695.92
July	476.84	646.08	692.13	811.07
August	460.40	593.69	473.85	583.13
September	707.05	506.39	696.24	562.64
October	717.05	875.16	777.04	891.00
November	432.70	391.86	410.16	388.58
December	86.54	169.81	93.32	141.46
Total	5218.76	5575.56	5776.07	6109.78
Hay Yield ²				
June	1863.47	1921.80	2065.28	2162.18
September	1647.54	1746.15	1862.22	1956.84
Total	3511.01	3667.95	3927.50	4119.02

¹ Average monthly yield across all tracts of land. Yield figures include a 10 percent loss in forage due to grazing.

² Hay yield is specified for the two months in which hay is harvested (1st cutting-June; 2nd cutting-September). Hay yields were reduced 10 percent for losses at harvesting (Fribourg 1988b.).

Qualities of grass-legume mixtures and the bermudagrass/tall fescue mixture were specified using the relative yields of each species, as were yield estimates of grass-legume forages. Once the monthly percentage of each forage species in the mixture was determined, forage quality was the weighted average quality of each species². The monthly ranges of occurrence for bermudagrass growing with tall fescue, as well as legumes with the grass systems, are presented in Appendix Table 6. These ranges were used as before to specify the monthly percent of bermudagrass in the bermudagrass/tall fescue mix, and ultimately the monthly quality of this system³. Monthly grazing and hay forage quality simulated under normal climatic conditions for each forage system are presented in Table IV-5.

Hay Inventory. Hay production in each system was added to a monthly inventory maintained on the operation. Beginning and ending hay inventory were determined each month after additions or deductions were made. First and second cutting hay were added to inventory at the end of June and September, respectively. The amount of inventory beginning each month was that available for feeding or sale during the month. Decision parameters, described in the next section, specified how the hay inventory was managed.

²Replacing yield variables with quality variables in equations IV.2 & 3, the quality of grass/legume mixtures was developed using the percentage of each forage determined earlier.

³Quality of the bermudagrass/tall fescue forage was determined using the bermudagrass and tall fescue quality variables in equation IV.2 along with the monthly percent of each species specified by the relative yield and monthly range of occurrence.

TABLE IV-5

MONTHLY FORAGE QUALITY SIMULATED UNDER NORMAL CLIMATIC CONDITIONS
FOR GRAZING AND HAY PRODUCTION IN EACH FORAGE SYSTEM

Month	Tall Fescue	Bermudagrass/ Tall Fescue	Tall Fescue + Legumes	Bermudagrass/ Tall Fescue + Legumes
----- percent total digestable nutrients ¹ -----				
Grazing Quality				
January	35.00	35.00	41.00	41.00
February	40.00	40.00	44.00	44.00
March	68.00	68.00	68.99	68.95
April	65.00	64.80	67.45	67.39
May	62.00	62.35	63.05	63.28
June	57.00	57.00	58.56	58.55
July	52.00	52.00	53.89	53.90
August	52.00	50.72	53.34	52.35
September	60.00	55.00	59.70	56.24
October	60.00	55.39	59.91	56.91
November	55.00	52.00	55.00	53.05
December	48.00	48.00	48.80	48.75
Hay Quality ²				
June	60.00	59.35	61.10	60.33
September	55.00	52.05	55.26	52.95

¹ Average monthly quality across all tracts of land.

² Hay quality is specified for the two months in which hay is harvested (1st cutting-June; 2nd cutting-September).

The Managerial Component

The function of managerial parameters was to describe the decision process and decisions made by cattle producers to control the forage-beef system. Two sets of decisions characterized the decision making process. Long-term decisions described the plan formulated by cattlemen to manage the operation under each system for the ten-year span. Such decisions included long-term stocking level and annual grazing and hay management. These plans were formulated for each system under normal, or expected, environmental conditions. In the short-term, climatic conditions fluctuate. Consequently, cattlemen must revise plans. Short-term decisions described how cattlemen responded to the changing environment. These decisions included necessary adjustments in grazing and hay management, hay feeding, hay purchase and sale, and ultimately stocking level if necessary.

Long-Term Decisions. A linear programming model was used to formulate long-term plans for each production alternative. The LP model was specified with a profit maximizing objective constrained by the resource availability, the necessity to balance forage production and animal requirements, and animal intake capacity. In matrix notation the model is expressed as follows: Find vectors $X_1 \dots X_6$ which maximize:

$$(IV.4) \quad \pi = \begin{bmatrix} c_1 & c_2 & c_3 & c_4 & c_5 & c_6 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \end{bmatrix}$$

subject to

(IV.5)

$$\begin{bmatrix}
 A_{11} & & & & & & \\
 A_{21} & A_{22} & A_{23} & & & & \\
 & A_{42} & A_{33} & A_{35} & & & \\
 & A_{52} & A_{44} & A_{45} & & & \\
 & & A_{54} & A_{55} & & & \\
 & & A_{63} & & & & \\
 A_{71} & & & A_{74} & A_{75} & A_{76} &
 \end{bmatrix}
 \begin{bmatrix}
 X_1 \\
 X_2 \\
 X_3 \\
 X_4 \\
 X_5 \\
 X_6
 \end{bmatrix}
 < =
 \begin{bmatrix}
 B_1 \\
 B_2 \\
 B_3 \\
 B_4 \\
 B_5 \\
 B_6 \\
 B_7
 \end{bmatrix}$$

$$X_i \geq 0 \quad (i = 1, \dots, 6)$$

where

π = annual profit

C_1 = vector of annual pasture production costs

C_2 and $C_5 = 0$

C_3 = vector of hay production costs

C_4 = vector of net returns from cattle production

C_6 = vector of purchased labor costs

X_1 = vector of pasture production activities (acres)

X_2 = vector of pasture consumption activities (head)

X_3 = vector of hay production activities (acres)

X_4 = vector of cattle production activities (head)

X_5 = vector of hay consumption activities (head)

X_6 = vector of purchased labor activities (hours)

A_{11} = matrix of land restrictions for each tract of land

A_{21} = matrix of mean monthly forage yields

A_{22} = matrix of maximum monthly grazing intake parameters

A_{23} = matrix to transfer monthly pasture production to hay production

A_{33} = vector to accumulate and transfer hay production to A_{35}

A_{35} = vector of maximum monthly hay intake parameters

A_{42} = matrix of energy available from maximum monthly grazing intake

A_{44} = matrix of monthly cattle energy requirements

A_{45} = matrix of energy available from maximum monthly hay intake

A_{52} , A_{54} and A_{55} = unit matrices to impose constraints so that grazing and hay consumption do not exceed maximum intake capacity

A_{63} = unit matrix to impose constraints so that acreage set-aside for hay production in each haying season is identical in the three months of each haying season

A_{71} = matrix of monthly labor requirements for pasture activities

A_{74} = matrix of monthly labor requirements for cattle activities

- A_{75} = matrix of monthly labor requirements for hay activities
 A_{76} = matrix to accumulate purchased labor required each month
 B_1 = vector of available land resources on each tract to which the $\leq$ restraint applies
 B_2 and B_4 = null vectors to which the $\leq$ restraint applies
 B_3 = null scalar to which the $=$ restraint applies
 B_5 = null vector to which the $\leq$ restraints apply
 B_6 = null vector to which the $\leq$ restraints apply
 B_7 = vector of available labor resources each month to which the $\leq$ restraint applies

Model design was such that results could be easily used in the simulation analysis. The structure of the LP model is apparent from IV.4 and IV-5. Specific model features and their details, however, warrant clarification.

Cattlemen were assumed to exhibit profit maximizing behavior when developing long-term plans. Thus, return and expense information was needed to specify the LP objective function. Estimated annual returns per cow generated by cattle sales from both spring and fall herds are displayed in Table IV-6. Receipts for the two herds differed due to their unique months of marketing weaned calves (spring herd-October; fall herd-June). Cattle prices were specified in the appropriate months of selling for each herd using five-year average prices during the 1983-87 period, adjusted to 1988 levels. The deflator was a price index (Federal Reserve System 1989) exclusive of cattle prices to deflate for price level changes regardless of the cattle cycle. Price data were obtained from Tennessee Feeder Calf Auctions (Tennessee Agricultural Statistics Service). Animal weights, identical for each herd, were set according to an average calf weaning weight of 500 pounds, a non-breeding heifer weight of 640 pounds, and culled cow and bull weights of 1000 and 1200 pounds, respectively. Total annual

TABLE IV-6

ESTIMATED BEEF COW-CALF RETURNS PER COW USED IN THE LONG-TERM
PLANNING (LINEAR PROGRAMMING) MODEL FOR SPRING AND
FALL CALVING HERDS

Item	Weight Each	Unit	Unit Price ¹		Quantity	Total Value	
			Spring Herd	Fall Herd		Spring Herd	Fall Herd
Gross Receipts ²							
Steer Calves	5.5	CWT	69.99	70.73	0.44	169.38	171.17
Heifers Calves	4.6	CWT	61.76	63.59	0.24	68.18	70.20
Non-Bred Heifers	6.4	CWT	57.34	58.37	0.03 ³	11.01	11.21
Culled Cows	10.0	CWT	40.01	44.20	0.16 ³	64.02	70.72
Aged Bulls	12.0	CWT	50.01	55.25	0.01	6.00	6.63
Total Gross Returns						318.59	329.93
Total Expenses						149.05	149.05
Total Net Returns ⁴						169.54	180.88

¹ Cattle prices are average Tennessee prices in October (Spring Herd) and June (Fall Herd) during 1983 through 1987, deflated to 1988 dollars.

² Assumes an 88 percent calf crop and 17 percent replacement rate.

³ Assumes a 1 percent death loss for cows.

⁴ Total net returns are returns to land, labor, capital and forage resources.

expenses were the sum of variable and fixed expenses as shown in Table III-10. Net returns used in the LP model (C_4) were defined as the residual returns to land, resident labor, capital and forage resources. Per acre pasture and hay production expenses (C_1 & C_3) are shown in Table III-9.

Features common to the simulation and LP models included the specification of monthly periods for forage and labor availability and requirements, division of the land resource into ten tracts, division of the beef herd into five animal classes, and use of the net energy system (National Research Council 1984) for expressing nutrient values and requirements. The land resource (200 acres) was divided into ten tracts (A_{11}) of twenty acres (B_1). Monthly forage yields were estimated on each tract according to its assumed year of useful life in forage production. Yields simulated under normal climatic conditions (refer to Table IV-6) were used to specify forage production on each tract (A_{21}). Forage was available to be grazed or transferred to hay production (A_{23} & A_{33}). Forage yield on acreage grazed included a 10-percent grazing loss. Acreage idled for hay production in any month of a haying season was constrained to be idled in other months of the haying season (A_{63}). Hay yields were reduced 10-percent due to losses at harvesting, and an additional 15-percent for storage and feeding losses (Fribourg 1988b.). Cattle intake and energy constraints were included as availabilities (A_{22} , A_{35} , A_{42} & A_{45}) and requirements (A_{44}) per month for each of cows, calves, weaned heifers, replacement heifers and bulls. The net energy system was

used to express energy values of cattle intake and requirements for maintenance (cows & bulls) and growth (calves & heifers).

The possibility exists that energy could be inadequate for cattle during months when pasture was mature and/or weathered, or when hay was of low quality. As forage quality declines, digestibility decreases and an animal's consumption capacity is reduced (Conrad et al.). Consequently, an animal may consume its intake capacity and still not satisfy energy requirements. Intake restrictions specified in the LP formulation account for this possibility. The relationship between forage quality and intake (Conrad et al. 1986) is shown in Figure IV-3. Using this relationship, along with monthly quality simulated under normal climatic conditions for each forage system (refer to Table IV-5), daily dry matter intake was specified for each animal classification. Daily intake levels, length of month, and monthly animal weights were combined to develop maximum animal consumption capacities for grazing (A_{22}) and hay (A_{35}) in each month. LP matrices A_{52} , A_{54} and A_{55} were necessary to impose constraints so that grazing and hay consumption did not exceed maximum intake capacities (Whitson et al. 1976). The net energy system was used to describe available energy for maintenance and growth from maximum animal intake capacities (A_{42} & A_{45}). Monthly available energy of each forage system was matched with monthly requirements (A_{44}) of each calving system (Appendix Table 8) to determine stocking level, grazing and hay management of the operation for each production system.

Cost of hired labor (C_6), if necessary, were also deducted from gross returns. Monthly forage, cattle and hay labor requirements

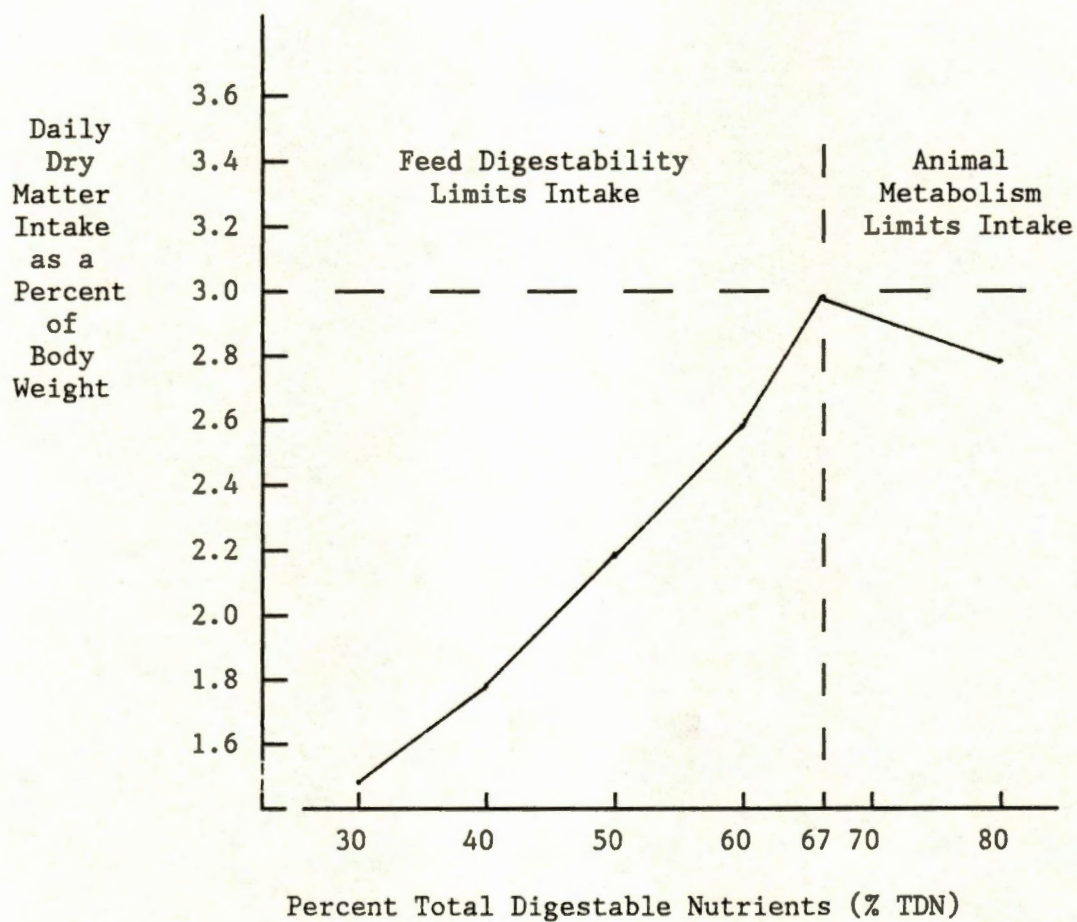


FIGURE IV-3

RELATIONSHIP BETWEEN PERCENT TOTAL DIGESTIBLE NUTRIENTS
AND DAILY DRY MATTER INTAKE

Source: Adapted from Conrad et al. and Whitson et al.

(A₇₁, A₇₄ and A₇₅, respectively) were matched with the available labor supply (B₇; refer to Table III-2). Additional required labor was accumulated (A₇₆) each month and assumed to be purchased. Since cattle production was assumed to be the supplemental enterprise on a rowcrop farming operation, labor required for the cattle and forage systems in excess of the existing supply was charged to the cattle operation.

Results of the long-term planning model are reported in Table IV-7. Herd sizes and hay acreages shown are the parameters used in the simulation model for the initial stocking rate in each production alternative. Animal numbers used with each forage system were rather similar for the spring and fall herds but with a few more cows in the fall herd than in the spring herd. The stocking rates for the bermudagrass/tall fescue systems were more than 20 percent greater than for the tall fescue systems. Adding legumes to the tall fescue increased stocking rate about 6 percent for the spring herd and over 15 percent for the fall herd. Stocking rate was less in each case for the tall fescue plus legumes than for the bermudagrass/tall fescue combination. For both spring and fall herds, stocking rate was greatest in the bermudagrass/tall fescue plus legumes system; over 30 percent greater than for tall fescue alone. Fall herd systems required ten more acres of hay than the spring counterpart in the grass forage system, and twenty more hay acres in the renovated systems. Higher winter feed requirements of cows lactating during the winter necessitated more hay. A greater proportion of annual hay was

TABLE IV-7

RESULTS OF THE LONG-TERM PLANNING MODEL--DECISION PARAMETERS
USED IN THE SIMULATION ANALYSIS FOR EACH PRODUCTION ALTERNATIVE

Item	Unit	Tall Fescue	Bermudagrass/ Tall Fescue	Tall Fescue + Legumes	Bermudagrass/ Tall Fescue + Legumes
Spring Herd					
Herd Size					
Cows	hd	101	126	107	132
Calves	hd	89	111	94	116
Weaned					
Heifers	hd	20	25	21	26
Replacement					
Heifers	hd	17	21	18	22
Bulls	hd	5	6	5	6
Hay Production ¹					
cutting 1	acre	70	50	60	50
cutting 2	acre	0	20	0	20
Fall Herd					
Herd Size					
Cows	hd	104	126	120	136
Calves	hd	92	111	106	120
Weaned					
Heifers	hd	21	25	24	27
Replacement					
Heifers	hd	18	21	20	23
Bulls	hd	5	6	5	6
Hay Production					
cutting 1	acre	50	40	60	40
cutting 2	acre	30	40	20	50

¹ Acreage of hay production at each cutting is the sum across all tracts of land. Hay production on each tract was specified in the simulation model. Acreage on each tract was rounded to the nearest ten acres to facilitate management and division of tracts for hay.

produced at the second cutting of the bermudagrass/tall fescue systems and for each forage system with fall calving. This result is attributed to greater yields of bermudagrass and lower animal requirements after weaning fall-born calves in late summer.

Short-term Decisions. Responding to environmental fluctuations is an essential part of managing a cattle operation. Although the winter period of decreased forage productivity can be predicted and planned for, unseasonable conditions during the year cannot be anticipated. Cattlemen must revise plans in response to the situations encountered. In this study such revisions were defined as short-term decisions. Short-term decisions were specified according to climatic conditions, time of year, and the status of the forage and cattle systems at specified decision points.

Climatic conditions determined the amount and quality of available forage during a year. To specify short-term decisions made by cattlemen, monthly forage production was defined as normal, surplus or deficit. If normal conditions prevailed, winter hay feeding level was the only short-term decision rendered. Variations from the long-term plan were unnecessary. In the event of surplus forage, profit maximizing stocking and hay production levels were maintained. Surplus hay was sold after the second cutting in October. Hay sales were the amount in excess of that required during a normal winter, minus a 10 percent reserve for severe or extended winters. Managerial response to months of deficit forage was more complex. Several options including grazing hay acreage, feeding extra hay, buying hay and reducing stocking level were available. Assumed use of each option depended

upon when forage was in short supply and status of the forage and cattle systems.

Short-term decisions made in response to deficit forage production were specified in each of two annual periods, the haying seasons (April through September) and other months (October through March). The sequence by which decisions to deal with deficit forage were exercised during the haying seasons was:

1. graze hay acreage
 - up to 50 percent of first cutting hay acreage
 - up to 100 percent of second cutting hay acreage
2. feed hay from inventory
 - up to 100 percent of inventory prior to first cutting
 - up to 50 percent of inventory after first cutting
3. wean and sell calves early
 - only in two months prior to scheduled weaning
4. sell cows

Grazing acreage set-aside for hay production was the first option available when forage supply was short. To facilitate pasture management, animals were allowed to graze hay land in increments of ten acres until enough acres were used to meet the forage deficit. Only 50 percent of first cutting hay acreage was available for diversion, while 100 percent of second cutting hay could be grazed. Forage yield on these diverted acres was equivalent to hay growth accumulated during months prior to grazing with the assumed 10-percent grazing loss, plus an additional 5-percent loss due to increased trampling of the accumulated growth. Feeding hay from inventory was the next option. Prior to harvesting first cutting hay (January through June), all hay in inventory was available for feeding (i.e. hay remaining from the previous year). After first cutting hay was harvested a maximum of 50 percent of hay inventory was allowed for

summer feeding to ensure some hay would be available during the winter. When option two was exhausted, cattlemen could wean calves and sell early all calves not needed for replacement stock. Calf sales due to a forage deficit were permitted only in the two months prior to the weaning date of each calving system (spring herd- August and September; fall herd- April and May). Early weaning had the effect of reducing forage demand by removing calf consumption and eliminating cow requirements for lactation. Finally if the forage deficit remained, the cow herd was reduced by selling open or dry cows first, and then cow-calf pairs until the deficit was alleviated. Herd reduction was the last resort due to significant expenses involved with restocking. If herd size was reduced, enough heifers were retained at weaning to replenish the herd up to an annual maximum replacement rate of 25-percent of long-term herd size.

During other months (October through March) decisions were exercised in the following sequence:

1. feed hay from inventory
--up to 100 percent of inventory
2. purchase and feed hay

Hay was fed from reserves until inventory was depleted, and then purchased to meet remaining requirements. Stocking level was not reduced during this time.

The criterion used to initiate short-term decisions is explained in the next section. Hay diversions, feeding and stocking adjustments impact on the ration available for animals in each month. Ultimately, these impacts determine animal performance.

The Cattle Component

Interaction among the forage, cattle and managerial parameters defined monthly characteristics of the ration fed each class of cattle. The available ration included the quantity and quality of both grazed pasture and hay. Using these variables, monthly animal performance for each class of cattle was developed. A schematic of the interaction among forage, cattle and managerial components to determine monthly ration parameters and animal performance is displayed in Figure IV-4.

Ration Parameters. The monthly ration fed each class of cattle was described by two parameters, quantity and quality. Ration quantity was defined as the amount of grazed pasture and hay fed in a month. The quality of ration was determined by a weighted average of the quality of each feed source (pasture and hay), weighted by the amount each contributed to the total ration. These parameters were assumed to describe the characteristics of forage available to the herd in each month.

To specify monthly ration quantity for cattle a sequence of steps was initiated. First, the amount of forage designated for herd grazing in each month was divided among the animal classifications. Forage was allocated to each class according to an estimate of their respective monthly intakes. Such a procedure was designed to incorporate competitive and dynamic relationships among grazing cattle for forage, due to growing animals changing forage demands.

The voluntary intake of cattle has been shown to be an increasing function of forage quality for rations containing less than 67 percent

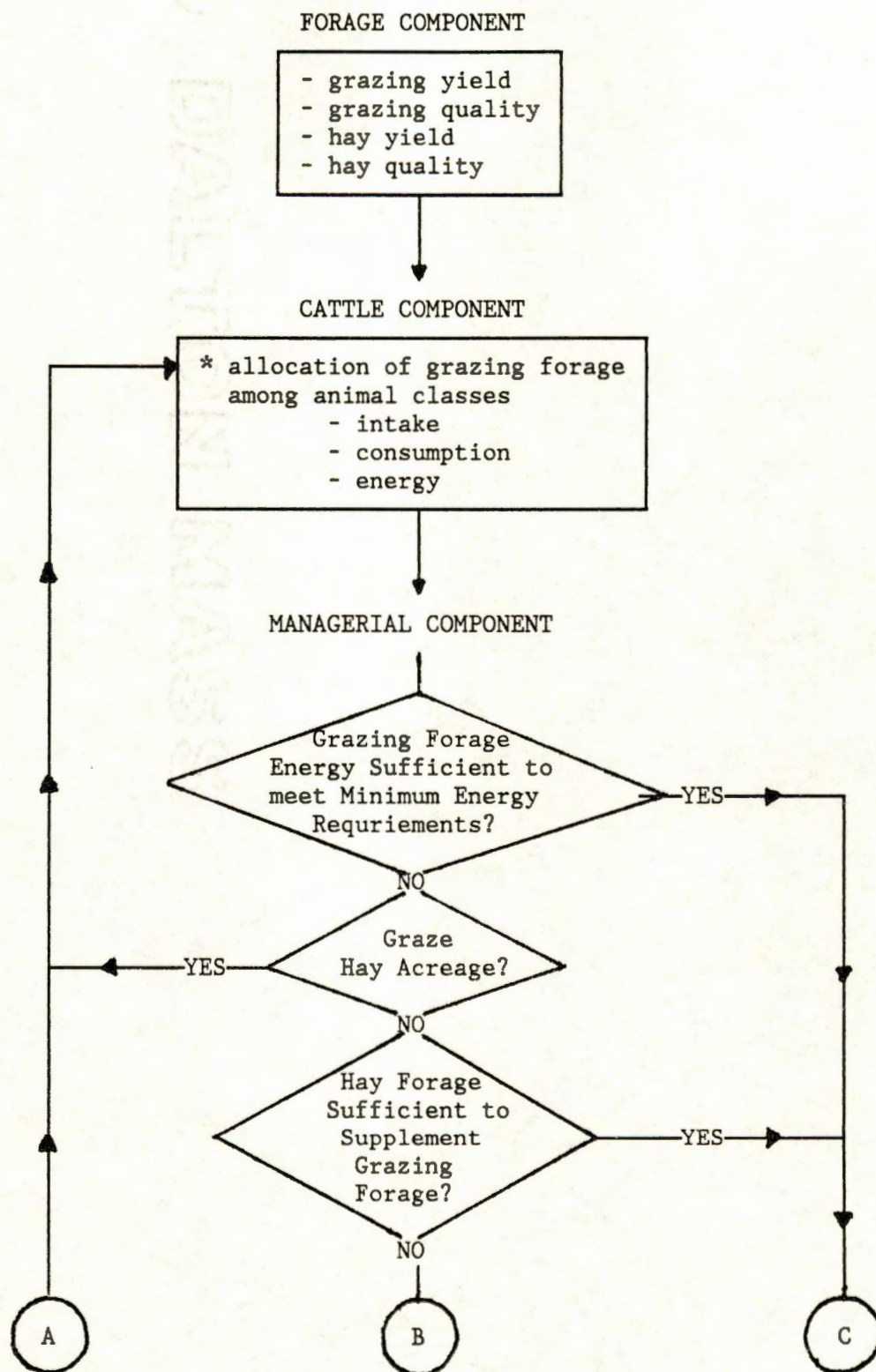


FIGURE IV-4

SCHEMATIC OF THE INTERACTION AMONG FORAGE, CATTLE AND MANAGERIAL COMPONENTS TO DETERMINE MONTHLY RATION PARAMETERS AND RESULTING ANIMAL PERFORMANCE

