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To the Graduate Council:

I am submitting herewith a dissertation written by David Glenn Keltner entitled "A Mathematical Model of Forage-Based Post-Weaning Growth of Beef Cattle." I have examined the final electronic 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 Animal Science.

James B. McLaren, Major Professor

We have read this dissertation and recommend its acceptance:

John C. Waller, James C. Quigley III, Henry A. Fribourg, S. Darrell Mundy, Robert A. McLean

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Accepted for the Council:

Vice Provost and
Dean of The Graduate School

A MATHEMATICAL MODEL OF PASTURE-BASED POST-WEANING GROWTH OF BEEF CATTLE

A Dissertation

Presented for the

Doctor of Philosophy

Degree

The University of Tennessee, Knoxville

David Glenn Keltner

December 1990

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ABSTRACT

Four three-year experiments were conducted using 1.2 ha pastures to evaluate the productivity of various forage species combinations and the performance of stocker steers grazing them. Forage systems used were (1) Common bermudagrass (*Cynodon dactylon* L. var. *dactylon*) + 112 or 224 kg N/ [CB]; (2) Common bermudagrass overseeded with high endophyte (*Acremonium coenophialum* Morgan-Jones & Gams) tall fescue (*Festuca arundinacea* Schreb.), ladino clover (*Trifolium repens* L.) and Kobe lespedeza (*Lespedeza striata* (Thunb.) H & A) [CB + HF + LEG]; (3) HF + 67 kg N/ha [HF]; (4) HF + LEG; (5) Low endophyte tall fescue + 67 kg N/ha [LF]; (6) LF + LEG; (7) Midland bermudagrass + varying rates of N [MB]; (8) MB + LEG; (9) MB + HF + 224 kg N/ha [MB + HF]; (10) MB + HF + LEG; (11) MB + LF + 224 kg N/ha [MB + LF]; (12) MB + LF + LEG; and (13) Orchardgrass (*Dactylis glomerata* L.) overseeded with ladino clover [OG + LC].

Systems analysis was used to determine relationships among climate, forage dry matter production, dry matter intake, and animal performance. This information was incorporated into a mathematical model which would provide estimates of productivity with varying inputs in southwest Tennessee. Data from Tennessee Feeder Calf Sales (1972-1988) were incorporated to estimate animal value. Forage

production budgets and stocker cattle budgets were included to provide estimates of the economic viability of stockering cattle on various forage species combinations.

Six components comprising the model were user input area, climatic characteristics, forage yield, forage intake, cattle gain, and price and budget. User supplied inputs included expected yearly precipitation, yearly average temperature, forage system, soil type, animal sex, muscling score, stocking rate, and animal purchase price, weight, and month. Monthly output variables from the model were forage dry matter yield, dry matter intake, pasture carrying capacity, cattle weights, gains, average daily gains, beef production, cattle value per animal and per hectare, and net income per ha.

Output for each forage system simulated under normal climatic conditions was compared. Pastures containing HF were the least productive in terms of animal performance and estimated net income. Bermudagrass pastures receiving nitrogen fertilization produced the greatest amounts of forage and supported the most animals. However, animal performance was similar to that of HF forage systems. Steers grazing pastures with LF and OG gained more weight than steers grazing any other forage system. These gains resulted in a large economic advantage for these forage systems.

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CHAPTER I

INTRODUCTION

Agriculture is the largest industry in Tennessee (Tennessee Agricultural Statistics Service, 1989). Agriculture accounted for $1.9 billion dollars of the state's total production in 1987. Sale of cattle and calves ranked first in receipts among farm commodities and accounted for 28.9% of agricultural cash receipts and 50.3% of receipts from livestock and livestock products.

Tennessee is well suited to beef cattle production due to the abundance of grassland and pastures. Located in the temperate climate zone of the eastern United States, Tennessee is ideal for a variety of forage species. Mild winters, warm summers and, usually, abundant precipitation result in an excellent supply of forage during most of the year. The predominant beef cattle enterprise is the production of calves which are sold at the many feeder calf sales held throughout the state. Most Tennessee beef cattle producers have maintained a cow herd with minimal inputs for the production of feeder calves. Generally these calves are weaned and sold in the fall or spring at weights of 150 to 250 kg. This sale weight is less than one-half of the expected mature weight of the animals.