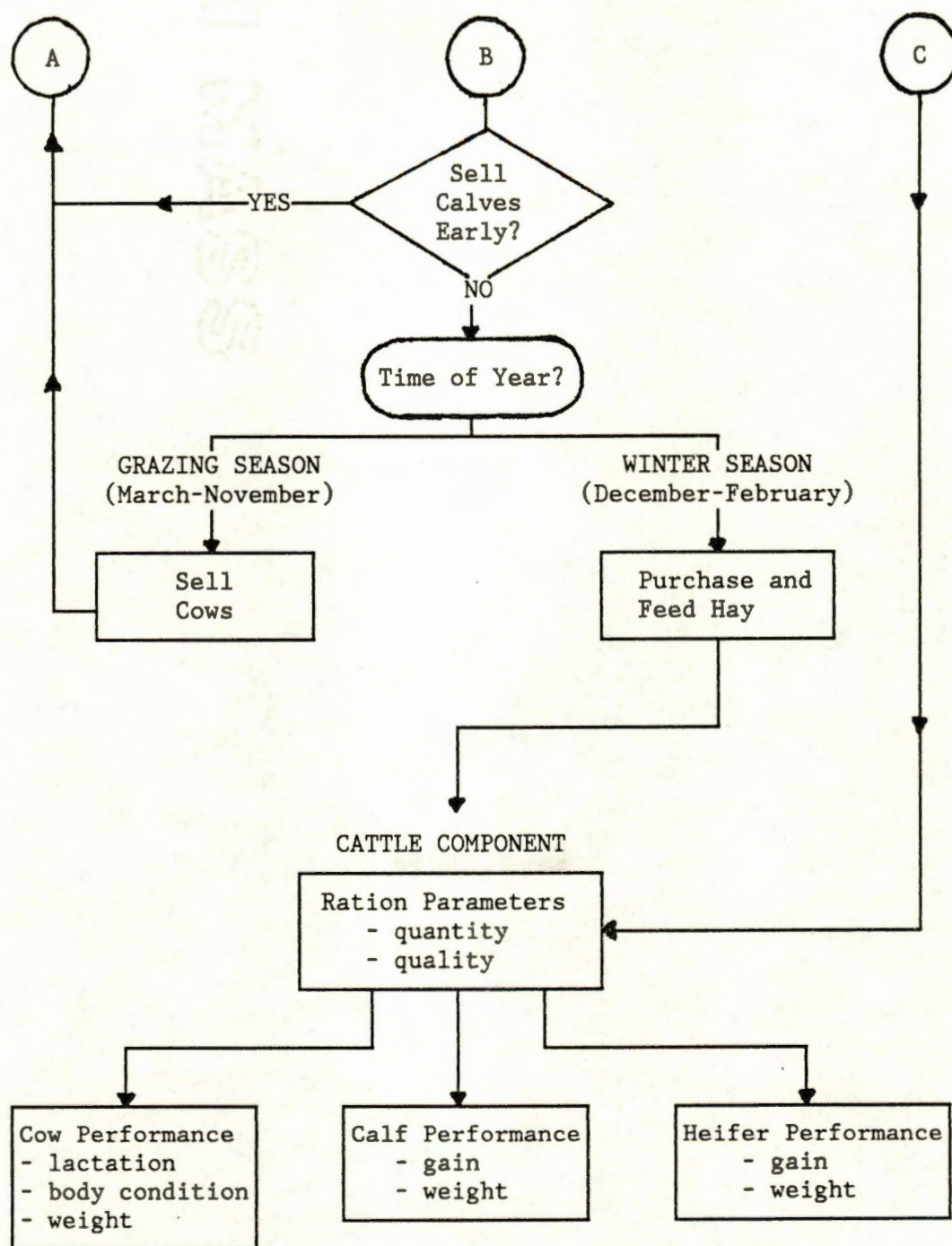


FIGURE IV-4 (continued)

total digestible nutrients (Conrad et al. 1966). For rations with a TDN percent of 67 or greater, Dinius et al. (1976) have estimated intake to be a decreasing function of quality. Using these intake relations, along with the quality of grazing forage, daily voluntary intake of cattle in each month was described by (refer to Figure IV-3);

$$(III.6) \quad DVI_{i,t} = \begin{cases} \frac{0.0107 EW_{i,t-1}}{[1 - (GQ_t / 100)]} & \text{if } GQ_t \leq 66 \\ [.061742 - .00045866 GQ_t] EW_{i,t-1} & \text{if } GQ_t > 66^4 \end{cases}$$

where

$DVI_{i,t}$ = daily voluntary intake (lbs. DM per animal) of animal class i during month t

$EW_{i,t-1}$ = animal weight (lbs.) maintained by animal class i at the end of month $t-1$ (or beginning weight in month t)

GQ_t = grazing forage quality (% TDN) during month t

$t = 1, \dots, 12$

$i = 1, \dots, 5$

Cow weight used in this relation was for a mature brood animal (1000 pounds) in good condition and thus, did not vary with month. Any weight change during a month was assumed to reflect a condition change and did not affect intake capability. Bull weight (1200 pounds) did not change during the year. As a calf matures, forage consumption comprises an increasing part of its diet. Holloway et al. (1982) have reported evidence that forage intake by nursing calves was primarily

⁴The intake relation for rations greater than 66 percent TDN was developed by Dinius and converted to a function of weight by Brorsen.

influenced by calf weight and forage quality, rather than milk consumption. Therefore, the intake of forage by a calf was determined using estimated calf weight at the beginning of each month, along with the quality of grazing forage in the month. Heifers, like calves, consume a greater amount of forage with maturity. Estimated heifer weights beginning each month were used to specify monthly forage intake of weaned and replacement heifers. The relative intake of each animal class was used to allocate total available grazing forage by the equation;

$$(IV.7) \quad DAGF_{i,t} = (TAGF_t * INPER_{i,t}) / HEAD_{i,t} / DAYS_{i,t}$$

with:

$$(IV.8) \quad INPER_{i,t} = DVI_{i,t} / TDVI_t$$

where:

$DAGF_{i,t}$ = daily available grazing forage (lbs. DM per head) for animal class i during month t
 $TAGF_t$ = total available grazing forage (lbs. DM) during month t
 $INPER_{i,t}$ = the percentage of total intake attributed to animal class i during month t
 $HEAD_{i,t}$ = number of head stocked in animal class i during month t
 $DAYS_{i,t}$ = number of days animal class i resides on the operation during month t
 $TDVI_t$ = sum of daily intake levels for all animal classes in month t
 $t = 1, \dots, 12$
 $i = 1, \dots, 5$

The resulting estimate ($DAGF_{i,t}$) indicates the quantity of available grazing forage for each class of cattle in a month. Since cattle consumption is constrained by either quantity of available forage or intake capability, the relation;

$$(IV.9) \quad DCC_{i,t} = \{ \min (DAGF_{i,t}, DVI_{i,t}) \}$$

where

$DCC_{i,t}$ = daily cattle consumption (lbs. DM per head) for animal class i during month t

was used to describe daily animal grazing forage consumption during each month.

Daily consumption limited the amount of available energy for cattle. Energy in the daily consumption was described as a function of ration quality (see National Academy of Sciences, p. ix) by;

$$(IV.10) \quad DCDE_{i,t} = 2.0041 [GQ_t / 100] [DCC_{i,t}]$$

where:

$DCDE_{i,t}$ = daily available digestible energy (Mcal per head) for animal class i during month t

The net energy system (National Research Council) was used to describe available and required energy for maintenance (cows & bulls) and growth (calves & heifers). This system has been widely adopted in the United States as the basis for growth simulation models and is recognized as a marked improvement over the older TDN system (Denhem and Spreen). Daily available energy was converted to that available for animal maintenance, and that for growth using the following conversion equations (National Research Council);

$$(IV.11) \quad DME_{i,t} = 0.82 [DCDE_{i,t}]$$

$$(IV.12) \quad DNEM_t = 1.37 (DME_t) - 0.138 (DME_t)^2 + 0.0105 (DME_t)^3 - 1.12$$

$$(IV.13) \quad DNEG_t = 1.42 (DME_t) - 0.174 (DME_t)^2 + 0.0122 (DME_t)^3 - 1.65$$

where:

$DME_{i,t}$ = daily available metabolizable energy (Mcal per head) for animal class i during month t

$DNEM_t$ = daily available net energy for cow and bull maintenance during month t
 $DNEG_t$ = daily available net energy for calf and heifer growth during month t

Once the available net energy in grazing forage was defined for each animal class, available energy was compared to minimum requirements, shown in Table IV-8, for decision analysis. If grazing energy was sufficient to meet minimum animal requirements, short-term decisions such as hay feeding were unnecessary. The ration fed each class of cattle was characterized by the quantity and quality of available grazing forage. Otherwise, short-term decisions were initiated. A deficit of energy during the haying seasons meant hay acreage was diverted to grazing. In such cases increments of ten acres were diverted to grazing, recomputing intake, consumption and energy for each increment until enough energy was available in grazing forage to meet the minimum requirements, or diversion limits were met. Hay was released from inventory within the seasonal feeding limits for animal classes still short of energy. A remaining deficit was addressed by early calf sales permitted during specified months. If early weaning resulted, grazing forage was reallocated among the remaining animals. Finally, herd reductions were made during typical grazing season months (March through November) if necessary to alleviate any remaining deficit in forage energy. Cows were sold one at a time by selling open or dry cows first, then cow-calf pairs. Herd reduction continued until available grazing and hay forage energy were sufficient to meet the minimum requirements of the remaining herd. During the typical

TABLE IV-8

MONTHLY NET ENERGY REQUIREMENTS PER ANIMAL FOR MAINTENANCE AND GROWTH
USED TO DETERMINE SHORT-TERM DECISIONS FOR
SPRING AND FALL CALVING HERDS

Month	Cows ¹ (NEM)	Bulls (NEM)	Calves (NEG)	Weaned Heifers (NEG)	Replacement Heifers (NEG)
----- Mcal per head ² per day -----					
Spring Herd					
January	13.40	8.73	0	1.87	5.39
February	11.11	8.73	0	2.10	5.65
March	7.61	8.73	0	2.31	0
April	7.61	8.73	0	2.55	0
May	7.61	8.73	0	2.79	3.46
June	7.62	8.73	0	0	3.61
July	7.64	8.73	0.35	0	3.84
August	7.72	8.73	0.74	0	4.10
September	7.95	8.73	1.11	0	4.35
October	8.52	8.73	1.43	0	4.61
November	9.62	8.73	0	1.46	4.86
December	11.35	8.73	0	1.65	5.12
Fall Herd					
January	7.61	8.73	0	2.79	3.46
February	7.62	8.73	0	0	3.61
March	7.64	8.73	0.35	0	3.84
April	7.72	8.73	0.74	0	4.10
May	7.95	8.73	1.11	0	4.35
June	8.52	8.73	1.43	0	4.61
July	9.62	8.73	0	1.46	4.86
August	11.35	8.73	0	1.65	5.12
September	13.40	8.73	0	1.87	5.39
October	11.11	8.73	0	2.10	5.65
November	7.61	8.73	0	2.31	0
December	7.61	8.73	0	2.55	0

¹Energy requirements for each class of cattle were based upon the following assumptions:

Cows--Requirements include energy for body maintenance (1000 lbs.) and gestation. Since hay is the primary feed source for cows during the winter season (December through February), additional requirements for lactation at an average level of 20 pounds of milk per head per day were included for the fall herd. Requirements for spring cow lactation were included for February at 9 pounds of milk per head per day. Thus, in the model an additional 6.95, 7.02 and 6.45 mcal of NEM were added to the fall herd requirements in

TABLE IV-8 (continued)

December, January and February, respectively. An additional 3.07 mcal of NEM was added to spring herd requirements in February.

Bulls--Requirements include energy for body maintenance (1200 lbs.).

Calves--Requirements include forage energy needed to supplement milk in the production of a 400 pound average weaned calf (320 lbs. of gain for 274 days, or an average daily gain of 1.25 lbs.). Calves were assumed to begin noticeable forage consumption at six weeks of age, although a minimum forage requirement was not specified until the calf reached five and one-half months of age.

Weaned Heifers--Requirements include energy to produce a 600 pound heifer from weaning to breeding (215 lbs. of gain for 196 days, or an average daily gain of 1.10 lbs.)

Replacement Heifers--Requirements include energy to produce an 850 pound heifer from breeding to calving (250 lbs. of gain for 274 days, or an average daily gain of 0.91 lbs.).

²Energy requirements are expressed as the net energy required for maintenance (NEM) of cows and bulls, and net energy required for growth (NEG) of calves and heifers.

Source: National Research Council

winter season (December through February) hay was purchased and fed when inventory levels were insufficient to satisfy herd requirements.

Minimum cow energy requirements were set differently for the typical grazing season (March through November) and winter months (December through February). During the grazing season requirements included energy for body and gestation maintenance. Available energy above this minimum determined cow lactation and body condition each month. Since cow maintenance requirements vary with body condition, minimum requirements each month were adjusted for condition (Klosterman) by adding:

$$(IV.14) \quad ADCOWR_t = [4.0 - \{(CW_{t-1}/2.2) / H\}] * 1.716$$

where:

$ADCOWR_t^5$ = adjustment factor (positive or negative depending upon cow weight) for cow energy requirements (Mcal digestible energy per day) in month t

CW_{t-1} = cow weight at end of month t-1 (or beginning of month t)
 $H = 113.64$; height at hooks of a 1000 pound cow in good condition (centimeters)

2.2 = conversion factor for kilograms to pounds

to the minimum requirement.

During winter months cows rely on hay as their primary feed source. Minimum energy requirements included energy for body and gestation maintenance in both herds, and lactation in the appropriate months for each herd (see Table IV-8, footnote 1). An average lactation level of 20 pounds of milk per day was used to specify fall

⁵Energy adjustment factor was converted to Mcal net energy for maintenance before adding to the minimum requirement.

herd lactation requirements during the winter. This level was set to ensure fall calving cows were fed enough winter hay to perform comparably with spring calving cows during April, May and June. Spring calving cows were lactating during February of the winter season. Lactation energy requirements were included in the minimum requirement using 9 pounds of milk produced per day in February.

Minimum energy requirements for bulls were set for body maintenance of a 1200 pound weight. Calf and heifer requirements were set according to minimum performance standards. Calves required forage energy to achieve a minimum 400 pound average weaning weight for steers and heifers. Weaned heifer requirements were set to produce at least a 600 pound heifer at breeding. Replacement heifers required energy to achieve a minimum weight of 850 pounds at calving.

The ration fed each animal class was the resulting combination of grazing and hay forage required to satisfy minimum monthly energy requirements. Available energy in the ration was utilized to determine performance of cows, calves and heifers each month. Bull performance was not critical to this study and, therefore, was assumed adequate.

Cow Performance. To determine cow weight and milk production in each month available maintenance energy was compared to maintenance energy requirements. At any time during the year the cow was gestating, lactating, or both. Energy requirements, therefore, reflected the unique maintenance needs of gestation and lactation during the appropriate months, along with body maintenance. Daily available and required maintenance energy were equated each month by;

$$(IV.15) \quad DNEM = DNEM_B + (DNEM_G / 1000) + DNEM_L$$

where:

$DNEM_B$ = daily required net energy for cow body maintenance (Mcal per head)

$$= 0.0428 (\text{intake cow weight} = 1000 \text{ lbs.})^{.75} \quad 6$$

$DNEM_G$ = daily required net energy for cow gestation maintenance (kcal per head)

$$= CBW(0.0149 - 0.0000407d)e^{0.05883d} - 0.0000804d^2$$

with: CBW = expected calf birth weight (= 80 lbs.)

d = day of gestation (requirement computed using the average for all days in a month)

$$e = 2.71828...$$

$DNEM_L$ = daily required net energy for cow lactation (Mcal per head)

$$= M_t [0.1 (F) + 0.35] / 2.2$$

with: M_t = daily milk production (lbs. per head) during month t

F = percent fat content of milk (= 4)

2.2 = conversion factor for pounds to kilograms

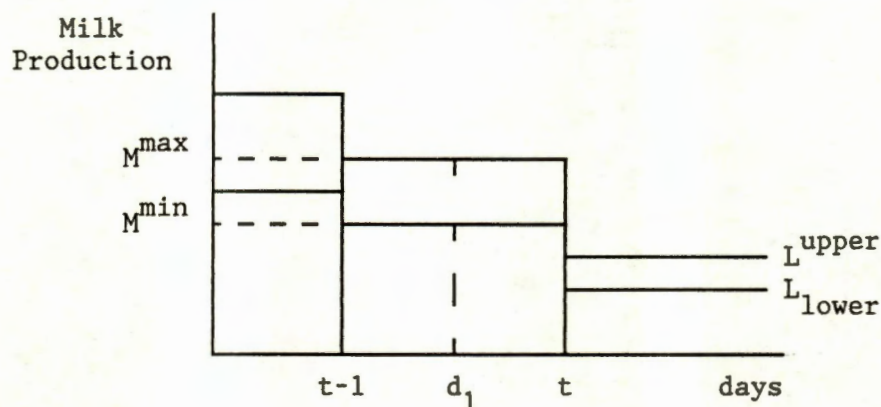
Assuming milkfat to be a constant percentage, M_t is the only unknown in equation IV.15. Daily milk production during a month was determined by rearranging the equation to;

$$(IV.16) \quad M_t = \frac{DNEM - DNEM_B - (DNEM_G / 1000)}{[0.1 (F) + 0.35] / 2.2}$$

In this formulation any excess or deficit energy was assumed to be reflected in the level of milk production. However, actual milk production is closely related to milk demand. The level of daily milk production during a month was, therefore, constrained by upper and lower bounds, defined as maximum and minimum milk intake levels. To explain how milk production was set each month the example illustrated

⁶Weight is measured in pounds as opposed to the NRC manual where weight is measured in kilograms. The adjustment factor is $(2.2)^{.75}$ or 1.8.

below is useful. On day d_1 of lactation, $M^{\max}$ and $M^{\min}$ define the range by which milk production was assumed to vary. Comparing the



estimate of milk production derived from IV.16 to these bounds, three cases were possible:

- (1) $M^{\max} \geq M_t \geq M^{\min}$
- (2) $M_t > M^{\max}$
- (3) $M_t < M^{\min}$

If case (1) resulted, the milk level defined by IV.16 was used and the amount of available energy was sufficient to meet required energy. If either case (2) or (3) was observed, $M^{\max}$ or $M^{\min}$ was used to describe milk production during the month. In these instances a surplus of energy (case 2), or a deficit of energy (case 3) existed. The amount of surplus or deficit energy was determined, using the estimated milk intake, by;

$$(IV.17) \quad EXNE_t = DNEM - DNEM_B - (DNEM_G/1000) - DNEM_L$$

where:

$EXNE_t$ = surplus (>0) or deficit (<0) net energy (Mcal per head) during month t

The maximum and minimum lactation levels were specified using information about milk production and intake from cows and calves grazing Tennessee pastures. Holloway et al. (1983) and Worley estimated lactation curves, measured from calf milk intake, for beef cows grazing high quality pastures (tall fescue + legumes) and low quality pastures (tall fescue). These results were adapted for this study by developing lactation bounds in each month for cows grazing the grass-legume mixtures and the pure grass stands. The equation used to determine average monthly milk production for cows grazing the pure grass systems, tall fescue and bermudagrass/tall fescue, was:

$$(IV.18) \quad M_t = 1.6764d^{0.828}e^{-0.0115d}$$

and the equation for each grass system renovated with legumes was:

$$(IV.19) \quad M_t = 1.6632d^{0.969}e^{-0.0121d}$$

where:

M_t = estimated milk production in month t (pounds of milk per day)
 d = day of lactation in month t
 $e = 2.71828...$

Holloway et al. (1983) reported milk intake estimates from each equation at 30 day intervals during lactation, along with variances of each estimate. Maximum monthly lactation bounds were specified using the average milk intake estimates from equations IV-18 & 19 in each month, plus one standard deviation of the estimates. Likewise, minimum monthly lactation bounds were set by deducting one standard deviation from the monthly estimates. Thus, milk production and intake were expressed separately for the grass and grass-legume

systems, and assumed to vary within one standard deviation of the average milk level each month. Average monthly lactation levels and bounds for the spring and fall calving herds grazing the grass and grass-legume systems are presented in Table IV-9.

Any surplus or deficit net energy in a month was assumed to be reflected in cow performance by changes in body condition. Klosterman et al. established a relationship between the height at hooks and the weight of a cow that can be used to adjust energy requirements for cows in different condition. The average weight (kg) to height (cm) ratio for a cow in good condition is 4.0:1. The adjustment in energy required by mature cows in different condition was determined to be:

$$(IV.20) \quad ADE^R = 1.716 (4.0 - W/H)$$

where:

ADE^R = the adjusted amount of energy required (Mcal DE per head)
 W = cow weight (kg)
 H = cow height at hooks (cm)

This relationship was modified to estimate cow weight change in relation to surplus or deficit energy in a month. For any weight level describing a cow in good condition, the height at hooks is determined using the weight to height ratio of 4.0:1. Thus, a 1000 pound cow in good condition would measure 113.64 centimeters at hooks. Rearranging equation IV.18 and substituting the surplus or deficit

TABLE IV-9

MONTHLY LACTATION BOUNDS USED TO SPECIFY MILK PRODUCTION FOR
 SPRING AND FALL CALVING HERDS GRAZING THE GRASS AND
 GRASS-LEGUME FORAGE SYSTEMS¹

Month	Grass Systems			Grass-Legume Systems		
	Average ²	Maximum	Minimum	Average	Maximum	Minimum
----- lbs. milk per head per day -----						
Spring Herd						
January	- ³	-	-	-	-	-
February	7.74	10.71	4.77	10.08	13.05	7.12
March	15.62	18.59	12.65	14.94	17.91	11.97
April	19.67	23.58	15.75	20.31	24.22	16.39
May	19.60	23.39	15.82	20.94	24.73	17.16
June	17.78	21.32	14.23	19.23	22.77	15.69
July	15.25	18.68	11.95	16.65	20.02	13.29
August	12.80	16.15	9.46	14.06	17.40	10.71
September	10.49	13.93	7.06	11.62	15.05	8.18
October	8.49	12.10	4.88	9.55	13.16	5.94
November	-	-	-	-	-	-
December	-	-	-	-	-	-
Fall Herd						
January	19.60	23.39	15.82	20.94	24.73	17.16
February	17.78	21.32	14.23	19.23	22.77	15.69
March	15.25	18.68	11.95	16.65	20.02	13.29
April	12.80	16.15	9.46	14.06	17.40	10.71
May	10.49	13.93	7.06	11.62	15.05	8.18
June	8.49	12.10	4.88	9.55	13.16	5.94
July	-	-	-	-	-	-
August	-	-	-	-	-	-
September	-	-	-	-	-	-
October	7.74	10.71	4.77	10.08	13.05	7.12
November	15.62	18.59	12.65	14.94	17.91	11.97
December	19.67	23.58	15.75	20.31	24.22	16.39

¹Grass forage systems are the tall fescue and bermudagrass/tall fescue systems. Grass-legume systems are each grass system renovated with legumes (red clover and annual lespedeza).

²Average daily milk production levels were developed in each month from equations IV-18 & 19. Maximum and minimum bounds were set at one standard deviation above and below, respectively, the average milk estimate in each month.

³Dashes indicate months in which cows are dry.

Source: Adapted from Holloway (1983) and Worley.

energy for the adjusted requirement⁷, the equation used to estimate weight change in a month was;

$$(IV.21) \quad WC_t = 2.2 \left[\frac{(6.864 \pm EXNE_t) GCH}{1.716} \right] - GCW$$

where

WC_t = weight change (lbs.) during month t
 GCW = weight (lbs.) of a cow in good condition (= 1000 lbs.)
 GCH = height (cm) of a cow in good condition (= 113.64 cm.)
 2.2 is the conversion factor for kilograms to pounds

If a surplus existed, the amount of the surplus was added in IV.19. Likewise, an energy deficit was subtracted in IV.19. The resulting weight change was used to develop cow weight at the end of each month by;

$$(IV.22) \quad ECW_t = BCW_t + WC_t$$

where;

ECW_t = ending cow weight (lbs.) in month t
 BCW_t = beginning cow weight (lbs.) in month t

This weight estimate was used for cows sold due to culling and stocking adjustments during the relevant months.

⁷The excess or deficit net energy is converted to the equivalent amount of digestible energy for this equation. Additionally, the amount of excess or deficit energy each period was bounded to preserve realism in the estimated cow weight.

Calf Performance. Next calf weight and growth were developed for each month. The calf was assumed to consume milk and forage and thus obtained energy from both feed sources. Available growth energy from milk was defined by;

$$(IV.23) \quad \text{milk DNEG} = 0.55 [M_t]$$

where:

milk DNEG = daily net energy available from milk (Mcal per head)
for growth
0.55 = net energy available per lb. of fresh milk (Mcal per head)
(National Academy of Sciences)

Thus, total energy for calf growth was specified as;

$$(IV.24) \quad \text{DNEG} = \text{milk DNEG} + \text{forage DNEG}$$

where:

DNEG = daily net energy (Mcal per head) available for growth

Calf weight and rate of gain were developed each month. Using the estimate of available growth energy, along with calf weight beginning each period, average daily gain (pounds per day) was expressed for steer and heifer calves each month as;

$$(IV.25) \quad \text{ADSCG}_t = [32.316 (\text{DNEG} / \text{BSCFW}_t^{.75})]^{0.911577}$$

$$(IV.26) \quad \text{ADHCG}_t = [26.239 (\text{DNEG} / \text{BHCfw}_t^{.75})]^{0.893655}$$

where:

ADSCG_t = average daily steer calf gain (lbs. per day) during month t
 ADHCG_t = average daily heifer calf gain (lbs. per day) during month t
 BSCFW_t = beginning steer calf weight (lbs.) in month t
 BHCfw_t = beginning heifer calf weight (lbs.) in month t

Average daily gain is the rate at which calves grew during a month. Steer and heifer weight estimates at the end of each month were calculated using beginning calf weight, daily gain, and length of time calves were retained each month by;

$$(IV.27) \quad ESCFW_t = [(ADSCG_t)(DAYS_t)] + BSCFW_t$$

$$(IV.28) \quad EHCFW_t = [(ADHCG_t)(DAYS_t)] + BHCFW_t$$

where:

$ESCFW_t$ = ending steer calf weight (lbs.) in month t
 $EHCFW_t$ = ending heifer calf weight (lbs.) in month t
 $DAYS_t$ = number of days calf resides on the operation in month t

These estimates were used to specify calf weights at weaning, and intake, consumption, energy and performance variables in the next month.

Heifer Performance. Weaned and replacement heifer growth and weight were also determined in each month. Heifers utilized available forage energy for weight gain. Average daily gain (pounds per day) was developed each month for both heifer categories with the equation;

$$(IV.29) \quad ADHG_t = [26.239 (DNEG / BHW_t^{.75})]^{0.893655}$$

where:

$ADHG_t$ = average daily weaned and replacement heifer gains (lbs. per day) during month t
 BHW_t = beginning weaned and replacement heifer weights in month t

Thus, ending weaned and replacement heifer weights each month were specified as;

$$(IV.30) \quad EHCFW_t = [(ADHCG_t)(DAYS_t)] + BHCFW_t$$

where:

EHW_t = ending weaned and replacement heifer weights in month t
 $DAYS_t$ = number of days weaned and replacement heifers resided on the operation in month t

Like calf weights, ending heifer weights were used to specify ration and performance variables in subsequent months.

The Price and Cost Component

Price and cost parameters were needed to describe the economic environment confronted by cattlemen. As with physical forces, economic conditions fluctuate. These fluctuations have serious implications for the profitability of cattle production. Consequently, an attempt was made to project price and cost variability over the ten-year planning span. Price and cost variables of utmost concern to cattlemen included livestock and hay prices, and input costs.

Cattle and Hay Price Estimation. An accurate forecast of livestock prices over the ten-year span was not possible. However, a representation of historical price variability was feasible and valuable for assessing the production alternatives. This was accomplished by forecasting cyclical price movements from historical data. While turning points of price cycles were too erratic to precisely forecast, a stochastic simulation of the expected cattle cycle offered a reasonable facsimile of possible future trends.

Since calf weights varied with forage productivity, prices were developed for 3-400, 4-500, 5-600 and 6-700 pound steer and heifer calves. Steer and heifer prices were then linearly interpolated according to their respective weights in months of weaning. Prices

were also needed for cull cows and bulls, replacement bulls and cow-calf pairs sold due to stocking reductions. VanTassell has shown slaughter bull prices to be approximately 1.25 times utility cow prices. Since Tennessee bull prices were unavailable, this relationship was adopted. Replacement bull and cow-calf pair prices were specified using estimates also developed by VanTassell. His bull prices were obtained from auction summary reports for registered Hereford bulls (American Hereford Journal). Cow-calf pair prices were obtained for young to middle aged, medium to large framed, #1 to #2 cows with baby to 300 pound calves at side, reported from North Central Texas Auction markets (Texas Department of Agriculture, 1972-85).

Harmonic regressions were used to project a potential path for the cattle cycle (Franzmann and Walker; Gutierrez; VanTassell). Ordinary least-squares equations estimated for cattle prices using the following cyclical trend model;

$$(IV.31) \quad P_{i,t} = \beta_0 + \beta_1 2\pi t + \beta_2 \sin(2\pi t/L1) + \beta_3 \cos(2\pi t/L1) \\ + \beta_4 \sin(2\pi t/L2) + \beta_5 \cos(2\pi t/L2) + \varepsilon$$

where:

$P_{i,t}$ = predicted price for cattle price class i in month t
 $L1$ = seasonal component (= 12 months)
 $L2$ = cyclical component (= 120 months)
 β_k = parameter estimates ($k = 1, \dots, 5$)
 $2\pi t$ = time trend component ($\pi = 3.1415927$)
 $\sin$ & $\cos$ = sine and cosine of variables to specify magnitude and frequency of seasonal and cyclical components

are displayed in Table IV-10. Following Franzmann and Walker, a 12 month seasonal component was specified for $L1$, and a 120 month cycle

TABLE IV-10

CATTLE PRICE ORDINARY LEAST-SQUARES EQUATIONS FOR
THE CYCLICAL TREND MODEL

Steer Prices

$$ST34 = 44.14^{(1)} + 0.037T + 2.323S1 - 1.607C1 - 14.886S2 + 9.919C2 + \epsilon$$

(24.1)** (14.4)** (1.9) (-1.3) (-11.2)** (7.9)**

$$R^2 = 0.67 \quad \text{STD DEV} = 12.21 \quad N = 192$$

$$ST45 = 41.83 + 0.033T + 1.999S1 - 1.442C1 - 12.821S2 + 8.833C2 + \epsilon$$

(27.7)** (15.5)** (1.9) (-1.4) (-11.7)** (8.5)**

$$R^2 = 0.69 \quad \text{STD DEV} = 10.08 \quad N = 192$$

$$ST56 = 39.64 + 0.031T + 1.228S1 - 1.268C1 - 10.890S2 + 8.172C2 + \epsilon$$

(31.5)** (17.4)** (1.5) (-1.5) (-11.9)** (9.4)**

$$R^2 = 0.73 \quad \text{STD DEV} = 8.41 \quad N = 192$$

$$ST67 = 37.95 + 0.029T + 0.812S1 - 0.915C1 - 9.499S2 + 7.724C2 + \epsilon$$

(35.3)** (18.8)** (1.1) (-1.2) (-12.2)** (10.4)**

$$R^2 = 0.75 \quad \text{STD DEV} = 7.19 \quad N = 192$$

Heifer Prices

$$HF34 = 36.32 + 0.030T + 2.079S1 - 2.124C1 - 12.387S2 + 8.752C2 + \epsilon$$

(23.9)** (13.7)** (2.0)** (-2.0)** (-11.2)** (8.4)**

$$R^2 = 0.66 \quad \text{STD DEV} = 10.16 \quad N = 192$$

$$HF45 = 34.71 + 0.029T + 1.743S1 - 1.745C1 - 11.144S2 + 7.886C2 + \epsilon$$

(25.9)** (15.0)** (1.9)* (-1.9)* (-11.4)** (8.5)**

$$R^2 = 0.69 \quad \text{STD DEV} = 8.97 \quad N = 192$$

$$HF56 = 33.01 + 0.028T + 1.186S1 - 1.328C1 - 9.707S2 + 7.548C2 + \epsilon$$

(28.3)** (16.7)** (1.5) (-1.7)* (-11.5)** (9.4)**

$$R^2 = 0.72 \quad \text{STD DEV} = 7.80 \quad N = 192$$

$$HF67 = 32.72 + 0.026T + 1.053S1 - 1.390C1 - 9.536S2 + 6.852C2 + \epsilon$$

(29.7)** (16.4)** (1.4) (-1.8)* (-11.9)** (9.0)**

$$R^2 = 0.72 \quad \text{STD DEV} = 7.37 \quad N = 192$$

TABLE IV-10 (continued)

Utility Cow Price

$$\text{UTCOW} = 26.68 + 0.016T + 1.620S1 - 1.411C1 - 6.468S2 + 5.348C2 + \epsilon$$

(39.0)** (16.8)** (3.5)** (-3.0)** (-13.0)** (11.4)**

$$R^2 = 0.75 \quad \text{STD DEV} = 4.58 \quad N = 192$$

Replacement Bull and Cow-Calf Pair Prices

$$\text{RBULL}^2 = 813.3 + 1.1T + 160.8S1 - 117.0C1 - 38.5S2 + 159.5C2 + \epsilon$$

(11.2)** (9.4)** (3.2)** (-2.3)** (-0.8) (3.1)**

$$R^2 = 0.43 \quad \text{STD DEV} = 454.57 \quad N = 168$$

$$\text{CWCF}^2 = 348.25 + 0.27T + 5.22S1 - 21.16C1 - 93.73S2 + 108.62C2 + \epsilon$$

(24.2)** (11.6)** (0.5) (-2.1)** (-9.3)** (10.5)**

$$R^2 = 0.68 \quad \text{STD DEV} = 90.10 \quad N = 168$$

Hay Price

$$\text{HAY} = 35.21 + 0.019T + 0.840S1 + 0.315C1 - 2.512S2 - 2.891C2 + \epsilon$$

(67.9)** (25.2)** (2.4)** (0.9) (-6.7)** (-8.1)**

$$R^2 = 0.83 \quad \text{STD DEV} = 3.47 \quad N = 192$$

¹t-values for each parameter are in parenthesis below parameter estimate.

²Obtained from VanTassell.

*Significant at the 90 percent level.

**Significant at the 95 percent level.

where:

STD DEV = standard deviation

N = number of observations

ST34, ST45, ST56 and ST67 = per cwt. steer prices for 3-400, 4-500, 5-600 and 6-700 pound steer calves, respectively

HF34, HF45, HF56 and HF67 = per cwt. heifer prices for 3-400, 4-500, 5-600 and 6-700 pound heifer calves, respectively

UTCOW = per cwt. utility cow price

RBULL = per head replacement bull price

CWCF = per head cow-calf pair price

HAY = per ton hay price received by farmers

TABLE IV-10 (continued)

$T = 2\pi t$
 $S1 = \text{SIN}(2\pi t/L1)$
 $C1 = \text{COS}(2\pi t/L1)$
 $S2 = \text{SIN}(2\pi t/L2)$
 $C2 = \text{COS}(2\pi t/L2)$
 $L1 = \text{cycle length of 12 months}$
 $L2 = \text{cycle length of 120 months}$
 $\epsilon = \text{residual error term}$

for L2. Steer, heifer and utility cow equations were estimated using monthly price data for 1972 through 1987. Price data were collected from reports of Tennessee feeder calf auction prices (Tennessee Agricultural Statistics) for medium frame choice steer and heifer calves, and utility cows. The replacement bull and cow-calf pair equations were those estimated by VanTassell.

The possibility existed that cattlemen would purchase or sell hay during a year. Thus prices were needed for bought and sold hay. Monthly hay prices received by farmers during the 1972-87 period were collected from Tennessee Agricultural Statistics. Alternative models were fitted to the data. Best results were obtained when hay prices were related to the cattle cycle. Hay prices closely followed the price cycle, reaching cyclical turning points approximately three years before those of the cattle cycle. This result was attributed to the inverse and lagged relationship between herd numbers and prices, thus effecting the demand for hay. The estimated equation for hay selling price is included in Table IV-10. The October price forecast was used during years in which hay was sold. Hay purchased was levied an additional \$3.00 per ton charge for hauling.

The prediction equations were stochastically simulated using correlated random normal deviates developed from the covariance matrix of harmonic function residuals. The cattle cycle was initiated in 1988 and forecasted over the ten-year span of 1989 through 1998. Graphs of the projected deterministic price cycles (projected without a trend) during this period for steers, heifers, utility cows and bulls, cow-calf pair and replacement bulls, and hay are shown in

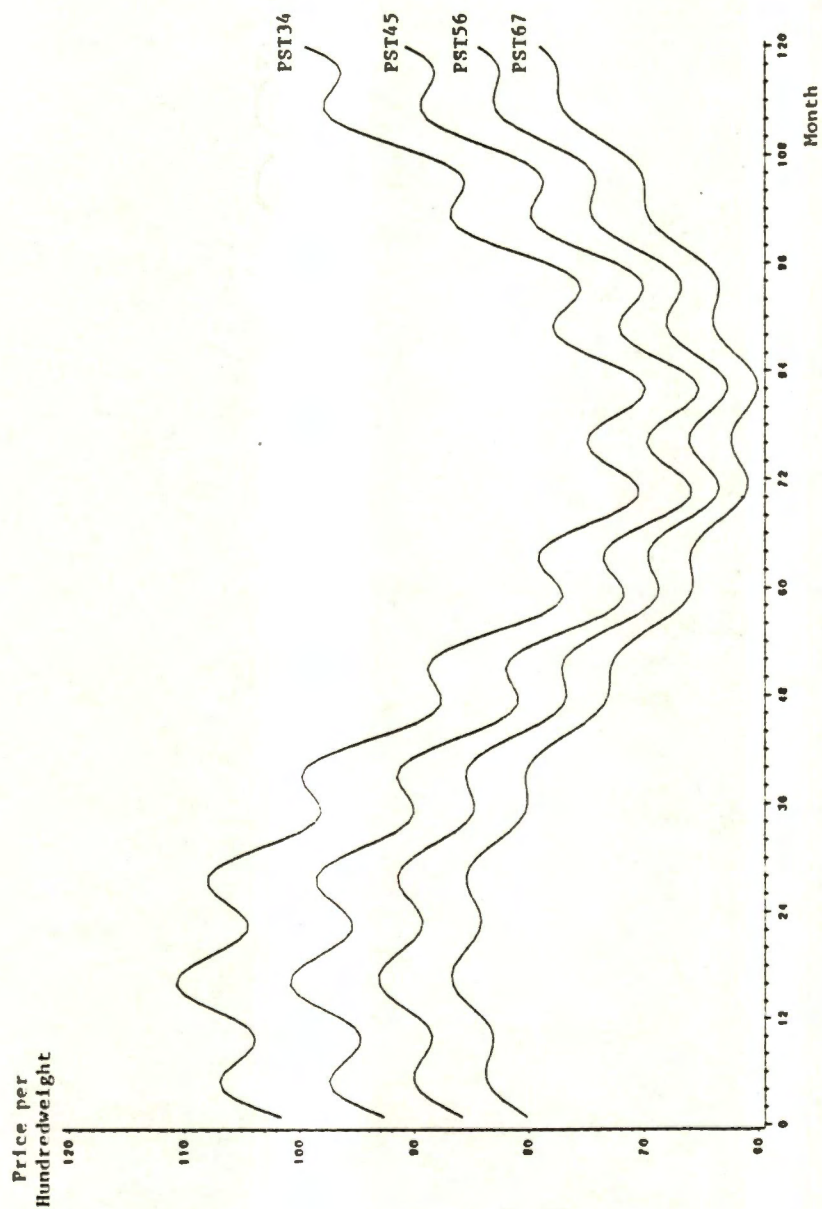
Figures IV-5, IV-6, IV-7, IV-8 and IV-9, respectively. Cattle and hay prices were simulated over the ten-year planning horizon for 100 iterations.

Price and Cost Levels. Inflation and interest rates were assumed to follow projected levels for each year of the ten-year planning span (1989-98). Estimates reported by the Food and Agricultural Policy Research Institute were used to specify assumed annual inflation and interest rates. Annual inflation and interest rate projections for each of the ten years are shown in Table IV-11. Inflation levels were specified by expense categories using forecasts of prices paid by farmers for different expense items. Since economic forecasts were available for only nine years (1989-97), expected 1997 conditions were assumed to prevail in 1998.

Cattle and hay price trends also followed the assumed economic environment for 1989 through 1998. Price projections using the estimated equations were detrended and inflated according to inflation forecasts in each year. Annual cattle and hay price levels were developed using aggregate GDP deflator forecasts, and a 0.725 transmission coefficient between inflation rates and farm input and output prices (Tweeten). These estimates are also presented in Table IV-11.

The Budgetary Component

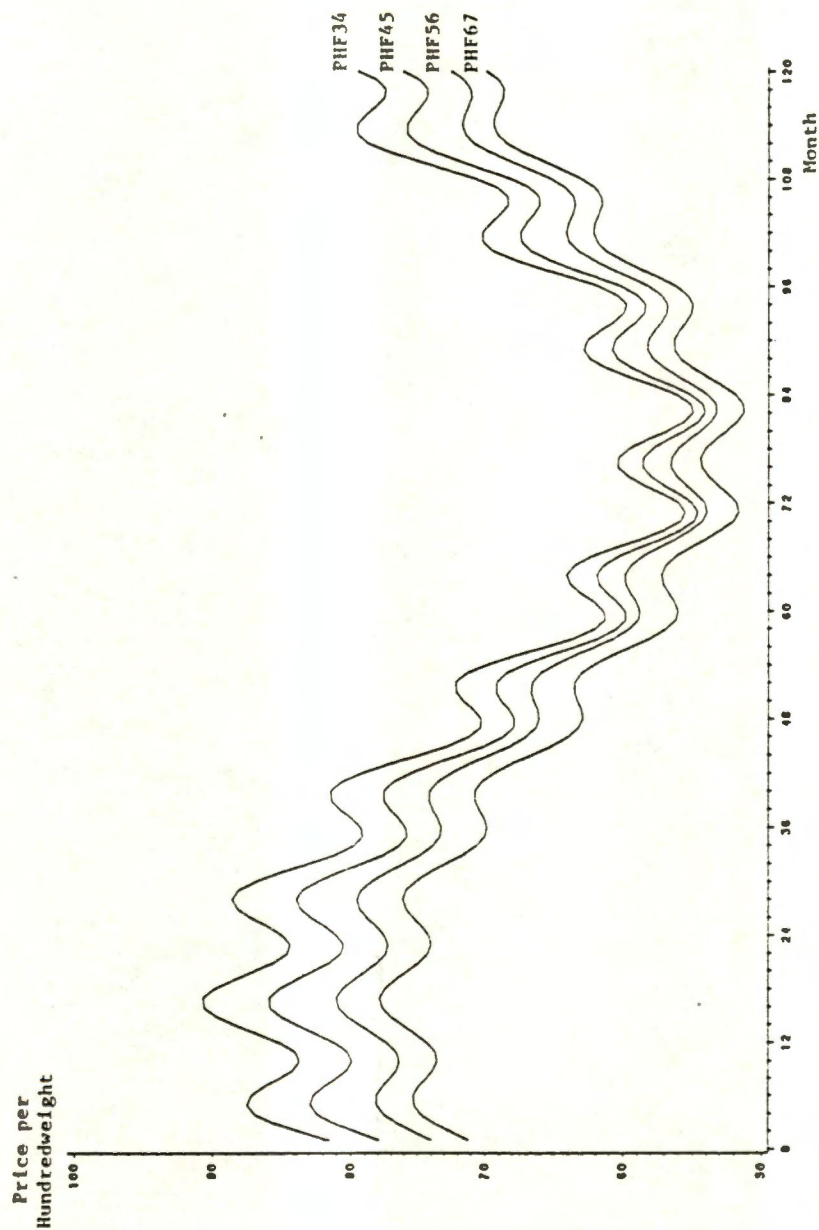
Annual financial characteristics of the cattle operation under each production alternative were summarized using a budgetary framework. Parameters developed in previous model components were combined to determine resultant budgetary variables for each of the ten years.



Legend: PST34=price of 3-400 pound steer calves, PST45=price of 4-500 pound steer calves,
 PST56=price of 5-600 pound steer calves, PST67=price of 6-700 pound steer calves

FIGURE IV-5

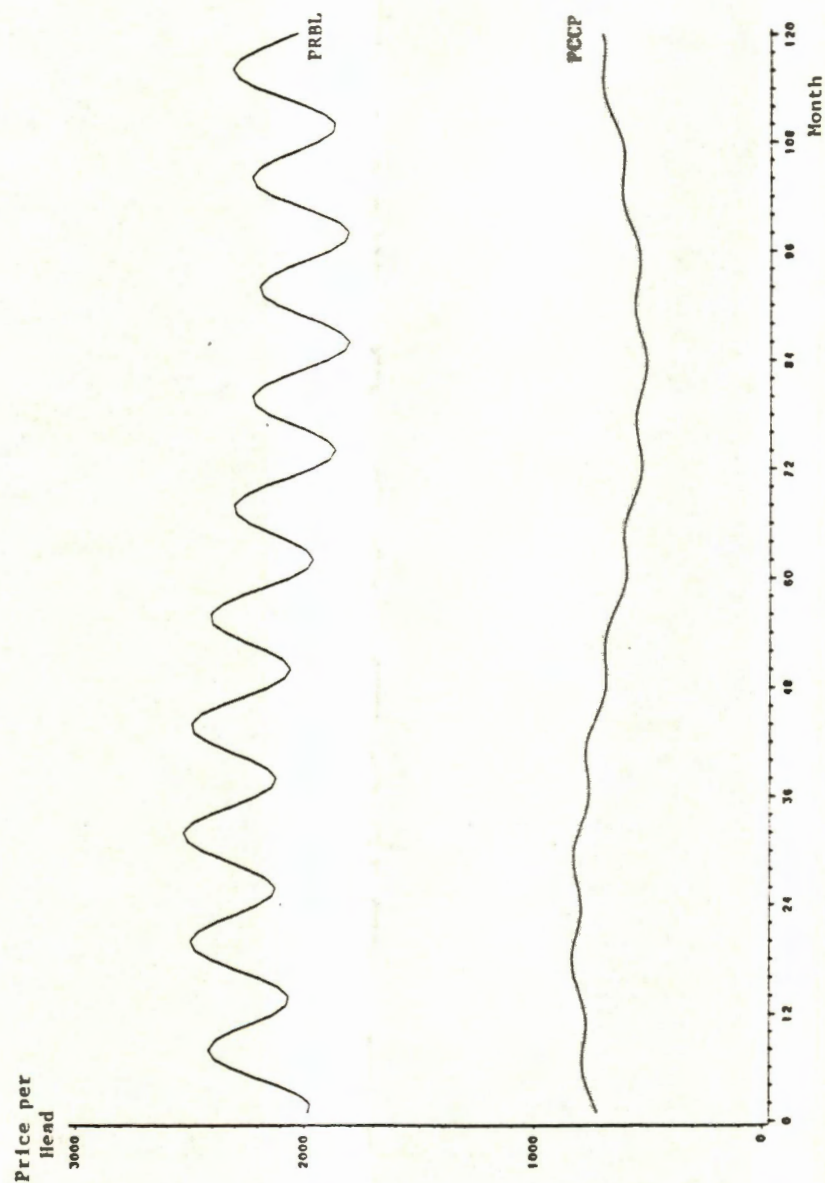
PROJECTED TEN-YEAR PRICE CYCLES FOR STEER CALVES OF VARYING WEIGHT CATEGORIES, 1989-1998



Legend: PHF34=price of 3-400 pound heifer calves, PHF45=price of 4-500 pound heifer calves,
 PHF56=price of 5-600 pound heifer calves, PHF67=price of 6-700 pound heifer calves

FIGURE IV-6

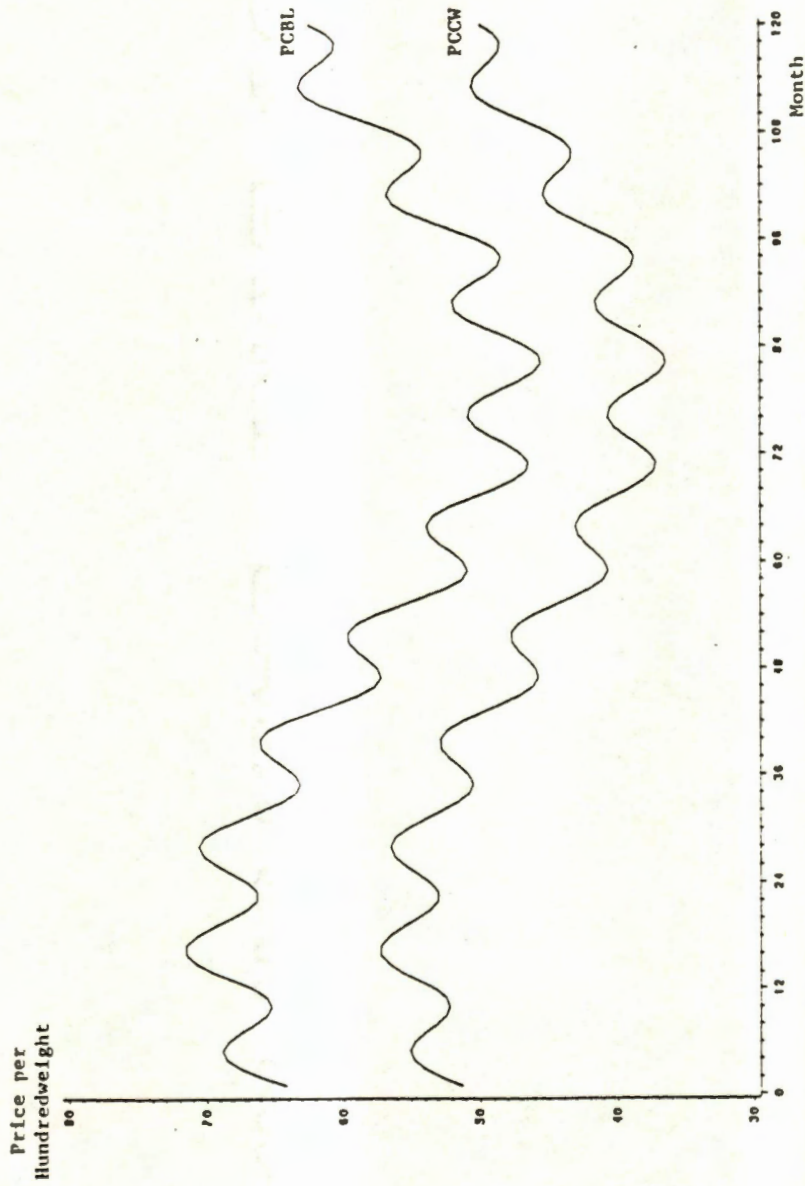
PROJECTED TEN-YEAR PRICE CYCLES FOR HEIFER CALVES OF VARYING WEIGHT CATEGORIES, 1989-1998



Legend: PCCP=price of cow-calf pairs, PRBL=price of replacement bulls

FIGURE IV-7

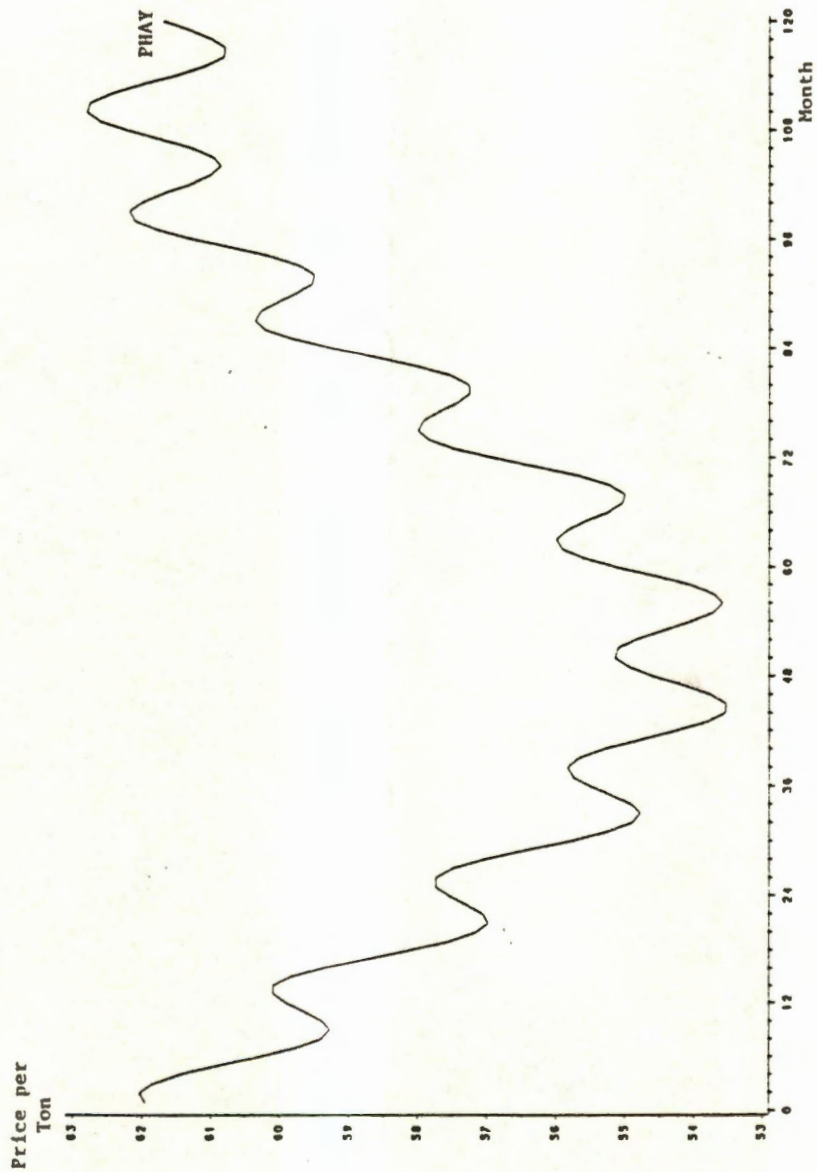
PROJECTED TEN-YEAR PRICE CYCLES FOR COW-CALF PAIRS AND REPLACEMENT BULLS, 1989-1998



Legend: PCCW=price of cull cows, PCBL=price of cull bulls

FIGURE IV-8

PROJECTED TEN-YEAR PRICE CYCLES FOR CULL COWS AND BULLS, 1989-1998



Legend: PHAY=price received for hay sold

FIGURE IV-9

PROJECTED TEN-YEAR PRICE CYCLE FOR HAY, 1989-1998

TABLE IV-11

ANNUAL INTEREST AND INFLATION RATES FOR 1989-1998

Item	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998 ¹
Annual Interest Rates ²										
Int-Term	10.7	10.6	10.5	10.4	10.6	10.9	11.5	12.1	12.7	13.4
Operating	12.8	12.7	12.6	12.5	12.7	13.1	13.8	14.6	15.3	16.1
Annual Percentage Change in Prices										
Cattle &										
Hay	2.9	3.0	2.5	2.5	2.6	2.8	3.2	3.3	3.6	3.6
Seed	3.1	3.6	3.0	3.0	3.3	4.0	4.5	5.8	5.9	5.9
Fertilizer	6.4	4.6	3.5	4.4	4.5	4.8	5.0	5.7	7.1	7.1
Chemicals	4.0	2.9	3.2	2.9	3.0	3.2	3.4	3.9	5.0	5.0
Farm										
Services	5.3	-2.4	1.4	2.3	2.9	3.7	4.0	4.7	4.9	4.9
Fuel & Lube	5.3	2.5	3.5	5.0	5.0	8.7	6.6	6.8	4.7	4.7
Repairs	2.5	2.6	3.7	4.2	4.4	4.8	5.1	5.2	5.5	5.5
Machinery	6.7	4.4	4.4	5.1	6.2	5.7	6.2	6.1	7.4	7.4
Insurance										
& Taxes	4.1	1.8	2.1	2.9	3.3	5.0	4.8	5.2	5.4	5.4
Labor	4.7	5.0	5.2	5.2	5.0	5.4	5.8	6.1	6.5	6.5
Other										
Inputs	4.3	1.8	2.0	2.9	3.2	5.1	4.6	5.1	5.3	5.3

¹Since 1998 projections were unavailable, 1997 levels were assumed to prevail in 1998.

²Interest rates charged each year on intermediate-term loans and short-term operating loans.

Source: Food and Agricultural Policy Research Institute and the Federal Reserve System

The budgets included annual gross receipts, operating and fixed expenses, and tax accounting of the cattle enterprise. Ultimately, net returns to various sets of fixed resources were computed. An outline of the various return and expense categories and items in each category is shown in Table IV-12.

Gross Receipts. Annual gross receipts of the cattle operation included cattle and hay sales. To accurately reflect the actual prices received by cattlemen for each receipt item, prices prevailing in selling months of each item were used as the per unit price received. Steer and heifer prices were further assigned according to their respective selling weights. Resulting weaning weights determined which of the 3-400, 4-500, 5-600 or 6-700 pound steer and heifer price categories were relevant. The number of head or tons of hay sold each month was used to compute annual gross receipts from each item.

Operating Expenses. Each year the cattle operation incurred operating expenses including pasture, hay, cattle, labor and operating capital costs. Pasture costs were separated into those for establishment, renovation of the grass-legume systems, and annual maintenance. Major expense items in each category included seed, fertilizer, and variable machinery costs. Items were charged to the production alternatives by the amounts used in each alternative. Annual per acre costs were then combined with the number of acres established (20), renovated (40 in the grass-legume systems), and maintained (180 in the grass systems; 140 in the grass-legume systems) each year to compute total annual pasture costs. Like pasture costs, operating expenses

TABLE IV-12

ORGANIZATION AND ITEMS OF THE BUDGETARY COMPONENT

Gross Receipts

- A. Cattle Sales
 - 1. Steer Calves
 - 2. Heifer Calves
 - 3. Non-Breeding Heifers
 - 4. Culled Cows
 - 5. Aged Bulls
 - 6. Cow-Calf Pairs
- B. Hay Sales

Operating Expenses

- A. Pasture Costs
 - 1. Establishment Costs
 - a. Seed (Sprigs)
 - b. Fertilizer and Lime
 - c. Machinery¹ Repairs, Fuel and Lubrication
 - 2. Renovation Costs
 - a. Seed and Inoculant
 - b. Fertilizer
 - c. Machinery Repairs, Fuel and Lubrication
 - 3. Annual Costs
 - a. Seed and Inoculant¹
 - b. Fertilizer
 - c. Machinery Repairs, Fuel and Lubrication
- B. Hay Costs
 - 1. Production
 - a. Twine
 - b. Machinery Repairs, Fuel and Lubrication
 - 2. Purchased Hay
- C. Cattle Costs
 - 1. Salt and Mineral
 - 2. Veterinary and Medicine
 - 3. Marketing
 - 4. Bull Replacement
 - 5. Machinery Repairs, Fuel and Lubrication
 - 6. Equipment Repairs
- D. Labor Costs
 - 1. Purchased Labor
- E. Operating Capital Costs

TABLE IV-12 (continued)

Fixed Expenses²

- A. Pasture Costs
 - 1. Machinery Depreciation, Interest, Insurance and Property Taxes
- B. Hay Costs
 - 1. Machinery Depreciation, Interest, Insurance and Property Taxes
- C. Cattle Costs
 - 1. Machinery Depreciation, Interest, Insurance and Property Taxes
 - 2. Equipment Depreciation, Interest, Insurance and Property Taxes

Net Returns

- A. Returns above Operating Expenses
- B. Returns above Operating and Fixed Expenses

Tax Accounting

- A. Machinery, Equipment and Bull Depreciation Deductions
- B. Taxes on Returns above Operating and Fixed Expenses

After-Tax Net Returns

- A. Annual Returns above Operating, Fixed and Tax Expenses
- B. Present Value of the Annual After-Tax Net Income Stream for Ten Years

¹Costs incurred only in the grass-legume systems.

²Fixed expenses were charged at the rate machinery and equipment items were used in each production alternative.

for hay production were charged on the number of acres actually harvested in each production alternative. Purchased hay was charged at the prevailing hay price according to the amount used in months extra hay was needed, plus a per ton hauling charge.

Annual operating expenses for cattle included salt and mineral, medical, marketing, bull replacement, and variable machinery and equipment costs. Each production alternative incurred annual cattle costs according to the number of head actually maintained on the operation during the year. Bull replacements were charged the prevailing market price in months prior to breeding when bulls were acquired. Machinery and equipment variable expenses were set according to annual machinery and equipment usage.

Labor expenses incurred each year included only labor required above the supply available to the cattle operation. Purchased labor was acquired in the amount and during the months needed at an hourly rate. Operating capital charges were set according to the annual operating expenses, using the prevailing interest rate for operating loans.

Fixed Expenses. Annual fixed expenses included fixed machinery and equipment costs associated with pasture, hay and cattle production. Fixed costs of machinery and equipment items were depreciation, interest, insurance and property taxes. A straight-line schedule was used to depreciate each item over its economic life (see Chapter III). Interest charges were based upon the average amount of capital invested during the ownership period, and were calculated using the annual prevailing interest rate for intermediate-term loans. Insurance costs

were also computed on the average capital invested using the prevailing insurance rate. Purchase prices and resulting annual tax rates were used to determine machinery and equipment property tax expenses each year.

Total annual fixed costs included the sum of depreciation, interest, insurance and property taxes for each of the machinery and equipment categories. Fixed costs charged each production alternative were based upon annual usage rates of machinery and equipment items in each alternative. Full ownership of livestock was assumed in each production alternative. Replacement heifers were used to replenish the cow herd each year. Investments in land and the cow herd and resident labor supply were considered as an initial unit of owned and operator contributed resources, and were not charged in net returns calculations.

Net Returns and Tax Accounting. Annual net returns from the cattle operation were determined by deducting from gross receipts the relevant expense items. Two net return measures summarized each year were returns above the specified operating expenses and returns above the specified operating and fixed expenses.

Tax accounting of the cattle operation was also considered. For income tax purposes the depreciation accruing each year for machinery, equipment and bulls was calculated. Machinery and equipment tax depreciation was specified as seven year property, while bulls had a five year recovery period. Depreciation was spread over the years using a straight-line schedule. Annual machinery, equipment and bull depreciation were used as a tax deduction, and net returns above

operating and fixed expenses were adjusted accordingly. Taxes were charged on returns above operating and fixed expenses according to the relevant tax bracket. Returns below \$29750 were taxed at a 15 percent marginal tax rate, while tax charges on net returns above this level were at a 28 percent marginal rate (Internal Revenue Service). Finally, after-tax net returns above the specified operating and fixed costs were summarized for each year of the ten-year span.

To compare and evaluate the eight production alternatives the net present value of after-tax net returns was computed for each iteration of the model. The net income stream accruing over the ten years (1989-1998) of an iteration was discounted to the 1989 price level using a 10 percent discount rate. Cumulative probability distributions of the income streams for 100 iterations were summarized for each production alternative. Relative profitability and riskiness of the alternatives were evaluated for cattle producers with adverse, neutral and loving risk preferences according to stochastic dominance criterion.

CHAPTER V

RESULTS AND DISCUSSION

Primary objectives of this research were to compare and evaluate the physical and economic performance of production alternatives on a commercial feeder calf operation. The alternatives in question were tall fescue and bermudagrass/tall fescue pasture systems, as grass stands and each with renovation of legumes (red clover and annual lespedesa), for feeder calf production in spring and fall calving systems. Each system was characterized by unique annual production, marketing and managerial traits. Success of the cattle operation under each alternative was examined in a stochastic climatic and economic environment.

A simulation model, COMFABS, was developed to examine the effect of uncertain conditions upon the performance of a representative cattle operation in West Tennessee. To obtain a representative sampling of the stochastic processes inherent in the model, a ten-year planning horizon was simulated for 100 iterations. Eight production alternatives were examined. Included were the combination of four forage systems, tall fescue (TF), bermudagrass/tall fescue (BF), tall fescue + legumes (TFL), and bermudagrass/tall fescue + legumes (BFL), with two calving systems, spring calving (SC) and fall calving (FC).

To facilitate the following discussions the production alternatives were designated as TFSC and TFFC for the tall fescue forage system with spring and fall calving herds; BFSC and BFFC for the

bermudagrass/tall fescue system with spring and fall herds; TFLSC and TFLFC, and BFLSC and BFLFC for the tall fescue + legumes and bermudagrass/tall fescue + legumes systems, respectively, with spring and fall herds. Resulting statistics for the eight production alternatives are presented and compared in the remainder of this chapter. Annual statistics for selected physical and economic variables are presented. In addition, budgetary performance of the cattle operation under each alternative is evaluated in each year of the ten-year span. Also, cumulative probability distributions of selected physical and economic performance variables are examined. After-tax net present value of income CPDs are ranked via stochastic dominance.

Comparisons among the production alternatives were made according to the intended objectives of this study. Returns and risks associated with using tall fescue (TF) versus bermudagrass/tall fescue (BF) grass pasture systems were described. A comparison of each grass system with renovation of legumes (TFL and BFL) was further made. Fall calving (FC) and spring calving (SC) systems were also compared.

Results and Comparison of the Production Alternatives

The effects each production alternative had upon the representative cattle operation were evaluated in each of three respects. The forage systems were evaluated by yield and quality variables, in addition to hay system performance and management variables. Animal performance in spring and fall calving herds on each forage system were then compared. Cattle variables, including herd numbers, sales, and animal weights, were examined in each alternative. Ultimately,

financial characteristics of the cattle operation under each production alternative were evaluated. Receipts, expenses and three measures of net returns were compared examined. Since the ten-year planning span was simulated 100 times for each alternative, the annual summary statistics were developed from 1000 years of observations.

Forage System Performance

Selected annual forage system performance statistics for the production alternatives are shown in Table V-1. Summarized variables include those describing annual forage production, hay production at each of the two cuttings, and hay management.

Forage Production. Annual forage yield was the amount of forage growth (lbs. dry matter) accumulated each year from January 1 through December 31. Mean yield in the grass systems was lower for the tall fescue (TF) system (5827.64 lbs. DM per acre) than the bermudagrass/tall fescue (BF) mixture (6233.46 lbs. DM per acre). Yield variability¹, however, was greater in the TF system. When each grass stand was renovated, mean yields increased by more than 600 pounds of dry matter per acre (TFL = 6471.25 lbs. DM per acre; BFL = 6857.50 lbs. DM per acre). Renovating tall fescue pastures (TFL) did reduce yield variation as compared to the grass stand alone, while renovated bermudagrass/tall fescue pastures (BFL) resulted in only a slight increase in yield variation compared to the BF system. Among

¹Yield variability, as with the variability of the other performance variables, was measured by the standard deviation of each distribution.

TABLE V-1

SELECTED FORAGE SYSTEM ANNUAL PERFORMANCE STATISTICS¹ FOR THE
CATTLE OPERATION UNDER FOUR FORAGE SYSTEMS (TF, BF, TFL, and BFL)
WITH SPRING AND FALL CALVING SYSTEMS (SC and FC)

Variable	Forage and Calving Systems ²							
	TFSC	TFFC	BFSC	BFFC	TFLSC	TFLFC	BFLSC	BFLFC
<u>Forage Production</u> ³								
Forage Yield (lbs. DM per acre) ⁴								
Mean	5827.64		6233.46		6471.25		6857.50	
Std Dev	145.12		100.04		133.30		120.00	
Minimum	5295.86		5911.00		6060.36		6505.35	
Maximum	6216.25		6506.07		6935.17		7311.03	
Forage Quality (% TDN)								
Mean	54.50		53.37		56.16		55.38	
Std Dev	0.00		0.02		0.01		0.02	
Minimum	54.50		53.32		56.13		55.34	
Maximum	54.50		53.46		56.18		55.41	
<u>Hay Production (first cutting)</u>								
Hay Acreage (acres)								
Mean	70.00	50.00	50.00	40.00	60.00	60.00	50.00	40.00
Std Dev	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Minimum	70.00	50.00	50.00	40.00	60.00	60.00	50.00	40.00
Maximum	70.00	50.00	50.00	40.00	60.00	60.00	50.00	40.00
Hay Yield (tons per acre)								
Mean	1.43	1.51	1.68	1.77	1.66	1.66	1.78	1.85
Std Dev	0.06	0.07	0.05	0.05	0.08	0.08	0.07	0.07
Minimum	1.23	1.30	1.53	1.61	1.47	1.47	1.61	1.68
Maximum	1.64	1.73	1.85	1.95	2.07	2.07	2.19	2.27
Hay Quality (% TDN)								
Mean	60.00	60.00	59.37	59.37	61.13	61.13	60.71	60.71
Std Dev	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Minimum	60.00	60.00	59.37	59.37	61.11	61.11	60.70	60.69
Maximum	60.00	60.00	59.37	59.37	61.15	61.15	60.73	60.73
<u>Hay Production (second cutting)</u>								
Hay Acreage (acres)								
Mean	0.00	28.90	20.00	38.31	0.00	18.62	20.00	46.62
Std Dev	0.00	3.03	0.00	3.75	0.00	3.45	0.00	5.35
Minimum	0.00	20.00	20.00	30.00	0.00	10.00	20.00	30.00
Maximum	0.00	30.00	20.00	40.00	0.00	20.00	20.00	50.00

TABLE V-1 (continued)

Variable	Forage and Calving Systems							
	TFSC	TFFC	BFSC	BFFC	TFLSC	TFLFC	BFLSC	BFLFC
Hay Yield (tons per acre)								
Mean	0.00	1.40	1.64	1.90	0.00	1.73	1.64	1.83
Std Dev	0.00	0.06	0.08	0.06	0.00	0.06	0.08	0.04
Minimum	0.00	1.19	1.12	1.69	0.00	1.54	1.12	1.64
Maximum	0.00	1.65	1.88	2.08	0.00	1.92	1.88	1.97
Hay Quality (% TDN)								
Mean	0.00	55.00	51.86	52.01	0.00	55.26	52.95	53.02
Std Dev	0.00	0.00	0.05	0.03	0.00	0.01	0.04	0.02
Minimum	0.00	55.00	51.71	51.93	0.00	55.17	52.84	52.95
Maximum	0.00	55.00	52.16	52.16	0.00	55.27	53.11	53.10
<u>Hay Management</u>								
Hay Fed (tons)								
Mean	58.74	82.52	79.73	110.11	60.48	88.23	83.20	112.25
Std Dev	0.74	0.86	0.71	1.08	0.69	2.66	0.73	3.19
Minimum	56.39	79.67	78.35	105.02	58.63	80.17	81.10	104.88
Maximum	61.00	85.36	82.91	113.57	62.59	92.41	85.16	123.59
Hay Purchased and Fed (tons)								
Mean	0.00	0.10	4.35	2.51	0.25	3.48	0.37	2.59
Std Dev	0.00	0.73	1.57	2.06	0.77	7.13	1.17	6.52
Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	0.00	9.20	6.79	12.25	3.64	22.99	4.30	22.82
Hay Sold (tons)								
Mean	14.42	4.67	10.34	0.07	9.74	4.66	6.26	6.85
Std Dev	3.67	3.12	2.73	0.36	3.93	4.31	2.31	5.88
Minimum	2.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	26.13	15.13	21.95	3.55	25.28	21.70	13.48	22.27

¹The statistics presented in this table were based upon annual measurements of each variable for 100 iterations of 10 years. Thus, statistics were based upon a sample size of 1000 observations.

²The forage and calving systems are: TFSC=tall fescue and spring calving; TFFC=tall fescue and fall calving; BFSC=bermudagrass/tall fescue and spring calving; BFFC=bermudagrass/tall fescue and fall calving; TFLSC=tall fescue plus legumes and spring calving; TFLFC=tall fescue plus legumes and fall calving; BFLSC=bermudagrass/tall fescue plus legumes and spring calving; and, BFLFC=bermudagrass/tall fescue plus legumes and fall calving.

TABLE V-1 (continued)

³Statistics are identical for the forage systems with both calving herds since annual forage production is independent of the calving system utilized.

⁴Reported yields are prior to the 10 percent deduction for grazing and hay harvesting losses.

all systems, however, differences in observed yield variations were slight.

Mean forage quality reported in each system was the annual average quality (percent total digestible nutrients) of each month. Quality of tall fescue is higher than that of bermudagrass, resulting in a greater annual mean estimate in the TF system (54.50% TDN) than the BF system (53.37% TDN). Legumes enhance forage quality. Thus, both renovated systems, TFL and BFL, had a higher mean forage quality (56.16 and 55.38% TDN, respectively) than the grass systems. Because forage quality data were unavailable, climatic effects on quality could not be measured. Forage quality during a year was specified for each month and varied solely by the estimated proportions of each species in the forage mixture. Consequently, annual observed variations of quality in the forage systems were slight.

Hay Production. The acreage used for hay production in each production alternative was set by the long-term decision component (LP) of the model. Any variation from this level represents acreage adjustments necessary to compensate for poor forage production. Comparing the resulting mean acreage used for first cutting hay in each alternative to the long-term plan reveals that forage production during April through June was never so poor as to necessitate grazing of hay acreage. Thus all of the acreage idled for first cutting hay in each forage system was harvested. However at the second cutting of hay, acreage adjustments were required in some instances. Production alternatives using fall calving grazed a portion of acreage idled for hay during July through September in low yield years. These adjust-

ments were slight, with no more than ten or twenty hay acres diverted to grazing in any year.

Mean hay yields at each cutting followed much the same pattern across alternatives as forage yields. First cutting hay yields were highest in the BF systems, and increased in both the TF and BF systems with renovation (TFL and BFL). At the second cutting, hay yields improved when the TF system was renovated (TFL) and were similar in the BF and BFL systems. The mean hay quality at each cutting exhibited a pattern similar to that of forage quality among the alternatives. Hay quality was higher in the renovated forage systems (TFL and BFL) when compared to the corresponding grass systems (TF and BF). Tall fescue tended to provide a higher quality hay than bermudagrass. Due to the data limitations previously mentioned, only slight annual variations in hay quality were observed.

Hay Management. Three variables, hay fed, hay purchased, and hay sold, were summarized to describe hay management on the cattle operation under each alternative. Mean hay fed is the average annual tonnage fed from farm inventory. BF systems supported larger herds, and thus generally required more hay than the TF systems. The most prominent difference among the alternatives was in the amount of hay fed in spring and fall calving systems. Fall herds required over 20 tons more hay annually than the spring herds with each forage system. Also, variability in the hay feeding level was much greater in the fall calving systems, although in absolute terms none of the systems experienced substantial variability.

In cases where the operation was short of hay during the winter the deficit was alleviated by purchasing hay. Mean hay purchased is the annual average tonnage purchased and fed. Little hay above farm inventory was required in most of the alternatives. Fall calving systems required more extra hay, particularly in the renovated systems, than spring calving systems. These systems were also more variable in the amount of hay required.

Annual average tonnage of hay sold was measured as the mean amount of hay sold in October of each year. The operator sold excess hay production during a year if the October inventory was above the average in a normal year, plus a 10-percent buffer. Spring calving systems tended to sell more and purchase less hay than their counterpart fall calving systems. This same relationship held when examining the variations in hay purchased and sold each year.

Cattle System Performance

Cattle system performance variables summarized for each alternative include annual herd size and sales, cow performance, and calf and heifer weights. These annual statistics for the production alternatives are presented in Table V-2.

Herd Size and Calf Sales. Annual herd size was the number of cows maintained on the cattle operation prior to weaning and culling each year. Long-term herd size was set by the decision component (LP) of the model. Since the cattle operation was not allowed to purchase additional cows in response to changing conditions, variations from the long-term herd size of each alternative would be due to reduced stocking. Cows were sold early each year (i.e. prior to the normal

TABLE V-2

SELECTED CATTLE SYSTEM ANNUAL PERFORMANCE STATISTICS¹ FOR THE
CATTLE OPERATION UNDER FOUR FORAGE SYSTEMS (TF, BF, TFL, and BFL)
WITH SPRING AND FALL CALVING SYSTEMS (SC and FC)

Variable	Forage and Calving Systems ²							
	TFSC	TFFC	BFSC	BFFC	TFLSC	TFLFC	BFLSC	BFLFC
<u>Herd Size and Calf Sales</u>								
Cow Herd Size (head)								
Mean	101	104	126	126	107	120	132	136
Std Dev	0	0	0	0	0	0	0	0
Minimum	101	104	126	126	107	120	132	136
Maximum	101	104	126	126	107	120	132	136
Steer Calves Sold (head)								
Mean	45	46	56	56	47	53	58	60
Std Dev	0	0	0	0	0	0	0	0
Minimum	45	46	56	56	47	53	58	60
Maximum	45	46	56	56	47	53	58	60
Heifer Calves Sold (head)								
Mean	25	25	31	31	26	29	32	33
Std Dev	0	0	0	0	0	0	0	0
Minimum	25	25	31	31	26	29	32	33
Maximum	25	25	31	31	26	29	32	33
<u>Cow Performance</u>								
Cow Weight (pounds)								
Mean	1148.7	1172.6	1087.0	1124.9	1168.0	1142.5	1113.1	1110.4
Std Dev	22.4	18.4	48.0	30.9	13.2	17.0	51.7	19.0
Minimum	993.9	1067.5	925.6	1020.6	1115.4	1081.7	913.7	1026.9
Maximum	1175.7	1189.6	1169.6	1181.7	1175.7	1187.9	1174.0	1153.7
Milk Production (pounds per day)								
Mean	15.53	15.14	15.16	14.12	17.32	14.74	16.08	14.95
Std Dev	0.43	0.41	0.35	0.14	0.37	0.35	0.31	0.28
Minimum	14.38	14.08	13.74	13.72	16.33	14.07	15.13	14.16
Maximum	16.77	15.89	15.95	14.96	18.09	16.42	17.01	15.71
<u>Calf and Heifer Weights</u>								
Steer Calf Weaning Weight (pounds)								
Mean	544.1	537.8	491.2	470.1	606.0	526.1	513.6	490.7
Std Dev	15.3	13.8	12.6	8.4	12.4	13.9	12.2	14.5
Minimum	492.3	492.4	441.1	446.9	568.9	493.4	480.0	461.8
Maximum	583.7	579.7	521.4	522.4	645.2	579.7	555.0	562.4

TABLE V-2 (continued)

Variable	Forage and Calving Systems							
	TFSC	TFFC	BFSC	BFFC	TFLSC	TFLFC	BFLSC	BFLFC
Heifer Calf Weaning Weight (pounds)								
Mean	460.6	455.7	418.2	401.0	510.4	446.1	436.2	417.7
Std Dev	12.4	11.1	10.2	6.8	9.9	11.2	9.9	11.7
Minimum	418.8	419.0	377.7	382.2	480.6	419.7	409.1	394.3
Maximum	492.6	489.3	442.5	443.1	541.8	489.3	469.5	475.3
Replacement Heifer Breeding Weight (pounds)								
Mean	645.5	682.5	568.5	602.9	708.0	675.1	588.5	620.2
Std Dev	16.1	11.4	11.0	8.0	12.8	12.1	10.4	13.2
Minimum	588.4	644.4	530.0	581.7	667.9	645.3	554.0	592.4
Maximum	701.0	724.4	598.4	658.2	749.7	720.0	625.3	682.4
Replacement Heifer Calving Weight (pounds) ³								
Mean	998.7	1000.0	883.4	926.7	1000.0	1000.0	907.0	954.5
Std Dev	5.0	0.0	11.2	10.9	0.0	0.0	10.9	16.8
Minimum	952.0	1000.0	841.2	902.4	1000.0	1000.0	946.0	1000.0
Maximum	1000.0	1000.0	990.6	1000.0	1000.0	1000.0	988.2	1000.0

¹The statistics presented in this table were based upon annual measurements of each variable for 100 iterations of 10 years. Thus, statistics were based upon a sample size of 1000 observations.

²The forage and calving systems are: TFSC=tall fescue and spring calving; TFFC=tall fescue and fall calving; BFSC=bermudagrass/tall fescue and spring calving; BFFC=bermudagrass/tall fescue and fall calving; TFLSC=tall fescue plus legumes and spring calving; TFLFC=tall fescue plus legumes and fall calving; BFLSC=bermudagrass/tall fescue plus legumes and spring calving; and, BFLFC=bermudagrass/tall fescue plus legumes and fall calving.

³Replacement heifer weights were constrained at 1000 pounds, the assumed weight of a brood cow in good condition.

17-percent culling at weaning) as a last resort in situations of poor forage production.

Mean cow herd size in all of the production alternatives remained constant in every year simulated. Given the results observed in each forage system, this outcome was expected. Reduced stocking occurred in poor forage production years only after acreage was diverted from hay to grazing, hay was fed, and/or calves were sold early. Because little hay acreage was required for grazing and hay feeding levels exhibited only slight variations, forage conditions never became severe enough to cause stocking reductions. Consequently, herd sizes remained stable at the long-term levels.

These same factors explain why the number of steer and heifer calves sold each year was constant in each alternative. Any variations in the number of calves would result from herd reductions causing cow-calf pairs to be sold. Reduced stocking was unnecessary in any of the production alternatives, therefore all calves were sold at weaning each year.

Cow Performance. Two variables, weight and milk production, were used to summarize annual performance of cows in each production alternative. Mean cow weight was the annual average weight (pounds) of each month. In this study a 1000-pound weight was used to describe a cow in good body condition. Weight variations above and below 1000 pounds, therefore, represent body condition changes. Annual mean cow weight in the production alternatives ranged from 1087.0 (BFSC) to 1172.6 (TFFC) pounds, indicating cows retained excess condition in each alternative. Cows in the fall calving systems were found to be

somewhat heavier than spring calving cows in the grass forage systems, and much the same weight in the renovated systems. Also, fall calving cows had less variable weights than spring calving cows in most instances. Differences among the forage systems were also observed. Cows grazing in the BF systems exhibited wider variations in weight, and thus condition, than cows grazing in the TF systems.

Mean cow milk production was the annual average milk production (pounds of milk per day) in each month cows were lactating. The resulting milk estimates indicated that spring calving cows performed better than fall calving cows during lactation. In each production alternative, spring calving cows produced more milk per day than their fall counterparts. The forage supply was greater and of a higher quality during months when spring calving cows were lactating, as opposed to fall calving lactation months. Among the forage systems, cows achieved greater average lactation levels in the renovated systems (TFL and BFL) than in the corresponding grass systems (TF and BF). Higher maximum and minimum bounds were specified for the renovated systems. Also, cow lactation was generally superior in the TF systems compared to the BF systems. Higher forage quality and lower stocking pressure in the TF systems likely account for this difference.

Calf and Heifer Weights. One of the more commonly examined performance measures of cow-calf production is the weight at which calves are weaned and sold each year. Statistics on weaning weights were summarized for both steer and heifer calves. Mean steer and heifer calf weaning weights are the annual average weights observed in

the respective weaning months of the spring and fall herds. Among the production alternatives, mean weaning weights ranged from 470.1 (BFFC) to 606.0 (TFLSC) pounds for steer calves, and 401.0 (BFFC) to 510.4 (TFLSC) pounds for heifer calves. Spring-born calves were generally weaned at a heavier weight than fall-born calves. Differences in weight variability for the spring and fall herds were only slight. Spring herd weaning weights were more variable than those of the fall herd with the grass systems (TF and BF), while with the renovated systems (TFL and BFL) fall herd weaning weights were more variable. Comparing mean weights across forage systems reveals much higher weights were obtained with the TF systems versus the BF systems, and generally higher weights were achieved in the renovated as opposed to the grass systems. Forage quality and stocking pressure differences among forage systems were the likely causes of these differences.

Two weight measurements were taken for replacement heifers in each production alternative. Mean replacement heifer breeding weight was the average annual weight achieved by weaned heifers at breeding. To obtain a high conception rate and ensure heifers are big enough at calving, a common recommendation is that heifers weigh 600-650 pounds before being bred (Cook). Generally, the production alternatives achieved breeding weights within or above this recommended range. However on the average, the BFSC and BFLSC systems fell short of the 600-pound minimum weight at 568.5 and 588.49 pounds, respectively. In contrast to calf weaning weights, heifer breeding weights were generally higher in fall than in spring calving systems. Fall born heifers were carried through the summer before breeding, whereas spring born

heifers are overwintered and thus tended to gain less from weaning to breeding. Like calf weights, heifer breeding weights were generally higher in the renovated systems than in the grass systems, and in the TF versus the BF systems.

Once bred, heifers should be fed to achieve 900-950 pounds of weight at calving (Cook). Each production alternative was on the average, near, at, or above this weight goal. Mean heifer calving weight measures the annual average weight of replacement heifers at calving. Among the production alternatives, weight comparisons were very similar to those of breeding weight. Fall calving heifers generally weighed more than spring calving heifers when calving. Heifers grazing in the TF systems were heavier at calving than heifers in the BF systems.

Financial Characteristics and Performance

Annual financial characteristics of the cattle operation with each production alternative are shown in Table V-3. Costs of purchased inputs, calf prices received, receipts and expenses, and net return statistics were summarized for each alternative.

Costs of Purchased Hay and Labor. Mean cost of purchased hay represents the annual average cost incurred by the cattle operation due to necessary hay purchases. Purchased hay was required in seven of the eight alternatives, with average annual costs ranging from \$7 (TFSC) to \$314 (BFSC). Except for the BFSC and BFFC alternatives, higher hay costs were incurred in the fall calving systems relative to the spring calving systems. With each forage system, purchased hay costs were more variable with the fall herd. BF systems required more

TABLE V-3

SELECTED ANNUAL FINANCIAL STATISTICS¹ FOR THE CATTLE OPERATION
UNDER FOUR FORAGE SYSTEMS (TF, BF, TFL, and BFL) WITH
SPRING AND FALL CALVING SYSTEMS (SC and FC)

Variable	Forage and Calving Systems ²							
	TFSC	TFFC	BFSC	BFFC	TFLSC	TFLFC	BFLSC	BFLFC
<u>Costs of Purchased Hay and Labor</u>								
Cost of Purchased Hay (dollars)								
Mean	0	7	314	179	17	233	25	173
Std Dev	0	49	120	148	51	476	74	435
Minimum	0	0	0	0	0	0	0	0
Maximum	0	652	562	784	243	1744	303	1652
Cost of Purchased Labor (dollars)								
Mean	1103	1272	1023	1446	931	1803	1624	1842
Std Dev	174	201	161	239	147	284	256	318
Minimum	862	994	799	1035	727	1408	1269	1135
Maximum	1411	1627	1309	1879	1191	2306	2078	2458
<u>Prices Received for Calves</u>								
Steer Calf Price (dollars per cwt.)								
Mean	87.72	90.85	91.37	96.67	84.44	90.93	88.21	95.57
Std Dev	10.48	9.83	11.88	11.37	9.91	9.90	10.70	11.26
Minimum	65.30	68.35	65.30	68.90	63.65	68.35	65.30	68.90
Maximum	118.05	122.47	127.83	132.42	118.05	125.23	123.25	132.42
Heifer Calf Price (dollars per cwt.)								
Mean	77.77	82.12	77.91	83.78	75.67	82.12	77.77	82.20
Std Dev	10.48	9.94	10.56	10.65	9.46	9.94	10.48	9.97
Minimum	52.46	56.73	52.46	56.73	53.86	56.73	52.46	56.73
Maximum	106.89	112.22	106.89	114.02	103.79	112.22	106.89	112.22
<u>Receipts and Expenses</u>								
Gross Receipts (dollars)								
Mean	43480	45784	50323	50554	47665	50977	52758	55719
Std Dev	5246	4995	6199	5760	5478	5662	6407	6370
Minimum	32679	33658	38085	37602	36356	37116	39924	41412
Maximum	57904	61762	68418	68050	63203	68607	69264	74625
Operating Expenses (dollars)								
Mean	19933	20616	24006	24641	22299	24588	25437	26535
Std Dev	2453	2554	3010	3072	2714	2793	3107	3077
Minimum	16623	17100	19699	20302	18711	20890	21416	22221
Maximum	24472	25584	29677	30884	27344	30699	31207	32641

TABLE V-3 (continued)

Variable	Forage and Calving Systems							
	TFSC	TFFC	BFSC	BFFC	TFLSC	TFLFC	BFLSC	BFLFC
Fixed Expenses (dollars)								
Mean	9109	9311	10773	10811	11043	11820	12754	13045
Std Dev	2109	2156	2494	2505	2557	2738	2953	3020
Minimum	6318	6428	7472	7472	7660	8170	8847	8994
Maximum	12979	13273	15350	15418	15734	16851	18173	18610
Tax Expenses (dollars)								
Mean	722	861	803	753	739	792	736	884
Std Dev	755	841	863	848	804	872	853	959
Minimum	0	0	0	0	0	0	0	0
Maximum	2555	2796	2741	2665	2688	2831	2736	2695
<u>Net Returns</u>								
Net Returns above Operating Expenses (dollars)								
Mean	23547	25168	26317	25913	25366	26389	27321	29183
Std Dev	5294	5337	6272	6183	5536	5980	6425	6752
Minimum	12741	13101	13785	13126	14084	12836	14445	14999
Maximum	34306	36350	39300	38370	36628	40246	40711	43927
Net Returns above Operating and Fixed Expenses (dollars)								
Mean	14438	15857	15544	15100	14324	14569	14567	16138
Std Dev	6182	6488	7334	7542	6714	7503	7736	8389
Minimum	2998	3668	1925	1779	2381	-76	-122	1424
Maximum	27540	29381	31299	30369	28427	30830	30586	33623
Net Returns above Operating, Fixed and Tax Expenses (dollars)								
Mean	13716	14996	14741	14347	13585	13777	13831	15254
Std Dev	5454	5667	6508	6734	5943	6667	6930	7470
Minimum	2998	3668	1925	1779	2381	-76	-122	1424
Maximum	27540	29381	31299	30369	28427	30830	30586	33623

¹The statistics presented in this table were based upon annual measurements of each variable for 100 iterations of 10 years. Thus, statistics were based upon a sample size of 1000 observations.

²The forage and calving systems are: TFSC=tall fescue and spring calving; TFFC=tall fescue and fall calving; BFSC=bermudagrass/tall fescue and spring calving; BFFC=bermudagrass/tall fescue and fall calving; TFLSC=tall fescue plus legumes and spring calving; TFLFC=tall fescue plus legumes and fall calving; BFLSC=bermudagrass/tall fescue plus legumes and spring calving; and, BFLFC=bermudagrass/tall fescue plus legumes and fall calving.

additional hay than corresponding TF systems, with the exception on the TFLFC alternative.

Labor was purchased for the cattle operation in each month when the available supply for cattle was insufficient to meet demand. Mean cost of purchased labor is the annual average cost attributed to labor purchases. Purchased labor was required in each of the examined alternatives. Average annual costs ranged from \$931 in the TFLSC alternative to \$1842 in the BFLFC alternative. Fall calving systems required more labor than the spring calving systems, and thus incurred higher annual costs. Because annual herd size and pasture management did not vary, the amount of annual purchased labor used by each alternative was constant. Cost variability reflects differences in the price of purchased labor each year.

Prices Received for Calves. Statistics on annual prices received for calves were summarized for both steer and heifer calves sold. Mean prices indicate the average annual price per hundredweight obtained for steer and heifer calves in the selling months of each alternative. Cattle price cycles were projected over the ten-year horizon for steers and heifers in varying weight categories. Prices received in each alternative reflect calf weight and market timing differences of each alternative.

The most obvious difference among the alternatives was in the calf prices received for fall--as compared to spring-born calves. On the average, fall-born calves were sold for approximately 3 to 7 dollars more per hundredweight than spring-born calves. Because average calf selling weights were similar for each herd, this result

was primarily attributed to the unique market timing of spring versus fall calving. Fall-born calves were sold at weaning in June, whereas spring-born calves were weaned and sold in October. The annual average price differences in these months provided a clear marketing advantage for the fall calving system.

Annual price received for calves was also higher in the BF systems compared to the TF systems. This difference reflects the weight differential observed for calves weaned in each of these systems. Calves produced in the BF systems were marketed at a lighter weight than calves in the TF systems, and thus were sold for a higher price.

Receipts and Expenses. Mean gross receipts describes the annual average dollar value obtained from the sale of farm outputs. Gross receipts were generated by annual steer and heifer calf sales, nonbreeding heifer sales, culled cow and bull sales, and cow-calf pair sales, in addition to any hay sold. Thus, a comparison of gross receipts among the alternatives provides an indicator of their relative production and price advantages.

Production alternatives including fall calving generated a greater annual value of sales than those using spring calving. Calf marketing provides the single largest source of annual receipts on a cow-calf operation. Because calf selling weights were, on the average, very similar in the fall and spring calving systems, the price advantage associated with marketing fall-born calves was reflected in higher gross receipts. In all instances, gross receipts increased when each grass pasture system was renovated with legumes. Higher

calf weights were obtained in the legume systems and the value of calves sold was greater, even at slightly lower calf prices.

Annual operating expenses were the cash expenses incurred by the cattle operation during the course of each year. Pasture, hay, cattle, labor and operating capital costs comprised the annual operating expenses (refer to Table IV-12 for the detailed list of items). Mean operating expenses indicate the annual average cash outlay for the purchase of items in each of the cost categories.

Average annual operating expenses were higher in production alternatives using fall calving compared to spring calving. These added costs were attributed to more purchased hay and labor, and more hay produced in systems using fall calving herds. Much higher operating expenses were incurred in alternatives that renovated grass pastures. Renovation costs, including additional seed, fertilizer and machinery usage, and higher annual pasture maintenance and labor costs resulted in a greater average cash outlay for annual production.

Fixed expenses included annual ownership costs for machinery and equipment used in pasture, hay and cattle production. Since the cattle operation was assumed to be part of a diversified farm where some machinery items are shared among the enterprises, fixed expenses were charged based on the proportion of annual machinery usage in forage and cattle production. Variability in fixed expenses among the alternatives, therefore, indicate differences in annual machinery usage. Within each production alternative, cost variations were due to changing prices and usage rates from year to year.

Because of the larger herd size annual machinery use and thus fixed expenses were greater for the BF systems than for the TF systems. Likewise, additional machinery use in renovated systems resulted in greater fixed expense charges as compared to the grass systems. Fixed expenses were also slightly higher for the fall calving systems than the spring calving systems, due to a greater annual usage of hay production equipment.

Income tax expenses were charged each year on returns above the operating and deductible fixed expenses. Mean tax expense for a production alternative is the annual average tax payment on net income. Tax expenses, therefore, were greater in the higher returning alternatives. Annual variation in tax expense was due to annual receipt and expense variations, and tax bracketing.

Net Returns. Annual net returns were computed above each of the expense categories. Summarized return measures were the net return above operating, above operating and fixed expenses, and above operating, fixed and tax expenses². Means of each category were the annual average net return generated by the cattle operation under each production alternative.

The BFLFC alternative provided the highest annual average net return above operating expenses (\$29,183), followed by the BFLSC

²Net return above operating expenses was the residual return to land, unpaid labor, fixed capital, livestock investment and management. Net return above operating and fixed expenses was the residual return to land, unpaid labor, livestock investment and management. Income tax expenses were deducted from the net return above operating and fixed expenses to compute after-tax net return.

(\$27,321) and TFLFC (\$26,389) alternatives. Fall calving systems generally had a higher average return above operating expenses than spring calving systems. Higher gross receipts from sales in the FC systems tended to more than offset the higher operating expenses. BF systems provided higher returns above operating expenses than TF systems in most instances. Annual average gross receipts and operating expenses were both higher in the BF systems, as opposed to the TF systems, thus the higher returns offset the higher costs. Other than the TFLSC alternative, renovated pasture systems ranked above the grass systems in terms of average returns above operating expenses.

When fixed costs were deducted the average net return comparison changed. Fall calving was still generally more profitable than spring calving; however, TF systems compared more favorably with the BF systems. Legume systems other than the BFLFC alternative were generally less profitable than the grass systems. Higher receipts from sales did not offset, in most instances, the additional fixed costs associated with pasture renovation. Among the production alternatives, BFLFC provided the highest mean net return above operating and fixed expenses (\$16,138), followed by the TFFC alternative (\$15,857). TFLSC and TFSC alternatives were least profitable (\$14,324 and \$14,438, respectively) when both operating and fixed expenses were considered.

Much the same ranking of production alternatives by net returns was obtained when tax expenses were deducted. BFLFC and TFFC alternatives were most profitable (\$15,254 and \$14,996, respectively), whereas TFSC and TFLSC alternatives were least profitable (\$13,716 and

\$13,585, respectively). In general, fall calving systems were more profitable than spring calving systems and legume systems were least profitable.

A comparison of the variability of net returns above operating, fixed and tax expenses was used to measure the relative riskiness of the production alternatives. While fall calving systems were generally more profitable, they also were more risky than spring calving systems. As measured by the standard deviations of each alternative, annual returns varied by about \$200 to \$7000 more in the FC versus the SC systems. Likewise, BF systems had more variable returns than TF systems, both with and without renovation. In addition, renovated systems had more variable returns than grass systems. Overall, the BFLFC and BFLSC alternatives were most risky (standard deviations of \$7,470 and \$6,930, respectively), while TFSC and TFFC alternatives were least risky (standard deviations of \$5,454 and \$5,667, respectively). Maximum returns attainable were highest in the BFLFC (\$32,005) and the BFSC (\$28,989) alternatives. Only in the BFLSC and TFLFC alternatives were the minimum net returns in any year negative (-\$122 and -\$76, respectively).

Budgetary Comparison of the Production Alternatives in Each Year

To further evaluate the financial performance of the cattle operation under each production alternative, after-tax net returns were compared and ranked in each year of the ten-year span. Cattle and hay prices were projected each year according to historical cyclical price movements. Price and cost levels were specified to

reflect forecasts for each year of the planning horizon. Consequently, the annual projected net returns provide an indication of the annual profitability of the cattle operation with each alternative for 1989 through 1998.

Mean annual after-tax net returns and their ranking in each year for the production alternatives is shown in Table V-4. A graphical depiction of the after-tax net returns attributed to the three most profitable production alternatives in each year is illustrated in Figure V-1. Since output prices were projected to follow a cyclical pattern during the ten-year span, net returns tended to follow this same pattern. A ten-year cattle price cycle was specified to prevail over the planning horizon. Yearly returns and rankings of each production alternative, thus, were evaluated at different points of the cattle cycle. To facilitate the following discussions, the cattle price cycle was separated into four periods; the peak (1990 through 1991), the declining phase (1992 through 1994), the trough (1995 through 1996), and the rising phase (1989 and 1997 through 1998).

Peak Years (1990 and 1991)

The projected cattle price cycle reached its peak during 1990 and 1991. At this time cattle prices were highest. BFLFC and BFFC alternatives were, on the average, most profitable at the peak of the price cycle. TFLSC and TFSC were least profitable. Production alternatives utilizing fall calving ranked highest in mean net returns, earning the top two rankings in 1990 and the top four rankings in 1991. Likewise, BF systems were more profitable than TF systems, also achieving the highest rankings in both years. Renovated BF systems ranked higher

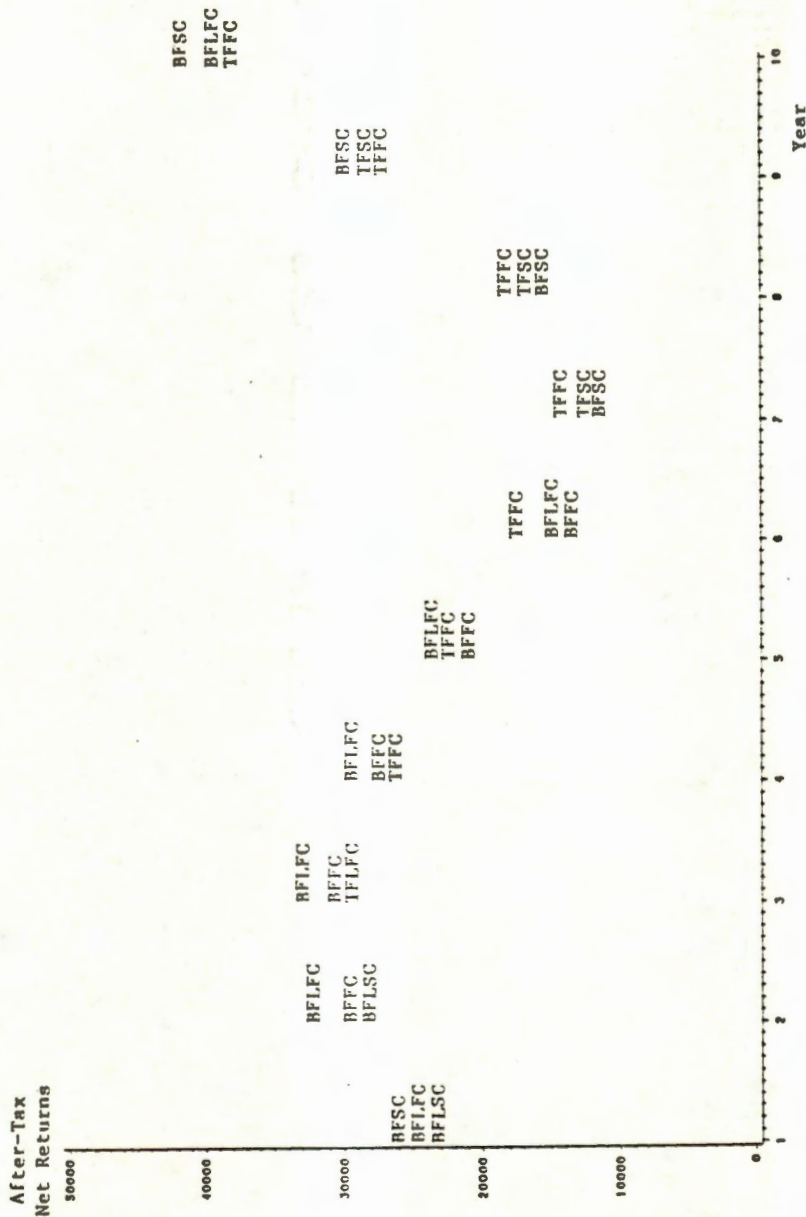
TABLE V-4

MEAN AFTER-TAX NET RETURNS AND RANKING BY YEAR FOR THE
CATTLE OPERATION UNDER FOUR FORAGE SYSTEMS (TF, BF, TFL and BFL)
WITH SPRING AND FALL CALVING SYSTEMS (SC and FC)

Forage and Calving ₂ Systems	Year									
	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
<u>Mean Annual After-Tax Net Returns (dollars)</u>										
TFSC	22703	25716	25618	22784	18167	13757	12662	17573	27719	38814
TFFC	23139	27496	28942	26754	22375	17111	15102	18061	26643	39300
BFSC	25507	28559	28403	24987	19164	13400	11601	17238	29408	42228
BFFC	23240	28778	30024	26923	21231	13986	10964	14076	23151	37674
TFLSC	22928	26764	26577	23540	18366	12924	10896	15663	25872	37005
TFLFC	22977	27444	29189	26110	20696	13777	10624	13076	20957	34674
BFLSC	24134	28598	28600	24464	18138	11386	8990	14065	25470	38565
BFLFC	24749	31426	32645	28967	22597	14434	11268	14147	23431	39582
<u>Annual Ranking¹ of After-Tax Net Returns</u>										
TFSC	8	8	8	8	7	5	2	2	2	4
TFFC	5	5	4	3	2	1	1	1	3	3
BFSC	1	4	6	5	5	6	3	3	1	1
BFFC	4	2	2	2	3	3	5	6	7	6
TFLSC	7	7	7	7	6	7	6	4	4	7
TFLFC	6	6	3	4	4	4	7	8	8	8
BFLSC	3	3	5	6	8	8	8	7	5	5
BFLFC	2	1	1	1	1	2	4	5	6	2

¹The production alternatives were ranked from 1 to 8, where 1 is the highest ranking and 8 the lowest ranking.

²The forage and calving systems are: TFSC=tall fescue and spring calving; TFFC=tall fescue and fall calving; BFSC=bermudagrass/tall fescue and spring calving; BFFC=bermudagrass/tall fescue and fall calving; TFLSC=tall fescue plus legumes and spring calving; TFLFC=tall fescue plus legumes and fall calving; BFLSC=bermudagrass/tall fescue plus legumes and spring calving; and, BFLFC=bermudagrass/tall fescue plus legumes and fall calving.



Legend: TFSC=tall fescue with spring calving, TFFC=tall fescue with fall calving, BFSC=bermudagrass/tall fescue with spring calving, BFFC=bermudagrass/tall fescue with fall calving, TFLSC=tall fescue plus legumes with spring calving, TFLFC=tall fescue plus legumes with fall calving, BFLSC=bermudagrass/tall fescue plus legumes with spring calving, BFLFC=bermudagrass/tall fescue plus legumes with fall calving

FIGURE V-1

MEAN AFTER-TAX NET RETURNS FOR THE CATTLE OPERATION WITH THE TOP THREE RATED PRODUCTION ALTERNATIVES IN EACH YEAR OF THE TEN-YEAR SPAN, 1989-1998

than the BF grass systems, while renovated and grass TF systems were ranked much the same.

Declining Phase Years (1992, 1993 and 1994)

After 1991, the projected cattle cycle began a downward trend approaching the trough by 1994. Cattle prices were declining throughout this period. Mean after-tax net returns were highest for the BFLFC and TFFC alternatives, and lowest in the BFLSC, TFSC and TFLSC alternatives. Compared to the previous period, fall calving systems were again most profitable with rankings well above those of spring calving systems. The competitive position of TF systems, however, did improve relative to the BF systems. TF systems generally climbed in ranking throughout this period as prices continued to decline.

Trough Years (1995 and 1996)

The projected cattle cycle bottomed in 1995 and was slightly higher in 1996. During these low price years the TFFC alternative was clearly superior to the other alternatives, ranking first in both 1995 and 1996. Compared to the previous years, spring calving fared much better relative to fall calving, and TF system rankings improved against BF systems. Renovated systems, however, generally declined in ranking or remained the same relative to the grass systems.

Rising Phase Years (1989, 1997 and 1998)

Projected cattle prices continued rising after 1996 and continued upward during 1997 and 1998. Prices were also rising at the beginning of the planning horizon in 1989. The BFSC alternative ranked first in each year prices moved upward, well ahead of the other alternatives.

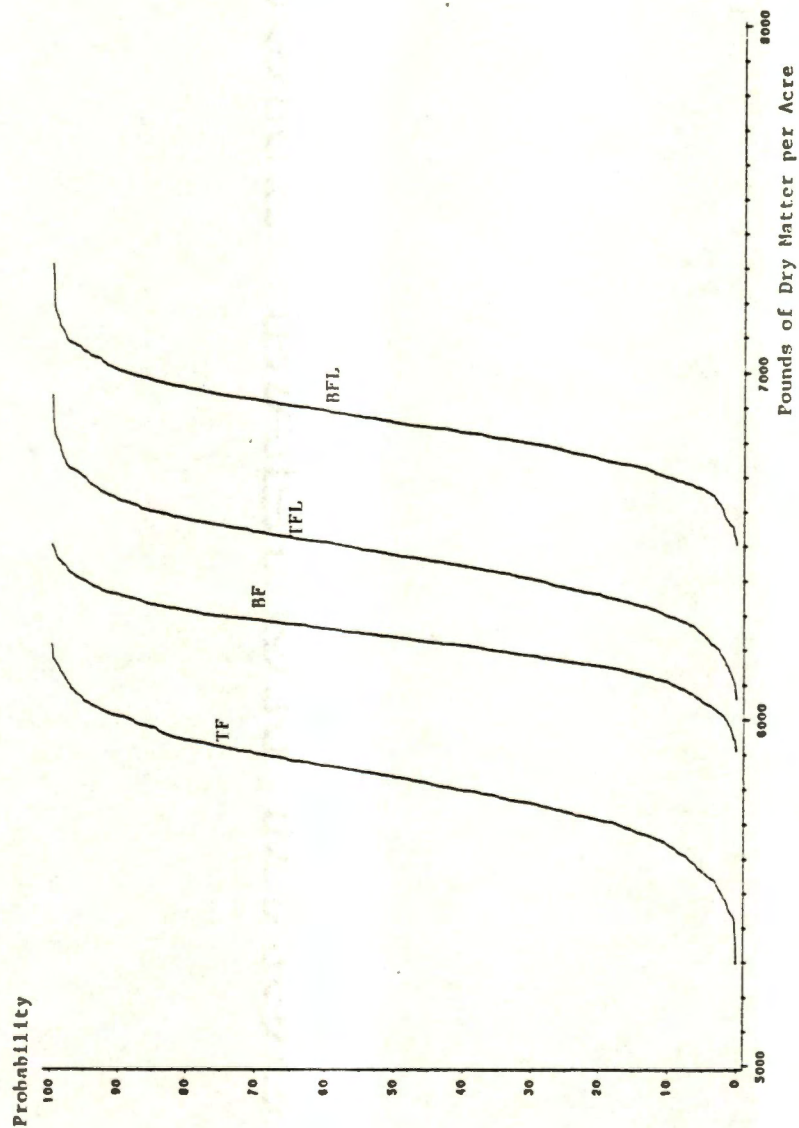
During this phase of the price cycle, no clear ranking of fall and spring calving systems, or TF versus BF systems was apparent. The legume systems, however, generally ranked below the grass systems.

Cumulative Probability Distributions of Selected Variables

Returns and risks associated with each production alternative were examined by the resulting cumulative probability distributions of selected performance variables. The cumulative probability distributions were developed from the simulated data sets of each alternative by sorting data on each variable in ascending order, and accumulating the probabilities of occurrence for each observation. CPDs of annual forage yield and average calf weaning weight, and the after-tax net present value of income were compared for the alternatives. Performance levels of each variable associated with various probabilities of attainment were also summarized and evaluated.

Annual Forage Yield

CPDs of annual forage yield from the four forage systems are plotted in Figure V-2. The distribution for the BFL system clearly dominated all other distributions since it was always positioned to the right of the others. Both renovated systems (TFL and BFL) were superior to the grass systems (TF and BF) in terms of annual forage yield. Likewise, the BF systems (BF and BFL) exhibited higher yields than the corresponding TF systems (TF and TFL, respectively). Because the forage systems differed very little in the annual estimated yield variability, CPDs for each system were found to have much the same slope and shape.



Legend: TF=tall fescue, BF=bermudagrass/tall fescue, TFL=tall fescue plus red clover and annual lespedesa legumes, BFL=bermudagrass/tall fescue plus red clover and annual lespedesa legumes

FIGURE V-2

CUMULATIVE PROBABILITY DISTRIBUTIONS OF ANNUAL FORAGE YIELD FOR THE CATTLE OPERATION UNDER FOUR FORAGE SYSTEMS

Annual forage yield at selected probabilities of attainment for each forage system are presented in Table V-5. The probabilities represent the estimated chance of achieving the associated forage yield in each system. These results further indicated the superior yields obtained in the renovated systems relative to the grass systems. At a yield level of 6500 pounds of dry matter per acre, the BFL and TFL systems had estimated probabilities of attainment of 100- and 40- to 50-percent, respectively. Estimated probabilities of achieving this yield level were 0-percent in both the TF and BF systems. BF systems also had greater probabilities of achieving higher yields than the associated TF systems.

Annual Average Calf Weight

Annual average calf weight is the average of steer and heifer calf weaning weights for each year. CPDs of calf weight in each production alternative are plotted in Figure V-3. The distribution for the TFLSC alternative clearly dominated all other distributions. Much higher forage yields were realized with the legume systems than the grass systems and thus, these systems supported more cows. However, the stocking rate was at a lower level for TFLSC than the other renovation alternatives (i.e. 107 cows in TFLSC versus 120 cows in TFLFC). Fewer animals used in this system allowed each cow and calf access to more forage and thus, produced higher calf gains. Distributions for the TF systems dominated those for the BF systems. Higher quality forage with tall fescue pastures and lower stocking levels were the likely explanations for this result. Also in most instances, heavier calves were produced with the renovated systems

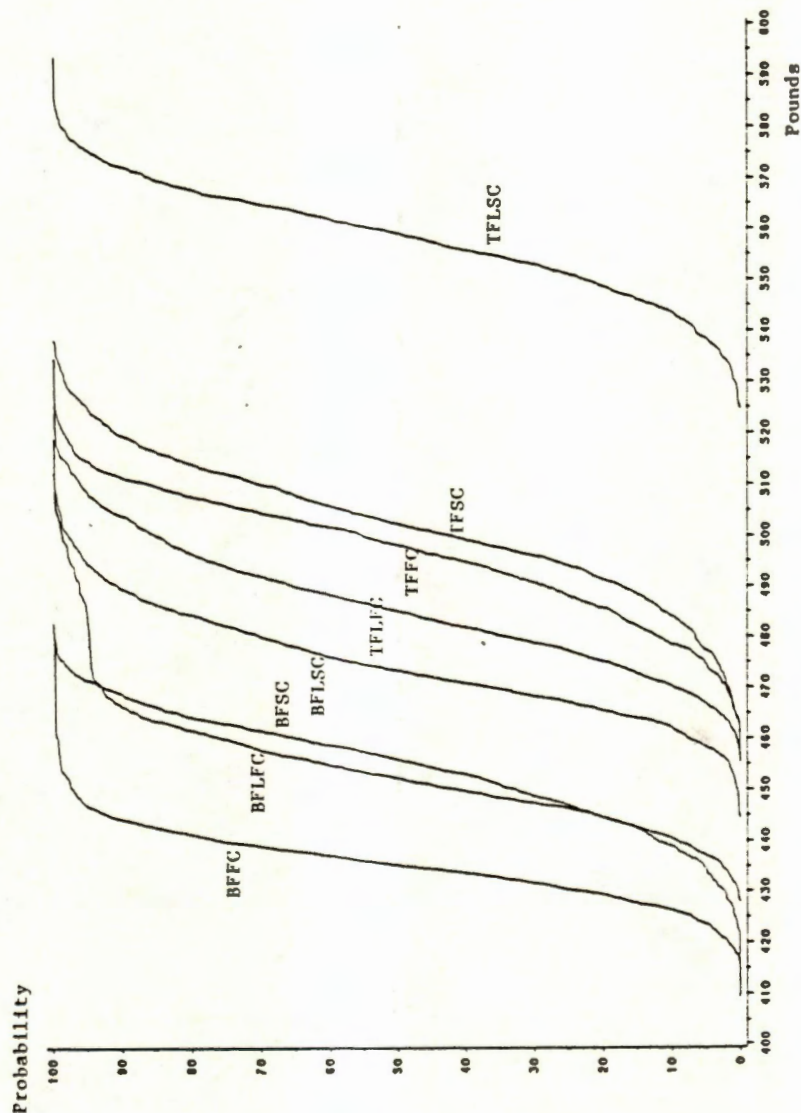
TABLE V-5

ANNUAL FORAGE YIELD BY SELECTED PROBABILITIES OF ATTAINMENT FOR THE
CATTLE OPERATION UNDER FOUR FORAGE SYSTEMS (TF, BF, TFL and BFL)

Probability ¹ (percent)	Forage System ²			
	TF	BF	TFL	BFL
----- pounds of dry matter per acre -----				
10	6010.43	6359.28	6632.32	7003.75
20	5940.34	6312.64	6576.48	6955.11
30	5902.25	6286.60	6540.48	6921.30
40	5868.32	6260.96	6510.82	6890.46
50	5835.91	6237.79	6473.75	6856.05
60	5797.86	6213.12	6442.88	6828.60
70	5761.23	6183.61	6405.72	6796.96
80	5712.51	6154.32	6361.57	6752.82
90	5640.94	6108.86	6298.44	6700.45
100	5295.86	5911.00	6060.36	6505.35

¹Probability represents the estimated percentage chance of achieving the reported yield in each forage system.

²The forage and calving systems are: TFSC=tall fescue and spring calving; TFFC=tall fescue and fall calving; BFSC=bermudagrass/tall fescue and spring calving; BFFC=bermudagrass/tall fescue and fall calving; TFLSC=tall fescue plus legumes and spring calving; TFLFC=tall fescue plus legumes and fall calving; BFLSC=bermudagrass/tall fescue plus legumes and spring calving; and, BFLFC=bermudagrass/tall fescue plus legumes and fall calving.



Legend: TFSC=tall fescue with spring calving, TFFC=tall fescue with fall calving, BFSC=bermudagrass/tall fescue with spring calving, BFFC=bermudagrass/tall fescue with fall calving, TFLSC=tall fescue plus legumes with spring calving, TFLFC=tall fescue plus legumes with fall calving, BFLSC=bermudagrass/tall fescue plus legumes with spring calving, BFLFC=bermudagrass/tall fescue plus legumes with fall calving

FIGURE V-3

CUMULATIVE PROBABILITY DISTRIBUTIONS OF ANNUAL AVERAGE CALF WEANING WEIGHT FOR THE CATTLE OPERATION UNDER FOUR FORAGE SYSTEMS WITH SPRING AND FALL CALVING

than with the corresponding grass systems. Spring herd weaning weights were greater than those obtained with the fall herd in each forage system. Lower stocking levels used in the spring herd systems were likely explanations for this difference.

The annual average calf weights at selected probabilities of attainment for each production alternative are shown in Table V-6. Probabilities indicate the estimated likelihood of achieving the reported calf weight in each production alternative. All alternatives provided a 100-percent probability of weaning an average calf above 400 pounds. Only in the four TF alternatives, however, was any estimated chance of producing a 500-pound average weaned calf obtained. Chances of weaning a 500-pound calf were 100 percent in the TFLSC alternative. For the TFSC and TFFC alternatives, a 50-percent probability existed for achieving an average weaning weight of 500 pounds. Lowest calf weights were obtained in the BFSC and BFFC alternatives, with average calf weights at the 100-percent probability level of just over 400 pounds.

After-Tax Net Present Value of Income

Annual net returns above operating, fixed and tax expenses were discounted to the 1989 price level using a 10-percent discount rate. The net income stream accruing over the ten years (1989-1998) of an iteration was summarized for each production alternative. Cumulative probability distributions of the income streams are plotted in Figure V-4.

Production alternatives TFFC, BFLFC and BFSC clearly dominated (i.e., were always preferred by all risk aversion groups) all other

TABLE V-6

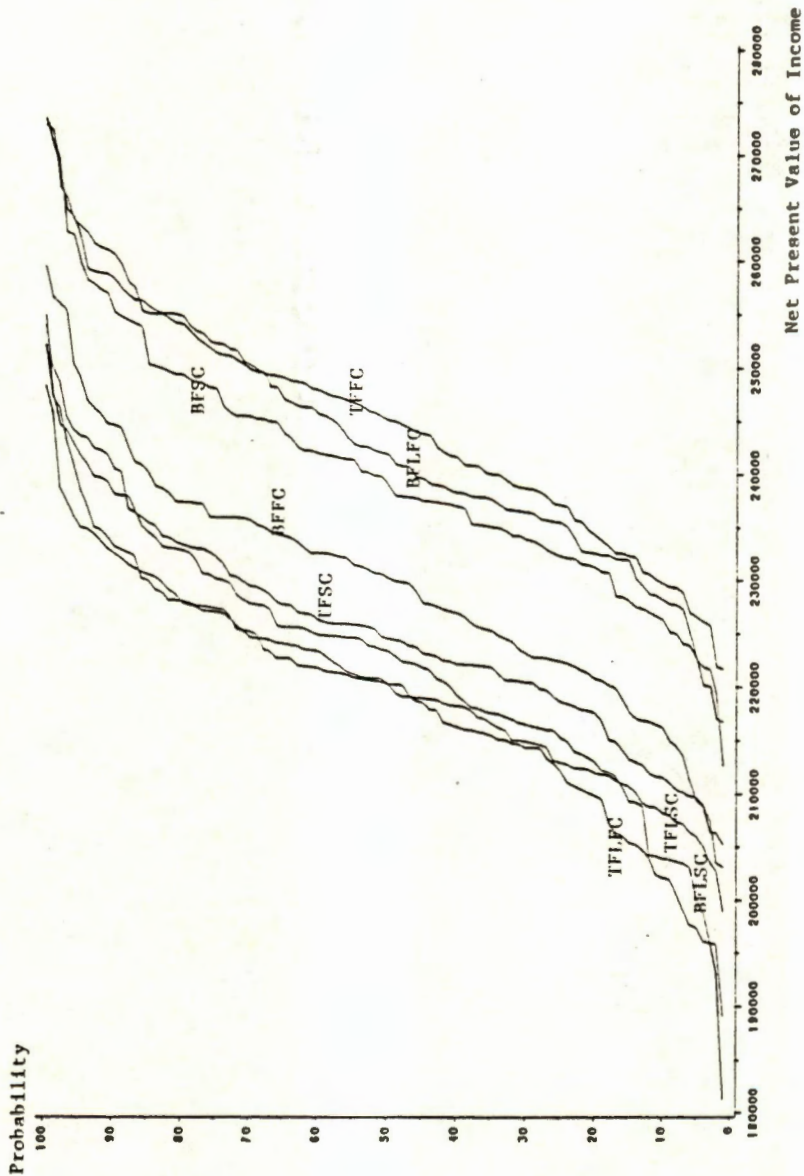
ANNUAL AVERAGE CALF WEIGHT BY SELECTED PROBABILITIES OF ATTAINMENT FOR
THE CATTLE OPERATION UNDER FOUR FORAGE SYSTEMS (TF, BF, TFL and BFL)
WITH SPRING AND FALL CALVING SYSTEMS (FC and SC)

Probability ¹ (percent)	Forage and Calving Systems ²							
	TFSC	TFFC	BFSC	BFFC	TFLSC	TFLFC	BFLSC	BFLFC
	----- pounds ³ -----							
10	519.4	511.3	469.0	444.2	572.1	503.9	489.6	466.5
20	513.9	507.6	464.3	441.4	567.6	496.5	484.4	461.7
30	509.9	504.4	461.6	439.0	564.7	492.1	480.1	457.8
40	505.7	501.6	458.8	437.1	561.8	488.4	476.0	454.8
50	502.3	498.1	456.0	435.3	559.1	485.2	473.5	452.4
60	499.2	494.9	453.1	433.8	555.7	482.0	470.9	449.8
70	496.0	490.9	448.8	431.8	553.0	478.9	468.5	447.5
80	491.4	485.8	444.6	429.5	548.6	475.2	465.6	444.6
90	484.2	478.6	439.0	426.3	543.5	470.4	462.2	440.5
100	455.6	455.7	409.4	414.5	524.7	456.6	444.5	428.1

¹Probability represents the estimated percentage chance of achieving the reported yield in each forage system.

²The forage and calving systems are: TFSC=tall fescue and spring calving; TFFC=tall fescue and fall calving; BFSC=bermudagrass/tall fescue and spring calving; BFFC=bermudagrass/tall fescue and fall calving; TFLSC=tall fescue plus legumes and spring calving; TFLFC=tall fescue plus legumes and fall calving; BFLSC=bermudagrass/tall fescue plus legumes and spring calving; and, BFLFC=bermudagrass/tall fescue plus legumes and fall calving.

³Average calf weight is the average of steer and heifer calf weaning weights.



Legend: TFSC=tall fescue with spring calving, TFSC=tall fescue with fall calving, BFSC=bermudagrass/tall fescue with spring calving, BFFC=bermudagrass/tall fescue with fall calving, TFLSC=tall fescue plus legumes with spring calving, TFLFC=tall fescue plus legumes with fall calving, BFLSC=bermudagrass/tall fescue plus legumes with spring calving, BFLFC=bermudagrass/tall fescue plus legumes with fall calving

FIGURE V-4

CUMULATIVE PROBABILITY DISTRIBUTIONS OF AFTER-TAX NET PRESENT VALUE OF INCOME FOR THE CATTLE OPERATION UNDER FOUR FORAGE SYSTEMS WITH SPRING AND FALL CALVING

distributions since these two were always below and to the right. Except for the BFLFC alternative, grass forage systems (TF and BF) dominated the legume forage systems (TFL and BFL), taking three of the top four rankings among the alternatives. Distributions for the BF systems were ranked ahead of those for the TF systems, with the exception of the TFFC alternative. Fall calving distributions dominated spring calving distributions in most cases, comprising three of the top four rankings. The four grass pasture alternatives ranked TFFC, BFSC, BFFC and TFSC, respectively, from highest after-tax net present value to lowest. Among the legume systems the BFLFC alternative clearly ranked first, followed by the BFLSC alternative. Ranking of the TFLSC and TFLFC alternatives could not be determined from visual inspection of the CPDs.

Ten-year after-tax net income present values at selected probabilities of attainment for each production alternative are shown in Table V-7. Probabilities indicate the estimated likelihood of attaining the reported income stream in each production alternative. A positive after-tax NPV was achieved in each alternative with incomes above \$180,000 over the ten-years at all probability levels. These results coincide with the finding that the grass systems generated slightly higher incomes than the renovated systems, except in the BFLFC alternative. All grass systems were reported with a 100-percent probability of attaining income streams above \$200,000. Among the legume systems only the BFLFC alternative had a 100-percent probability of achieving this level of income. However, the other renovated systems had 90-percent probabilities of obtaining income streams above

TABLE V-7

TEN-YEAR AFTER-TAX NET PRESENT VALUE OF INCOME BY SELECTED
PROBABILITIES OF ATTAINMENT FOR THE CATTLE OPERATION UNDER
FOUR FORAGE SYSTEMS (TF, BF, TFL and BFL) WITH SPRING AND
FALL CALVING SYSTEMS (SC and FC)

Probability ¹ (percent)	Forage and Calving Systems ²							
	TFSC	TFFC	BFSC	BFFC	TFLSC	TFLFC	BFLSC	BFLFC
----- dollars -----								
10	240621	258384	255323	244717	232657	233334	238171	260660
20	233496	254917	249560	237462	227941	228088	232944	254222
30	229543	250373	245555	235800	225300	224779	227893	249931
40	226335	248018	242072	232627	221835	223426	224979	245720
50	224639	245117	239005	230283	220384	220355	223479	241948
60	222182	241692	237042	226985	218319	216380	219289	238345
70	220523	238780	233951	223207	214977	214407	216577	236498
80	217657	234349	231333	220871	212048	209892	213068	232612
90	211610	229860	226384	216283	208299	202140	203923	228245
100	203116	221754	212773	205265	198943	189163	181221	216773

¹Probability represents the estimated percentage chance of achieving the reported yield in each forage system.

²The forage and calving systems are: TFSC=tall fescue and spring calving; TFFC=tall fescue and fall calving; BFSC=bermudagrass/tall fescue and spring calving; BFFC=bermudagrass/tall fescue and fall calving; TFLSC=tall fescue plus legumes and spring calving; TFLFC=tall fescue plus legumes and fall calving; BFLSC=bermudagrass/tall fescue plus legumes and spring calving; and, BFLFC=bermudagrass/tall fescue plus legumes and fall calving.

\$200,000. The two highest rated production alternatives, TFFC and BFLFC, had probabilities of generating a \$250,000 income stream at 30- to 40-percent and 20- to 30-percent, respectively.

Evaluation by Stochastic Dominance

The cumulative probability distributions of after-tax net present value of income for each production alternative were compared using stochastic dominance with respect to a function. Risk aversion coefficients were needed to serve as the basis for preference measurements (Pratt 1964; King and Robison 1981). King and Robison (1981) elicited risk aversion coefficients in the interval $-.0001$ to $.0001$ for annual income. Following the scaling³ of risk aversion coefficients for ten-year after-tax net present value of income used by Lemieux et al. (1982), absolute risk aversion intervals of $-.00001$ to 0 , 0 to $.00001$, and $-.00001$ to $.00001$ were used to distinguish producers who are risk loving, risk adverse, and risk neutral, respectively.

Preference ordering of the eight production alternatives for each risk aversion group is presented in Table V-8. In each of the risk aversion categories the preference ordering were identical. The TFFC alternative was most preferred by risk adverse, neutral and loving producers. For the BF alternatives, BFLFC was most preferred in each

³Implications of the scaling used to specify risk aversion coefficients are presented in Raskin and Cochran (1986).

TABLE V-8

PREFERENCE ORDERING BY RISK AVERSION INTERVALS FOR THE
EIGHT PRODUCTION ALTERNATIVES¹ ON THE REPRESENTATIVE CATTLE OPERATION

Rank	Risk Aversion Interval ²		
	Risk Adverse	Risk Neutral	Risk Loving
1st Most Preferred	TFFC	TFFC	TFFC
2nd Most Preferred	BFLFC	BFLFC	BFLFC
3rd Most Preferred	BFSC	BFSC	BFSC
4th Most Preferred	BFFC	BFFC	BFFC
5th Most Preferred	TFSC	TFSC	TFSC
6th Most Preferred	BFLSC	BFLSC	BFLSC
7th Most Preferred	TFLSC	TFLSC	TFLSC
8th Most Preferred	TFLFC	TFLFC	TFLFC

¹Production alternatives are: TFSC=tall fescue and spring calving systems, TFFC=tall fescue and fall calving systems, BFSC=bermudagrass/tall fescue and spring calving systems, BFFC=bermudagrass/tall fescue and fall calving systems, TFLSC=tall fescue + legumes and spring calving systems, TFLFC=tall fescue + legumes and fall calving systems, BFLSC=bermudagrass/tall fescue + legumes and spring calving systems, BFLFC=bermudagrass/tall fescue + legumes and fall calving systems.

²Risk aversion coefficients were: 0.0 to 0.00001 for risk adverse, -0.00001 to 0.00001 for risk neutral, and -0.00001 to 0.0 for risk loving.

risk preference category. The grass forage systems (TF and BF) rated higher than the legume systems, with the exception of the BFLFC alternative. Among the legume forage systems, the BFLFC alternative ranked second overall, while the other alternatives rated last (sixth, seventh and eighth). Fall calving was preferred to spring calving with all but the TFL alternatives (TFLSC and TFLFC).

CHAPTER VI

SUMMARY, CONCLUSIONS AND IMPLICATIONS

The risks confronting cattle producers in the southwestern portion of Tennessee are both economic and environmental in nature. Environmental forces mainly affect the level and quality of available forage to produce cattle. Major hindrances to abundant forage production are variable temperature and precipitation levels.

Efforts to alleviate the uncertainty in forage production have been a major research emphasis among biological scientists. Several combinations of forage species and alternative calving seasons have been tested under Tennessee conditions. These alternatives vary in their costs of implementation, as well as in their ability to increase total beef production. Each alternative performs differently in response to changes in environmental states. Economic conditions also effect the relative success of each alternative because of their unique production, marketing and managerial traits.

The general objective of this research was to compare and evaluate production and economic characteristics of alternative forage and calving systems for commercial feeder calf production operations. Four forage systems were analyzed; including, tall fescue pastures (TF), bermudagrass/tall fescue pastures (BF), tall fescue pastures renovated with red clover and annual lespedesa legumes (TFL), and bermudagrass/tall fescue pastures renovated with red clover and annual

lespedeza legumes (BFL). Coupled with each forage system were spring and fall calving systems (SC and FC). Thus, eight production alternatives were examined.

Methodology and Procedures

Because numerous and interrelated physical and economic relationships characterize the forage-beef production setting, a systems approach was adopted in this study. Alternative components, or subsystems, were identified and combined to describe the operation of the forage-beef system. Several dynamic and stochastic processes contribute to the complexity involved with forage-beef production. Consequently, simulation analysis was the chosen methodology. Simulation allowed the flexibility necessary to model the complex relationships, and provided an estimate of the distribution of outcome variables.

A cattle operation in southwestern Tennessee was designated as the unit of analysis. Since typical cattle operations in this area are supplemental enterprises on rowcrop farms, this characteristic was retained in this study. Planning and performance of the cattle operation, however, was examined independent of the whole-farm business. The land resources used in cattle production consisted of 200 acres of land suitable for pasture and hay production, a size sufficient to support at least 100 cows. A representative mix of soil series was used to characterize each acre of the operation. Labor resources available for cattle production included the supply remaining after rowcrop requirements were satisfied. Machinery and

equipment resources were available to establish, renovate and maintain pastures; to prepare, bale and handle hay production in the form of large round bales; and for routine management of the cow herd. Charges for machinery and equipment were based upon expected annual use as a proportion of the total annual use in each production alternative.

The simulation model developed in this study, COMFABS, was dynamic, stochastic, and recursive in nature. Six interrelated component parts: namely climatic, forage, cattle, managerial, price and cost, and budgetary components, comprised the model. Interaction and feedback among these components gave the simulator its operation structure. Operation of COMFABS involved monthly periods during which accumulated forage and cattle variables were assigned, and then evaluated to determine management decisions each month. Using Monte Carlo techniques, random climatic conditions, forage production, cattle weights, and cattle prices were simulated over a ten-year planning horizon (1989-1998) for 100 iterations. These stochastic production and price parameters were then combined, and annual returns and expenses were computed.

Several output variables, including annual forage, cattle and financial performance measures, were summarized and compared among the eight production alternatives. Budgetary performance of the cattle operation in each year of the ten-year span was examined. Also, cumulative probability distributions of annual forage yield and average calf weight, and the after-tax net present value of income were evaluated. The CPDs of after-tax net present value were analyzed

using stochastic dominance with respect to a function. Three levels of risk aversion were examined. Production alternatives were ranked for cattle producers who would be categorized as being risk adverse, risk neutral and risk loving.

Results

Estimated annual forage yield was greatest in the grass forage systems renovated with legumes, with mean yields of more than 600 pounds of dry matter per acre higher than for the unrenovated, grass only systems. Per acre bermudagrass/tall fescue forage yields, with and without renovation, were about 400 pounds of dry matter higher than tall fescue yields. Legume forage systems provided a higher quality forage than the grass systems, and average quality of tall fescue exceeded that of the bermudagrass/tall fescue mixture. Differences among the forages in estimated yield and quality variability were slight. None of the forage systems exhibited substantial yield and quality fluctuations.

Forage production was never low enough to necessitate grazing of first cutting hay. At the second cutting, acreage diversions were required during some years for alternatives utilizing fall calving; however, these were infrequent and included only a few acres. Hay yields and qualities followed much the same pattern across alternatives as forage yields, exhibiting only slight variations.

Fall calving herds required more hay from both inventory and purchases than spring calving herds. Likewise, bermudagrass/tall fescue systems generally required more hay than the tall fescue

systems. An inverse relationship was found between amounts of hay purchased and sold in each alternative. Variability in the levels of hay fed, purchased or sold was not great for any of the systems studied.

Number of cows and calves sold each year remained at the specified long-term levels in each production alternative. Forage production in any year simulated was never low enough that stocking adjustments were necessary.

Estimated annual mean cow weight in each alternative was greater than 1000 pounds, indicating cows retained excess condition. Fall calving cows were somewhat heavier than spring calving cows and experienced less annual weight variability. Spring calving cows produced more milk per day than their fall counterparts. Cows achieved greater average lactation levels in the forage systems renovated with legumes as compared to the grass systems. Also, milk production levels were generally greater for the tall fescue systems compared to the bermudagrass/tall fescue systems.

Spring-born calves were generally weaned at a heavier weight than fall-born calves. Differences in calf weight variability between the herds was slight. Much higher weaning weights were observed in the tall fescue systems versus the bermudagrass/tall fescue systems. Likewise, weaning weights of calves were generally heavier for renovated pastures than for grass alternatives. Mean heifer breeding weights were above 600 pounds in most alternatives. In contrast to calf weaning weights, heifer breeding weights were generally higher in fall than in spring calving systems. Breeding weights were generally

higher for renovated and tall fescue systems than for grass and bermudagrass/tall fescue systems, respectively. Replacement heifers calved at approximately 900 pounds in each alternative. Calving weight comparisons among the alternatives were very similar to those of breeding weight.

On the average, fall-born calves were sold for approximately 3 to 7 dollars per hundredweight more than spring-born calves. This difference was primarily attributed to the unique market timing of each herd. Annual prices received for calves was also higher in bermudagrass/tall fescue systems than in tall fescue systems, reflecting the weight differential observed for calves marketed from each system.

Production alternatives including fall calving generated a greater annual value of sales than those using spring calving, due primarily to higher calf prices. In all instances, gross receipts increased when each grass pasture system was renovated. Average annual operating expenses were higher in fall calving and renovated production alternatives as compared to spring calving and grass pasture alternatives, respectively. Annual production costs were higher for purchased hay and labor in the fall herd alternatives, and added input and machinery costs were incurred with pasture renovation to add legumes. Fixed costs for each year were greater in the bermudagrass/tall fescue systems compared to the tall fescue systems. Likewise, the added machinery use for renovation increased fixed costs relative to the unrenovated systems.

Mean annual net returns above operating expenses were generally higher in fall calving versus spring calving systems, bermudagrass/tall fescue versus tall fescue systems, and renovated versus grass systems. Higher gross receipts generated by these systems more than offset their higher operating expenses. Overall, the bermudagrass/tall fescue plus legumes and fall calving alternative provided the highest average return above operating expenses. When fixed costs were deducted, however, tall fescue systems compared more favorably with bermudagrass/tall fescue systems. Likewise, many of the legume systems were less profitable than their corresponding grass system. Fall calving was still generally more profitable than spring calving, and bermudagrass/tall fescue plus legumes with fall calving remained the alternative with the highest average returns. Much the same ranking of alternatives was obtained when tax expenses were deducted.

After-tax net returns were generally more variable in fall as opposed to spring calving systems, and in the bermudagrass/tall fescue system against the tall fescue system. In addition, net returns were more variable for the renovated systems than for the grass systems. Overall, the renovated bermudagrass/tall fescue system used with both spring and fall herds had the most variable returns, while returns generated by the tall fescue system with spring and fall calving were least variable.

Production alternatives utilizing fall calving generated greater annual after-tax net returns than those utilizing spring calving during peak and declining years of the cattle price cycle. Also during these years the incomes from the bermudagrass/tall fescue

systems exceeded those from tall fescue systems. However, relative returns from tall fescue systems improved as cattle prices declined. At lowest cattle prices, tall fescue systems compared more favorably with bermudagrass/tall fescue systems, and spring calving ranked better against fall calving. Renovated systems generally rated lowest in annual returns during the low cattle price years. When cattle prices were in the increasing phase, no clear rankings of the forage and calving systems were apparent. Renovated systems, however, generally remained lower in annual returns relative to the grass systems. Overall, the renovated and unrenovated bermudagrass/tall fescue with fall calving alternatives provided the greatest returns when cattle prices were highest. The tall fescue and fall calving alternative ranked first during the lowest price years, and the bermudagrass/tall fescue and spring calving alternative had the highest returns during years prices moved upward.

Examination of the cumulative probability distributions (CPDs) of annual forage yield basically confirmed the results discussed earlier. The highest yields were for renovated pastures, and bermudagrass/tall fescue systems yielded higher than the tall fescue systems. Consequently, renovated and bermudagrass/tall fescue systems had greater probabilities for achieving higher yields than unrenovated and tall fescue systems, respectively. CPDs for each forage system had a steep slope, indicating that none of the systems experienced substantial yield variability.

The CPD of annual average calf weight for the tall fescue plus legumes and spring calving alternative clearly dominated all other

distributions. Relatively low cow numbers used with this high yielding forage system produced heavier calves at weaning. Distributions for the tall fescue systems dominated those of the bermudagrass/tall fescue systems, and larger calves were generally weaned from the renovated systems than from corresponding grass systems. Spring herd weaning weights were also slightly higher than those obtained in the fall herd.

Production alternatives, tall fescue with fall calving, bermudagrass/tall fescue plus legumes with fall calving, and bermudagrass/tall fescue with spring calving clearly dominated all other alternatives according to examination of the CPDs of after-tax net present value of income. Alternatives including grass forage systems comprised three of the top four rankings, and bermudagrass/tall fescue systems generally ranked ahead of the tall fescue systems. Fall calving distributions dominated spring calving distributions in most cases, also comprising three of the top four rankings.

Preference ordering of the eight production alternatives according to stochastic dominance was identical for each risk aversion group. The tall fescue with fall calving alternative was most preferred by risk adverse, neutral and loving producers. The alternative using bermudagrass/tall fescue plus legumes with fall calving ranked second overall for each risk preference category. Grass forage systems were generally preferred to renovated systems, as was fall to spring calving.

Model Limitations and Implications for the Results

The model developed in this study, COMFABS, has several limitations with respect to the validity of the results. Caution, therefore, must be exercised in interpreting the results and the conclusions they may suggest.

A limitation common to most research on forage-beef production concerns the estimation of forage yield and yield variability during a year. Due to the significant time and expense involved in conducting forage production research, primary data on forage yield and quality were limited. Only yield measurements on each forage species were available. Secondary data on forage quality were employed as estimates of monthly forage quality. Furthermore, the functional forms specified to estimate the forage-climate relationships have restricted ability to describe typical production peaks and slumps. Tall fescue normally exhibits a decline in production during summer months. This characteristic, however, could not be represented adequately by the equation specified for tall fescue yield. Consequently, yields may be overestimated in some months and underestimated in other months. Other attempts to overcome such problems have used linear yield equations for various seasons of the year (e.g. Riechers 1986). This approach, however, requires a substantial amount of forage data during each season. A possible alternative approach to estimation of forage yield and yield variability is the use of a spline function (Suits et al. 1978) with polynomial segments for different periods of a year.

The narrow range by which annual forage yield was observed to vary suggests that yield variability was underestimated in this study.

The limited amount of yield variability resulted in little variation in model results with respect to hay feeding or diversion of hay acreage to grazing, and no necessary adjustments in stocking levels. Severe climatic fluctuations in recent years and their implications for cattle producers (McCampbell 1988; Williams 1986) cause speculation that yield variability was underestimated. Limitations associated with the functional forms of the forage equations, mentioned previously, likely attributed to this result.

The analysis of pasture renovation was limited in several respects. Legume systems included red clover and annual lespedesa. These forage species, although commonly recommended for use in grass pastures, are not as persistent or cost effective as perennial legumes such as white clovers. Ladino clover is most commonly recommended for pasture renovation in Tennessee pastures (Fribourg 1978; Burns 1975) due to its perennial nature and low cost maintenance. Unfortunately data on the yields of ladino clover were unavailable for use in this study. Results of this study indicated that in most systems, pasture renovation was not as profitable as using grass pastures. However, had the information necessary to evaluate ladino clover in pasture renovation been available, renovated systems may have compared more favorable with the grass systems.

Further difficulties were encountered due to the absence of yield and quality measurements on legumes growing with the grass species. Procedures were therefore necessary to estimate yield and quality of the grass-legume mixtures. Without the primary data, it is difficult to speculate how well the procedures used estimated the yield and

quality actually obtained with grass-legume mixtures. The possibility exists, however, that yield and/or quality was underestimated in the renovated systems. Lower ratings obtained for the grass-legume systems, relative to the grass systems, may in part be attributed to the lack of primary data on forage production of these systems, and inadequacies with the procedures developed to address this shortcoming.

Limitations are also inherent in the cattle performance component of the model. Animal protein requirements and availabilities were not considered. With the forages evaluated in this study, protein requirements of the cow-calf pair were generally assumed to be met when sufficient energy was obtained from grazing. However, during the winter seasons when lower quality hay forage are fed, protein deficiencies are more likely. Some type of protein supplementation may be necessary during these periods. Also, protein considerations become more important for growing animals, such as in the development of replacement stock.

Model refinements would certainly enhance the capability to estimate body composition of cows and growing heifers. No procedures were developed to describe the energy transfer from forage intake to muscle development and fat. Conversely, the model does not describe how fat may be utilized as an energy source when the forage supply is limited.

Dry matter intake of beef cows is extremely variable and difficult to specify. Estimates of forage intake used in this study varied solely by forage quality (percent TDN) and animal weight. More

precise estimates, however, could be specified if environmental factors, animal productive stage and available protein were more fully considered (National Research Council 1984, pg. 31-32). Likewise, selective grazing normally exhibited by cattle was omitted in this analysis because of measurement difficulties. Selective grazing has important implications for the performance of beef animals and pasture composition and growth.

Other possibly significant measures of performance were also not evaluated in this analysis. Conception, calving and death rates may vary each year with pasture types and breeding and calving periods. Data were unavailable to measure these potential differences among the production alternatives. Further analyses would certainly be enhanced by proper specification of these critical variables.

Climatic conditions and the resulting forage production were used as the sole basis for decision making by cattle producers. In actual practice, however, producers respond to both production and price variations. No feedback mechanisms were specified for how cattlemen would respond to changes in cattle prices. Decisions to sell calves early or postpone marketing in relation to price, as well as climatic fluctuations, would add to the representation of producer behavior.

Conclusions

Caution must be exercised when attempting to transfer the results of this study to cattle producers. Several limitations of the model were discussed in the previous section. These limitations have important implications for the validity of the results. Consequently,

any conclusions drawn from the results are valid only within the context of the model developed in this study. Conclusions of this study, therefore, are presented with emphasis on model design and operation, as well as the results.

For the cattle operation, results indicated that feeder calf production is a potentially profitable enterprise over the the planning horizon examined (1989-1998). All eight production alternatives generated positive mean after-tax net returns to the residual resources. However, capital charges for land and cattle investment and for the value of resident labor used were not deducted from gross receipts. Full cost of all resources would greatly reduce expected profitability of the forage-beef enterprise. The profitability of cattle production, therefore, would vary for individual farm situations. The debt and net worth position of an individual producer would have an important effect on the survivability of a beef unit of the type analyzed here as an independent economic unit.

Among the production alternatives, the innovative bermudagrass/tall fescue forage system compared well with the more commonly used tall fescue system. A greater annual forage yield and improved production distribution permitted a higher carrying capacity with the BF systems relative to the TF systems, even though forage quality and calf weights were lower. Given the assumptions and procedures employed in this study, renovated grass pastures with red clover and annual lespedesa were less profitable, in most instances, than unrenovated pastures. This finding was the result of higher fixed costs associated with greater labor and machinery use for renovation.

When fixed costs were excluded, the legume systems rated much higher against the grass systems. Individual producers may not view fixed cost charges in the same respect as handled in this study, especially on rowcrop farms where cattle production is a supplemental enterprise. Consequently, pasture renovation, a common recommendation among biological scientists, should not be discarded as a viable alternative because of the results of this analysis. This claim is further substantiated by the model limitations associated with the analysis of pasture renovation mentioned above.

The fall calving system rated very well versus the traditional spring calving system. While weaning weights were similar in each calving system, higher prices were obtained for fall-born calves marketed in June as opposed to spring-born calves marketed in October. This significant price advantage tended to offset greater production and feeding costs necessary in fall calving systems. Results were sensitive to the cattle prices used over the planning horizon. Since cattle prices cannot be accurately predicted into the future, further sensitivity analysis would be valuable for assessing effects of the position of the cattle cycle upon performance of the cattle operation. Other planning horizons, which begin and end at different points of the cattle price cycle, might alter comparisons of the alternatives evaluated in this study.

Within the context of the model assumptions and procedures, annual net returns were observed to be least variable in the tall fescue systems. Bermudagrass/tall fescue systems were found to be more risky. This result is counter to the recognized notion that

combining cool- and warm-season grass species reduces production variability by more evenly distributing the annual forage supply. Model limitations associated with estimating forage production variability, and the larger herd sizes used with the bermudagrass/tall fescue systems, likely contribute importantly to this result.

Net returns generated by the production alternatives were evaluated in each year of the planning horizon. Results of this analysis showed that bermudagrass/tall fescue systems were, on the average, more profitable than tall fescue systems when cattle prices were highest. Also during these high price periods the fall calving systems generated greater profits than spring calving systems. When cattle prices were lowest, however, both the TF and SC systems improved in ranking relative to the BF and FC systems, respectively. The differential between cattle prices of various weight categories narrowed when prices are low, and widened at higher prices. Heavier calves sold from the TF and SC systems obtained a higher price relative to those sold from BF and FC systems when the cattle price cycle experienced its trough. Likewise, the price differential between heavier calves sold from the TF and SC systems, and lighter calves sold from BF and FC systems widened at the peak of the cycle. Findings of this analysis suggest that utilizing a diversified forage and/or calving program may be more profitable, on the average, than a specialized management strategy. Diversification may also be an effective means of reducing the price risks associated with forage-beef production.

The assumed macroeconomic environment was critical to the relative success of the production alternatives. Types and levels of input use were different among the alternatives. Consequently, the assumed annual interest and inflation rates for the various input categories would affect each alternative differently. Since these macroeconomic variables cannot be precisely forecasted over the ten-year planning horizon, deviations of actual levels from the forecasts could have a significant effect on the relative profitability of each production alternative.

Implications for Further Research

Simulation modeling is an extremely flexible technique capable of handling the dynamic, stochastic and recursive characteristics of forage-beef production. The model developed in this study, COMFABS, could be modified to examine several other management strategies of which understanding would be valuable for making recommendations to Tennessee cattle producers. At this point, however, a more rigorous validation of the capabilities of COMFABS for replicating the characteristics and performance of forage-beef systems is needed.

Several limitations of COMFABS were presented in the previous sections. The initial step toward further research involves addressing these shortcomings. Refinements are absolutely necessary in the procedures used to estimate forage yield and yield variability. Additional data on forage yield of alternative species and mixtures would be of great benefit. Likewise, forage quality and composition data are needed. The estimation of yield and quality variations would

certainly be enhanced by alterations in the functional relationships among forage production and climatic variables. Measuring cattle performance could be improved by consideration of protein requirements and availabilities. Further refinements in techniques used for measuring intake, such as specification of the influences of environmental factors and selective grazing, deserve attention. Ultimately, comparing simulation results to those obtained in actual experiments would offer a means of validating COMFABS, or suggesting areas where further refinements in modeling techniques are warranted.

More development of the decision making component of COMFABS would be valuable. Testing is needed to examine the sensitivity of model outputs to variations of critical decision parameters, such as stocking levels and hay management. Feedback mechanisms from price variations, in addition to climatic variations, would be more representative of producer behavior. Eventually, alternative decision criteria could be incorporated and evaluated in terms of their utility at the producer level.

Much of the feeder cattle production in Tennessee occurs on small supplemental farm enterprises. Typically, resources utilized in cattle production have few other uses. Further model developments which attempt to describe the role of cattle production within the whole-farm framework could add to the understanding of Tennessee beef production.

Below is a list of possible issues to which future research using COMFABS could be directed.

1. Fungus-Infected Tall Fescue versus Fungus-Free Tall Fescue
2. Stockpiling Tall Fescue and Other Winter Grazing Strategies
3. Diversified Forage and Calving Programs
4. Retained Ownership or Backgrounding of Feeder Calves

The recent discovery of a fungal endophyte resident in tall fescue pastures has critical implications for both pasture and grazing cattle production. New fungus-free varieties offer potential for reducing the detrimental consequences to cattle, but may pose new problems for pasture production. Stockpiling tall fescue and other winter grazing strategies may help to reduce overwintering costs of cattle, especially for fall calving herds who have relatively high nutritional requirements during the winter. Utilizing diversified forage and calving programs may provide higher returning alternatives with reduced risk. Retained ownership or backgrounding of feeder calves may have profit potential, and would certainly give producers greater flexibility in timing calf marketings.

Each of these issues, among others, present important research and practical concerns for scientists and cattle producers, respectively. With appropriate refinements of COMFABS, these concerns could be addressed. However, significant data requirements are involved with research in these areas. Prior to planning and implementing research on any of these topics, more interaction and cooperation among biological and economic scientists are needed.

REFERENCES

REFERENCES

- American Hereford Journal. 1972-86. "Yearly Auction Averages." Kansas City, Missouri. Various Issues.
- Anderson, J.R. 1974. "Simulation: Methodology and Application in Agricultural Economics." Review of Marketing and Agricultural Economics. 42:3-55.
- Angirasa, A.K., C.R. Shumway, T.C. Nelson and T.C. Cartwright. 1981. "Integration, Risk and Supply Response: A Simulation and Linear Programming Analysis of a East Texas Cow-Calf Producer." Southern Journal of Agricultural Economics. 13:89-98.
- Bagley, C.P., J.C. Carpenter, Jr., J.I. Feazel, F.G. Hembry, D.C. Huffman and K.L. Koonce. 1987. Effects of Calving Season and Stocking Rate on Beef Cow-Calf Productivity. Louisiana Agricultural Experiment Station. Bulletin No. 777. February.
- Boehlje, M.D. and V.R. Eidman. 1984. Farm Management. New York: John Wiley and Sons.
- Bond, J., J.B. Powell and B. T. Weinland. 1984. "Behavior of Steers Grazing Several Varieties of Tall Fescue during Summer Conditions." Agronomy Journal. 76:707-709.
- Boulding, K.E. 1956. "General Systems Theory--The Skeleton on Science." Management Science. Volume 2.
- Brorson, W.B., O.L. Walker, G.W. Horn and T.R. Nelson. 1983. "A Stocker Cattle Growth Simulation Model." Southern Journal of Agricultural Economics. 15:115-122.
- Buckner, R.C. 1985. "The Fescues." in Forages: The Science of Grassland Agriculture. ed. M.E. Heath, R.F. Barnes and D.S. Metcalfe. pp. 233-40. Ames: Iowa State University Press.
- Burns, J.D. 1975. Renovate Grass Pastures. Tennessee Agricultural Extension Service. Circular 714.
- Burton, G.W. and W.W. Hanna. 1985. "Bermudagrass." in Forages: The Science of Grassland Agriculture. ed. M.E. Heath, R.F. Barnes and D.S. Metcalfe. pp. 247-54. Ames: Iowa State University Press.
- Byers, F.M. 1986. "Nutritional Management of the Beef Herd." in Livestock Feeds and Feeding. ed. D.C. Church. pp. 228-247. Prentice Hall. Englewood Cliffs, New Jersey.

- Carpenter, J.C., Jr., H.E. Harris, J.I. Feazel, F.G. Hembry, K.L. Koonce and D.C. Huffman. 1979. Economic Implications of Producing Beef Calves with Four Pasture Management Systems. Louisiana Agricultural Experiment Station. Bulletin No. 721. October.
- Chien, Y.I. and G.L. Bradford. 1976. "A Sequential Model of the Farm Firm Growth Process." American Journal of Agricultural Economics. 58:456-465.
- Clements, A.M. Jr., H.P. Mapp Jr. and V.R. Eidman. 1971. A Procedure for Correlating Events in Farm Firm Simulation Models. Oklahoma State University. Agricultural Experiment Station. Bulletin 1493. August.
- Conrad, H.R., A.D. Pratt and J.W. Hibbs. 1966. "Regulation of Feed Intake in Dairy Cows. II. Change in Importance of Physical and Physiological Factors with Increasing Digestibility." Journal of Dairy Science. 49:54-62.
- Cook, M.K. undated. "Developing Replacement Heifers." in Southern Regional Beef Cow-Calf Handbook. SR 1000.
- Denham, S.C. and T.H. Spreen. 1980. "Introduction to Simulation of Beef Cattle Production." in Simulation of Beef Cattle Production Systems. ed. T.H. Spreen and D.H. Laughlin. pp. 39-62. Westview Press, Inc. Boulder, Colorado.
- Dinius, D.A., R.F. Brokken, K.P. Borard and T.S. Rumsey. 1976. "Feed Intake and Carcass Composition of Angus and Santa Gertrudis Steers Fed Diets of Varying Energy Concentration." Journal of Animal Science. 42:1089-1097.
- Dobson, J.W., C.D. Fisher and E.R. Beaty. 1976. "Yield and Persistence of Several Legumes Growing in Tall Fescue." Agronomy Journal. 68:123-125.
- Federal Reserve System. 1989. Federal Reserve Bulletin. Washington, D.C., March.
- Food and Agricultural Policy Research Institute. 1988. FAPRI Ten-Year International Agricultural Outlook. FAPRI Staff Report 1-88.
- Forcherio, J.C. 1986. "The Evaluation of Forage Systems for Fall Calving Cows." M.S. thesis. University of Tennessee.
- Franzmann, J.R. and R.L. Walker. 1972. "Trend Models of Feeder, Slaughter, and Wholesale Beef Cattle Prices." American Journal of Agricultural Economics. 507-12.
- Fribourg, H.A. 1978. "Tall Fescue Productivity After Renovation With Legumes or Fertilization With Nitrogen." Tennessee Farm and Home Science. Progress Report 107.

- Fribourg, H.A. and J.R. Overton. 1979. "Persistence and Productivity of Tall Fescue in Bermudagrass Sods Subjected to Different Clipping Managements." Agronomy Journal. 71:620-624.
- Fribourg, H.A., J.B. McLaren, K.M. Barth, J.M. Bryan, and J.T. Connell. 1979. "Productivity and Quality of Bermudagrass and Orchardgrass-Ladino Clover Pastures for Beef Steers." Agronomy Journal. 71:315-320
- Fribourg, H.A. 1983. Computer Program for Teaching Forage Management and Utilization: Beef Forage Management System (BFMS). Dept. of Plant and Soil Science. University of Tennessee. Agricultural Experiment Station Research Report 83-10.
- Fribourg, H.A., R.J. Carlisle, and J.B. McLaren. 1984. "Bermudagrass, Tall Fescue, and Orchardgrass Pasture Combinations with Clover and N Fertilization for Grazing Steers. II. The Species Composition Index and Variability in Forage Growth and Consumption, and Animal Performance." Agronomy Journal. 76:615-619.
- Fribourg, H.A. 1988a. Unpublished data on forage productivity by soil series characteristic of West Tennessee.
- Fribourg, H.A. 1988b. Plant Scientist. University of Tennessee. personal communication.
- Gebremeskel, T. and C.R. Shumway. 1979. "Farm Planning and Calf Marketing Strategies for Risk Management: An Application of Linear Programming and Statistical Decision Theory." American Journal of Agricultural Economics. 61:363-370.
- Gilliam, Jr., H.C. 1984. The U.S. Beef Cow-Calf Industry. U.S. Department of Agriculture. Economic Research Service. Agricultural Economic Report No. 515. Washington, D.C. September.
- Gutierrez, P.H. 1985. "The Impasse to Selected Management Practices on the Economic Survivability of a Ranch Unit: An Analysis for a Southern Plains Ranch." Ph.D. dissertation. Oklahoma State University.
- Halbrook, W.A., D.R. Reneau, C.P. West, B.J. Hankins, C. Garner, H.J. Humphries and T.J. Wood. 1986. 1985 Forage Production Budgets for Western Arkansas. University of Arkansas. Arkansas Agricultural Experiment Station Special Report 120.
- Halter, A.N. and G.W. Dean. 1965. "Use of Simulation in Evaluating Management Policies under Uncertainty: Application to a Large Scale Ranch." Journal of Farm Economics. 47:557-73.

- Hemken, R.W., J.A. Boling, L.S. Bull., R.H. Hatton, R.C. Buckner and L.P. Bush. 1981. "Interaction of Environmental Temperature and Anti-Quality Factors on the Severity of Summer Fescue Toxicosis." Journal of Animal Science. 52:710-714.
- Hemken, R.W., J.A. Jackson and J.A. Boling. 1984. "Toxic Factors in Tall Fescue." Journal of Animal Science. 58:1011-1016.
- Hicks, J.R. 1946. Value and Capital. 2nd ed. London: Oxford University Press.
- High, J.W. Jr., L.M. Safley, O.H. Long, H.R. Duncan and T.W. High, Jr. 1965. Combinations of Orchardgrass, Fescue and Ladino Clover for Producing Yearling Steers. Tennessee Agricultural Experiment Station. Bulletin 388. February.
- High T.W. Jr., E.J. Chapman, B.L. Wittenberg and J.W. High, Jr. 1965. Fescue Pastures, Under Different Management Systems, and Orchardgrass-Clover for Yearling Slaughter Steer Production. Tennessee Agricultural Experiment Station. Bulletin 385. February.
- Hobbs, C.S., T.W. High, Jr. and I. Dyer, Jr. 1965. Orchardgrass and Fescue Pastures for Producing Yearling Slaughter Steers. Tennessee Agricultural Experiment Station. Bulletin 386. February.
- Holloway, J.W., W.T. Butts, Jr., J.D. Beaty, J.T. Hopper and N.S. Hall. 1979. "Forage Intake and Performance of Lactating Beef Cows Grazing High and Low Quality Pastures." Journal of Animal Science. 48:692-700.
- Holloway, J.W., W.T. Butts and T.L. Worley. 1982. "Utilization of Forage and Milk Energy by Angus Calves Grazing Fescue or Fescue-Legume Pastures." Journal of Animal Science. 55:1214-23.
- Holloway, J.W., T.L. Worley and W.T. Butts, Jr. 1983. Lactation Curves of Angus Cows Grazing Fescue-Legume or Fescue Pastures. Tennessee Agricultural Experiment Station. Bulletin 616. April.
- Holloway, J.W. 1984. "Factors Controlling Intake of Fescue and Fescue-Legume Pastures." in Proc. Carl B. and Florence E. King Workshop: Utilization of Fescue by Cattle. pp. 41-54. Arkansas Agriculture Experiment Station. Fayetteville, Arkansas. Special Report 116. June.
- Hoveland, C.S., R.L. Haaland, C.C. King, Jr., W.B. Anthony, E.M. Clark, J.A. McGuire, L.A. Smith, H.W. Grimes and J.L. Holliman. 1980. "Association of Epichloe Typhina Fungus and Steer Performance on Tall Fescue Pasture." Agronomy Journal. 72:1064-65.

- Hoveland, C.S. and E.D. Donnelly. "The Lespedesas." in Forages: The Science of Grassland Agriculture. ed. M.E. Heath, R.F. Barnes and D.S. Metcalfe. pp. 128-35. Ames: Iowa State University Press.
- Internal Revenue Service. 1988. Your Federal Income Tax. United States Department of Treasury. Publication 17.
- Johnson, L.A. 1987a. Field Crop Budgets for 1988. Agricultural Economics and Resource Development. Agricultural Extension Service. University of Tennessee. AE & RD Information Report No. 151.
- Johnson, L.A. 1987b. Forage and Livestock Budgets for 1988. Agricultural Economics and Resource Development. Agricultural Extension Service. University of Tennessee. AE & RD Information Report No. 150.
- Johnson, S.R. and G.C. Rausser. 1977. "Systems Analysis and Simulation: A Survey of Applications in Agricultural and Resource Economics." in A Survey of Agricultural Economics Literature: Volume 2. ed. G.G. Judge, R.H. Day, S.R. Johnson, G.C. Rausser and L.R. Martin. pp. 157-301. Minneapolis: University of Minnesota Press.
- Kartchner, R.J., L.R. Rittenhouse and R.J. Raleigh. 1979. "Forage and Animal Management Implications of Spring and Fall Calving." Journal of Animal Science. 48:425-429.
- Keller, L.H. 1987. Systems Approach in Farm Management. University of Tennessee. Department of Agricultural Economics and Rural Sociology. Staff Paper. 87-04. November.
- Kimery, L.D. 1987. "An Analysis of the 1985 Beef Cattle Survey of the 21 Counties of Extension Service District One and Some Comparisons with 1981 Survey Results." M.S. thesis. University of Tennessee.
- King, R.P. 1979. "Operational Techniques for Applied Decision Analysis under Uncertainty." Ph.D. dissertation. Michigan State University.
- King, R.P. and L.J. Robinson. 1981. Implementation of the Interval Approach to the Measurement of Decision Making Preferences. Michigan State University. Agricultural Experiment Station Research Report No. 418.
- Kletke, D.D. 1979. Operation of the Enterprise Budget Generator. Oklahoma State University. Agricultural Experiment Station Research Report P-790. August.

- Klosterman, E.W., L.G. Stanford and C.F. Parker. 1968. "Effect of Cow Size and Condition and Ration Protein Content Upon Maintenance Requirements of Mature Beef Cows." Journal of Animal Science. 27:242-46.
- Lemieux, C.M., J.W. Richardson and C.J. Nixon. 1982. "Federal Crop Insurance vs. ASCS Disaster Assistance for Texas High Plains Cotton Producers: An Application of Whole-Farm Simulation." Western Journal of Agricultural Economics. 7:141-53.
- Leontief, W. 1971. "Theoretical Assumptions and Nonobserved Facts." American Economic Review. 61:1-7.
- Mapp, H.P., M.L. Hardin, O.L. Walker and T. Persaud. 1979. "Analysis of Risk Management Strategies for Agricultural Producers." American Journal of Agricultural Economics. 61:1071-1077.
- Mapp, H.P. and G.A. Helmers. 1984. "Methods of Risk Analysis for Farm Firms." in Risk Management in Agriculture. ed. P.J. Barry. pp. 116-128. Ames: Iowa State University Press.
- Matches, A.C., S. Bell, M. Mitchell and F.A. Martz. 1977. Pasture Systems for Season-Long Grazing. Research Report. Cooperative University of Missouri Columbia--Southwest Missouri Center.
- McCampbell, H. 1988. "Dry Weather Ills Keep Hanging On." BEEFWEEK. October.
- McCloud, D.E. and R.J. Bula. 1985. "Climatic Factors in Forage Production." in Forages: The Science of Grassland Agriculture. ed. M.E. Heath, R.F. Barnes and D.S. Metcalfe. pp. 33-42. Ames: Iowa State University Press.
- McLaren, J.B., R.J. Carlisle, H.A. Fribourg, and J.M. Bryan. 1983. "Bermudagrass, Tall Fescue, and Orchardgrass Pasture Combinations with Clover or N Fertilization for Grazing Steers. I. Forage Growth and Consumption, and Animal Performance." Agronomy Journal. 75:587-592.
- McLaren, J.B. and H.A. Fribourg. 1987. "The Fescue Fungus and Beef Production." in Proc. Southeastern Forage and Grassland Expo '87. pp. 69-70. Greenville, Tennessee. June 18-20.
- Midwest Plan Service. 1977. Structures and Environment Handbook. 9th Edition. Iowa State University.
- Mitchell, R.L., J.B. McLaren and H.A. Fribourg. 1986. "Forage Growth, Consumption, and Performance of Steers Grazing Bermudagrass and Fescue Mixtures". Agronomy Journal. 78:675-80.

- Modigliani, F. and K.J. Cohen. 1961. "The Role of Anticipations and Plans in Economic Behavior and Their Use in Economic Analysis and Forecasting." Studies in Business Expectations and Planning. no. 4. Bureau of Economic and Business Research. University of Illinois, Urbana.
- Montgomery, M.J. and B.R. Baumgardt. 1965. "Regulation of Food Intake in Ruminants. II. Rations Varying in Energy Concentration and Physical Form." Journal of Dairy Science. 48:1623.
- Mueller, R.G. and G.A. Harris. 1967. "Economics of Selected Alternative Calving Dates." Journal of Range Management. 20:67-69.
- Mundy, S.D. and M. Gray. 1986. Types of Farming in Tennessee. Tennessee Agricultural Experiment Station. Bulletin 646. August.
- National Academy of Sciences. 1972. Atlas of Nutritional Data on United States and Canadian Feeds. National Academy Press. Washington, D.C.
- National Oceanic and Atmospheric Administration. 1951-87. Climatological Data: Tennessee. Volumes 56-92.
- National Research Council. 1984. Nutrient Requirements of Beef Cattle. Sixth Revised Edition. National Academy Press. Washington, D.C.
- Naylor, T.H. 1971. Computer Simulation Experiments with Models of Systems. New York: Wiley.
- Nerlove, M. 1958. The Dynamics of Supply: Estimation of Farmer's Response to Price. Baltimore: The Johns Hopkins Press.
- Owens, T.O., Jr. and E.L. Moore. 1974. A Comparison of Various Methods of Calculating Heat Unit Requirements of Tomatoes. Mississippi Agricultural and Forestry Experiment Station. Technical Bulletin 70.
- Petriz, D.C., V.L. Lechtenberg and W.H. Smith. 1980. "Performance and Economic Returns of Beef Cows and Calves Grazing Grass-Legume Herbage." Agronomy Journal. 72:581-584.
- Pope, C.A., III and C.R. Shumway. 1984. "Management of Intensive Forage-Beef Production under Yield Uncertainty." Southern Journal of Agricultural Economics. 16:37-43.
- Pratt, J.W. 1964. "Risk Aversion In the Small and In the Large." Econometrica. 32:1332-36.

- Raskin, R. and M.J. Cochran. 1986. "Interpretations and Transformations of Scale for the Pratt-Arrow Absolute Risk Aversion Coefficient: Implications for Generalized Stochastic Dominance." Western Journal of Agricultural Economics. 11(2):204-210.
- Richardson, J.W. and G.D. Condra. 1978. A General Procedure for Correlating Events in Simulation Models. Texas Agricultural Experiment Station. Department of Agricultural Economics. (mimeo).
- Richardson, J.W. and G.D. Condra. 1981. "Farm Size Evaluation in the El Paso Valley: A Survival/Success Approach." American Journal of Agricultural Economics. 63:430-437.
- Richardson, J.W. and C.J. Nixon. 1986. Description of FLIPSIM V: A General Firm Level Policy Simulation Model. The Texas Agricultural Experiment Station. Bulletin 1528. July.
- Riechers, R.K. 1986. "An Economic Analysis of Alternative Stocking Rate Adjustment Strategies for Short Duration Grazing Systems in the Texas Rolling Plains." M.S. thesis. Texas A&M University.
- Saez, R.R., C.R. Shumway, M. Rouquette, Jr. and L.L. Jones. 1981. Profit Potential and Risk in Intensified Forage-Beef Production, East Texas. Texas Agricultural Experiment Station. Departmental Technical Report No. 81-4. June.
- Sanders, J.O. and T.C. Cartwright. 1979a. "A General Cattle Production System Model Part 1--Structure of the Model." Agricultural Systems. 4:217-27.
- _____. 1979b. "A General Cattle Production System Model Part 2--Procedures Used for Simulating Animal Performance." Agricultural Systems. 4:289-309.
- Stokes, K.W., D.E. Farris and T.C. Cartwright. 1981. "Economics of Alternative Beef Cattle Genotype and Management/Marketing Systems." Southern Journal of Agricultural Economics. 13:1-10.
- Suits, D.B., A. Mason, and L. Chan. 1978. "Spline Functions Fitted by Standard Regression Methods." Review of Economics and Statistics. 132-139.
- Taylor, R.E. 1984. Beef Production and the Beef Industry: A Beef Producer's Perspective. Burgess Publishing Company. Minneapolis, Minnesota.
- Taylor, W.L. 1985. "Red Clover." in Forages: The Science of Grassland Agriculture. ed. M.E. Heath, R.F. Barnes and D.S. Metcalfe. pp. 109-17. Ames: Iowa State University Press.

- Tennessee Agricultural Statistics Service. 1988. Tennessee Agricultural Statistics 1988. Nashville, Tennessee.
- Texas Department of Agriculture. 1972-85. Texas Livestock Market News. Austin, Texas. selected weekly issues.
- Thorton, R.F. and D.J. Minson. 1973. "The Relationship Between Apparent Retention Time in the Rumen, Voluntary Intake and Apparent Digestibility of Legume and Grass Diets in Sheep." Australian Journal of Agricultural Research. 24:889.
- Tweeten, L. 1980. "An Economic Investigation into Inflation Passthrough to the Farm Sector." Western Journal of Agricultural Economics. 5:89-106.
- U.S. Department of Agriculture/Iowa State University. 1982. National Resources Inventory. data files.
- U.S. Department of Commerce. Bureau of the Census. 1982. Census of Agriculture. Washington Government Printing Office.
- Van Soest, P.J. 1982. Nutritional Ecology of the Ruminant. Corvallis, Oregon: O & B Books, Inc.
- VanTassell, L.W. 1987. "Risk Management by Livestock Producers: A Ranch Simulation in the Texas Rolling Plains." Ph.D. dissertation. Texas A&M University.
- Waller, J.C. 1988. Animal Scientist. University of Tennessee. personal communication.
- Whitson, R.E., D.L. Parks and D.B. Herd. 1976. "Effects of Forage Quality Restrictions on Optimal Production Systems Determined by Linear Programming." Southern Journal of Agricultural Economics. 8:1-4.
- Williams, B. 1986. "The Bitter Harvest of Spring '86." BEEFWEEK. August.
- Williams, D.L. 1975. "An Economic Analysis of Beef Production in the Delta and Brown Soil Area of Tennessee." Ph.D. dissertation. University of Tennessee.
- Worley, T.L. 1981. "Patterns of Forage and Milk Intake by Angus Cows Grazing High and Low Quality Pastures." M.S. thesis. University of Tennessee.

APPENDIXES

APPENDIX A

TABLES

TABLE A-1

ESTIMATED EXPENSES PER ACRE, TALL FESCUE,
UPLAND SOILS, WEST TENNESSEE, 1988

Item	Unit	Cost/Unit	Quantity	Cost (\$)
Establishment Expenses				
Fescue Seed (KY 31)	LBS	1.03	15.00	15.45
Fertilizer				
N	LBS	0.22	60.00	13.20
P ₂ O ₅	LBS	0.24	60.00	14.40
K ₂ O ⁵	LBS	0.14	60.00	8.40
Lime	TON	13.83	2.00	27.66
Machinery (Variable) ¹	AC	13.08	1.00	13.08
Machinery (Fixed) ²	AC	28.86	1.00	28.86
Total Establishment Expenses				121.05
Prorated Over Ten Years				12.11
Annual Variable Expenses				
Fertilizer				
N	LBS	0.22	60.00	13.20
P ₂ O ₅	LBS	0.24	30.00	7.20
K ₂ O ⁵	LBS	0.14	30.00	4.20
Machinery ¹	AC	5.26	1.00	5.26
Total Variable Expenses				29.86
Annual Fixed Expenses				
Establishment Costs Prorated Over 10 Years				12.11
Machinery ²	AC	8.99	1.00	8.99
Total Fixed Expenses				21.10
Total Annual Expenses				50.96

¹Variable machinery expenses include repairs, fuel and lubrication.

²Fixed machinery expenses include depreciation, interest and insurance.

TABLE A-2

ESTIMATED EXPENSES PER ACRE, HYBRID BERMUDAGRASS INTERSEEDED WITH
TALL FESCUE (10" ROWS), UPLAND SOILS, WEST TENNESSEE, 1988

Item	Unit	Cost/Unit	Quantity	Cost (\$)
Establishment Expenses				
Bermuda Sprigs (Tifton 44)	BU	1.06	20.00	21.20
Fescue Seed (KY 31)	LBS	1.03	15.00	15.45
Fertilizer				
N	LBS	0.22	90.00	19.80
P ₂ O ₅	LBS	0.24	60.00	14.40
K ₂ O ⁵	LBS	0.14	60.00	8.40
Lime	TON	13.83	2.00	27.66
Herbicide (Simazine)	LBS	4.00	3.00	12.00
Machinery (Variable) ¹	AC	17.72	1.00	17.72
Machinery (Fixed) ²	AC	39.75	1.00	39.75
Total Establishment Expenses				176.38
Prorated Over Ten Years				17.64
Annual Variable Expenses				
Fertilizer				
N	LBS	0.22	90.00	19.80
P ₂ O ₅	LBS	0.24	30.00	7.20
K ₂ O ⁵	LBS	0.14	30.00	4.20
Machinery ¹	AC	5.26	1.00	5.26
Total Variable Expenses				36.46
Annual Fixed Expenses				
Establishment Costs Prorated Over 10 Years				17.64
Machinery ²	AC	8.99	1.00	8.99
Total Fixed Expenses				26.63
Total Annual Expenses				63.09

¹Variable machinery expenses include repairs, fuel and lubrication.

²Fixed machinery expenses include depreciation, interest and insurance.

TABLE A-3

ESTIMATED EXPENSES PER ACRE, PERENNIAL GRASS PASTURES RENOVATED
WITH LEGUMES (RED CLOVER & ANNUAL LESPEDESA),
UPLAND SOILS, WEST TENNESSEE, 1988

Item	Unit	Cost/Unit	Quantity	Cost (\$)
Renovation Expenses				
Red Clover Seed (Kenstar)	LBS	2.06	4.00	8.24
Annual Lespedesa Seed (Kobe)	LBS	1.03	8.00	8.24
Inoculant	PKG	1.08	0.90	0.97
Fertilizer				
N	LBS	0.22	0.00 ¹	0.00
P ₂ O ₅	LBS	0.24	60.00	14.40
K ₂ O	LBS	0.14	60.00	8.40
Machinery (Variable) ²	AC	7.31	1.00	7.31
Machinery (Fixed) ³	AC	20.23	1.00	20.23
Total Renovation Expenses				67.79
Prorated Over Five Years				13.56
Annual Variable Expenses				
Overseeding ⁴				
Red Clover	LBS	2.06	2.00	4.12
Annual Lespedesa	LBS	1.03	8.00	8.24
Inoculant	PKG	1.08	0.75	0.81
Fertilizer				
N	LBS	0.22	30.00	6.60
P ₂ O ₅	LBS	0.24	45.00	10.80
K ₂ O	LBS	0.14	45.00	6.30
Machinery ²	AC	6.89	1.00	6.89
Total Variable Expenses				43.76
Annual Fixed Expenses				
Renovation Costs Prorated Over 5 Years				13.56
Machinery ³	AC	13.39	1.00	13.39
Total Fixed Expenses				26.95
Total Annual Expenses				70.71

TABLE A-3 (continued)

- ¹ Nitrogen is not applied at renovation to minimize the competition between the established grass species and the legume seedlings.
- ² Variable machinery expenses include repairs, fuel and lubrication.
- ³ Fixed machinery expenses include depreciation, interest and insurance.
- ⁴ Red Clover is overseeded every 2 years. Annual Lespedeza is overseeded each year.

TABLE A-4

ESTIMATED EXPENSES PER ACRE, HAY HARVESTING AND FEEDING (1200-POUND
LARGE ROUND BALES), UPLAND SOILS, WEST TENNESSEE, 1988

Item	Unit	Cost/Unit	Quantity	Cost (\$)
First Cutting (June)				
Variable Expenses				
Twine	TON	0.58	1.50	0.87
Machinery ¹	AC	14.89	1.00	14.89
Fixed Expenses				
Machinery ²	AC	36.62	1.00	36.62
Total First Cutting Expenses				52.38
Second Cutting (September)				
Variable Expenses				
Twine	TON	0.58	1.50	0.87
Machinery ¹	AC	14.89	1.00	14.89
Fixed Expenses				
Machinery ²	AC	36.62	1.00	36.62
Total Second Cutting Expenses				52.38

¹Variable machinery expenses include repairs, fuel and lubrication.

²Fixed machinery expenses include depreciation, interest and insurance.

TABLE A-5

TENNESSEE FORAGE RESOURCES--PERCENT OF TOTAL ANNUAL PRODUCTION
BY MONTH FOR SELECTED FORAGES

Month	Tall Fescue	Bermudagrass/ Tall Fescue	Bermudagrass	Red Clover	Annual Lespedeza
----- percent of annual production -----					
January	2	1	0	1	0
February	6	2	0	2	0
March	14	4	0	10	0
April	20	12	8	25	0
May	15	18	10	20	3
June	6	15	15	12	12
July	2	14	25	6	35
August	3	11	20	6	30
September	7	8	15	7	18
October	15	9	5	8	2
November	8	4	2	2	0
December	2	2	0	1	0

Source: Fribourg (1983)

TABLE A-6

RANGE OF LEGUME OCCURRENCE IN THE GRASS-LEGUME MIXTURES AND BERMUDA-
GRASS OCCURENCE IN THE BERMUDAGRASS/TALL FESCUE MIXTURE, BY MONTH

Month	Legumes in the Grass/Legume Mix	Bermudagrass in the Bermudagrass/Tall Fescue Mix
----- percent ranges -----		
January	15 - 40	0
February	15 - 40	0
March	25 - 50	0
April	25 - 50	5 - 10
May	20 - 35	20 - 35
June	10 - 30	25 - 50
July	10 - 25	60 - 85
August	10 - 20	60 - 85
September	10 - 30	50 - 75
October	15 - 35	25 - 55
November	15 - 35	10 - 30
December	15 - 40	0

Source: Fribourg (1988b.)

TABLE A-7

TENNESSEE FORAGE RESOURCES--QUALITY BY MONTH FOR SELECTED
FORAGES USED IN GRAZING AND HAY PRODUCTION

Month	Tall Fescue ¹		Bermudagrass		Red Clover		Lespedeza	
	Grazing	Hay	Grazing	Hay	Grazing	Hay	Grazing	Hay
----- percent total digestible nutrients -----								
January	35	- ²	-	-	50	-	-	-
February	40	-	-	-	50	-	-	-
March	68	-	-	-	70	-	-	-
April	65	-	63	-	70	-	-	-
May	62	-	63	-	65	-	65	-
June	57	60	57	58	60	63	65	65
July	52	-	52	-	59	-	60	-
August	52	-	50	-	58	-	60	-
September	60	55	50	50	60	57	55	55
October	60	-	50	-	60	-	50	-
November	55	-	45	-	55	-	-	-
December	48	-	-	-	50	-	-	-

¹Two cuttings of hay may have been produced during a year. The first cutting included growth accumulated during April, May and June, while the second cutting was that in July, August and September. Hay quality is that at harvest in June and September.

²Dashes indicate months of no forage growth or hay harvesting.

Source: National Academy of Sciences and Fribourg (1988b.)

TABLE A-8

MONTHLY NET ENERGY REQUIREMENTS PER ANIMAL FOR MAINTENANCE AND GROWTH
USED IN THE LONG-TERM PLANNING (LINEAR PROGRAMMING) MODEL FOR
SPRING AND FALL CALVING HERDS

Month	Cows ¹ (NEM)	Bulls (NEM)	Calves (NEG)	Weaned Heifers (NEG)	Replacement Heifers (NEG)
----- Mcal per head ² -----					
Spring Herd					
January	338.0	270.5	0	162.6	370.3
February	397.8	244.3	0	169.6	170.0
March	438.0	270.5	0	188.4	0
April	484.1	261.8	2.6	202.1	0
May ³	445.2	270.5	32.1	103.0	138.0
June	394.9	261.8	53.8	0	251.8
July	400.8	270.5	79.4	0	288.0
August	366.9	270.5	98.8	0	259.1
September	368.3	261.8	117.3	0	279.1
October	373.6	270.5	135.1	0	301.5
November ⁴	242.7	261.8	0	137.4	327.0
December	291.2	270.5	0	152.2	362.1
Fall Herd					
January ³	445.2	270.5	32.1	103.0	138.0
February	394.9	244.3	53.8	0	251.8
March	400.8	270.5	79.4	0	288.0
April	366.9	261.8	98.8	0	259.1
May	368.3	270.5	117.3	0	279.1
June ⁴	373.6	261.8	135.1	0	301.5
July	242.7	270.5	0	137.4	327.0
August	291.2	270.5	0	152.2	362.1
September	338.0	261.8	0	162.6	370.3
October	397.8	270.5	0	169.6	170.0
November	438.0	261.8	0	188.4	0
December	484.1	270.5	2.6	202.1	0

¹Energy requirements for each class of cattle were based upon the following assumptions:

Cows--Requirements include energy for body maintenance (1000 lbs.), gestation and lactation at an average level of 16 pounds of milk per head per day.

Bulls--Requirements include energy for body maintenance (1200 lbs.).

Calves--Requirements include forage energy needed to supplement milk in the production of a 500-pound average weaned calf (420 lbs.).

TABLE A-8 (continued)

of gain for 274 days, or an average daily gain of 1.53 lbs.). Calves were assumed to begin noticeable forage consumption at six weeks of age.

Weaned Heifers--Requirements include energy to produce a 675-pound heifer from weaning to breeding (215 lbs. of gain for 196 days, or an average daily gain of 1.10 lbs.)

Replacement Heifers--Requirements include energy to produce an 900-pound heifer from breeding to calving (225 lbs. of gain for 274 days, or an average daily gain of 0.82 lbs.).

²Energy requirements are expressed as the net energy required for maintenance (NEM) of cows and bulls, and net energy required for growth (NEG) of calves and heifers.

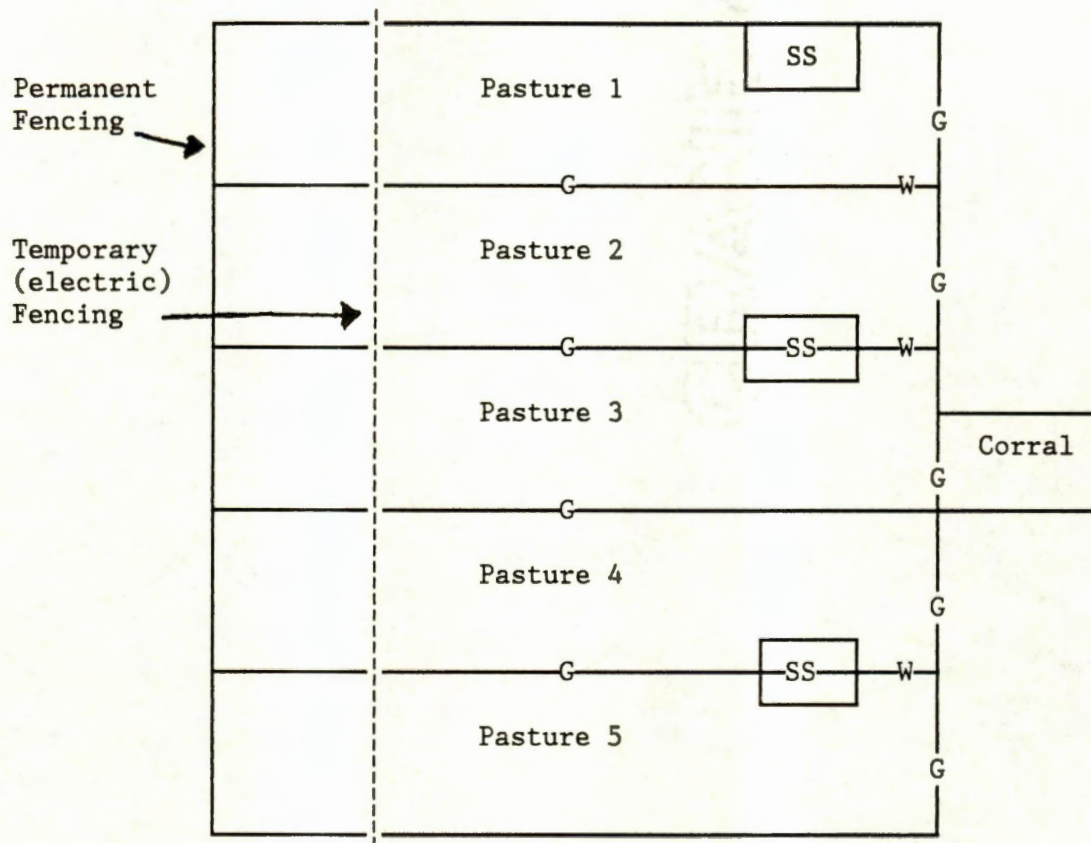
³An 85-percent conception rate was assumed for weaned heifers, with non-bred heifers sold after pregnancy checking in July for the spring herd and March for the fall herd. Therefore, replacement heifer requirements were increased by 15 percent during May through July in the spring herd, and January through March in the fall herd to account for non-bred heifers maintained during these periods.

⁴Cows herds were culled annually at the end of October in the spring herd and June in the fall herd, and replenished with replacement heifers in the calving month of each herd (spring herd--February; fall herd--October). Therefore, cow requirements were reduced by 17 percent (the replacement rate) during November through January in the spring herd, and July through September in the fall herd.

Source: National Research Council

APPENDIX B

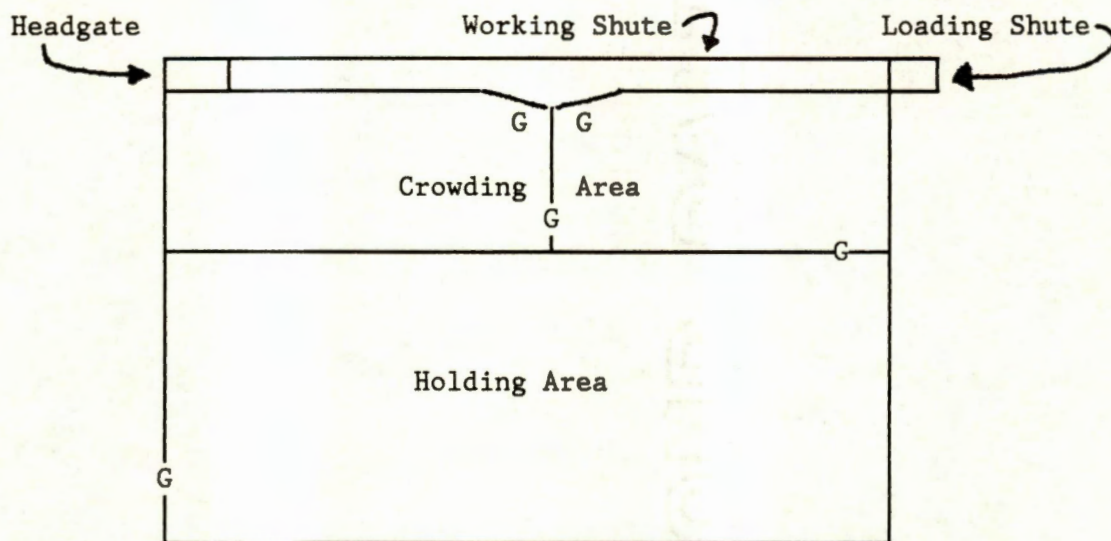
FIGURES

DesignSpecifications

- 200 acres of pasture divided into 5 pasture lots
- Permanent Fencing around perimeter of pastures and dividing pastures into 5 lots; 1 post per rod.
- Temporary (electric) Fencing to divide each lot into areas designated for hay production or idled
- Gates (G); 9-16' steel
- Water Tanks (W); 3-115 gallon with float and heater
- Shade Shelters (SS); 3-20 sq. ft. per cow total capacity

FIGURE B-1

SCHEMATIC OF THE DESIGN AND SPECIFICATIONS OF PASTURES
AND RELATED EQUIPMENT ON THE CATTLE OPERATION

DesignSpecifications

- Capacity of 100 cows
- Holding Area 20 sq. ft. per head
 - 5-2" X 6" slats rough lumber; posts every 8'
- Crowding Area 12 sq. ft. per head
 - 5-2" X 6" slats rough lumber; posts every 8'
 - Gates (G); 2-8' and 2-6' steel
- Headgate (manual)
- Working Shute
 - 5-2" X 6" slats rough lumber; posts every 6'
 - Width 3'
- Loading Shute
 - Width 3'; Length 5'

FIGURE B-2

SCHEMATIC OF THE DESIGN AND SPECIFICATIONS OF CORRAL
AND RELATED EQUIPMENT ON THE CATTLE OPERATION

VITA

William David McBride was born in Greencastle, Indiana on June 30, 1960. He was raised on a livestock-crop farm in Montgomery County, Indiana. He attended elementary and junior high schools in Waynetown, Indiana, and graduated from North Montgomery High School in 1978.

In September of 1978 he entered Purdue University as a student in the School of Agriculture. His major was Farm and Business Management, and he was awarded a Bachelor of Science degree in May, 1982.

Since January of 1983 he has been employed as a Graduate Research Assistant by the Department of Agricultural Economics and Rural Sociology at the University of Tennessee. The author completed the requirements for a Master of Science degree in Agricultural Economics in 1986. Upon obtaining this degree, he began pursuit of a Doctor of Philosophy degree at the University of Tennessee. He was awarded a Doctor of Philosophy degree during August of 1989, majoring in Agricultural Economics. His area of specialty was Production Economics-Farm Management.

Dr. McBride accepted a position with the United States Department of Agriculture, Economic Research Service upon graduation.