In recent years, the University of Tennessee Cooperative Extension Service has promoted backgrounding through a program called "Add 300" (Neel, 1986). Backgrounding is a post-weaning enterprise which involves growing calves to weights of 270 to 320 kg. Although slightly different from backgrounding, "stockering" is another term often used as a synonym for backgrounding. Both refer to growing lightweight weaned calves into feedlot-ready yearlings.

Tennessee is well suited to this post-weaning phase of beef production because of the abundant supply of weaned calves and forage. There are many questions and problems associated with this growing segment of the Tennessee beef cattle industry. For instance, which is the best forage or forage system to use? When are the best times to buy cattle and the best time to sell? What are the optimum buy and sell weights? Forage growth cycles need to be defined with respect to seasonal stocking rates, and animal management must be matched to these forage cycles to maximize forage production and utilization. Answers to these and many other questions are known if other factors of the system are fixed. Therefore, answers for all situations are not similar. These important questions should be evaluated while considering the entire system, since a change in one input

can affect other parts of the system. For this reason, a systems approach to analyzing beef cattle backgrounding operations is necessary.

The primary objective of this study was to determine relationships which exist among the various components of stocker cattle-forage management systems evaluated at Ames Plantation, Grand Junction, Tennessee, from 1970 through 1985. A secondary objective was to incorporate coefficients describing these relationships and seasonal feeder cattle prices into a deterministic model for prediction of likely outcomes of backgrounding programs in southwest Tennessee using these forage systems.

CHAPTER II

LITERATURE REVIEW

Inter-disciplinary Research

Since the early 1950's many reports of research results regarding livestock-forage systems have been published. However, division of animal scientists by disciplines impeded livestock-forage system research (Rawlins, 1988). Rather, each discipline concentrated on its area of expertise (Dent and Blackie, 1979; Smith, 1982). For many decades this division hampered development of grazing systems models by creating a void in inter-disciplinary knowledge between the animal and plant interface (Minson, 1983.)

Inter-disciplinary knowledge can be gathered only from systems analysis type research. Systems generally are defined as sets of interrelated components which interact in some complex manner to attain specific objectives (Atwood, 1977). Systems analysis examines an array of components of systems to determine relationships among those components.

Seven future developments which will significantly impact animal agriculture were listed by Thomas (1981). Included among these were increased competition for land, water and grain, greater environmental awareness and

increased concern for human health. For animal agriculture to continue as a large and viable industry, production of animal products must become more efficient. Systems research can identify problems associated with interactions between management and resource constraints in livestock-forage systems. This type of research can also provide information concerning economic viability of forage systems under various input situations (Little, 1985). The Beef Improvement Federation (BIF) (1986) recognizes that systems research provides means to measure efficiency of animal production and therefore will aid in determining inputs which are necessary for maximum herd efficiency.

Recently, there has been an increase in systems research in agriculture (Fitzhugh and Byington, 1982). Such research uses a team approach, with research teams composed of animal scientists, plant and soil scientists, pathologists, veterinarians, economists, engineers, virologists, biologists, etc.

Systems Analysis and Simulation

Increased inter-disciplinary research has provided large quantities of data for determining relationships among variables used in system models. This increased availability of inter-disciplinary data and advanced

computer technology have led to rapid increases in modeling of livestock-forage systems during recent years. Systems modeling supports a variety of flexible applications dependent upon objectives of the researcher.

The most basic application of livestock-forage systems modeling is its use to allocate scarce resources efficiently. These types of models, called activity analyses, are usually directed at profit maximization (Wilton et al., 1974, Miller et al., 1978) but may also seek to conserve resources (Rodriguez and Roath, 1987) or evaluate alternative livestock-forage or crop production systems (Schwab, 1974).

From these activity analyses more sophisticated simulation models have developed. Simulation is the construction of a detailed model designed to approximate a 'real world' system (Gafsi, 1970). The primary difference between simulation and activity analysis is that simulation does not specify a control program for decision making. As implied by definition, simulation is more detailed than activity analysis and is limited only by depth of knowledge and capacity of data management facilities (Eidman, 1971). Forrester (1968) visualized simulation as presenting a mental image of a system with numerical values assigned to effects and relationships. Simulation has other valuable characteristics such as (1)

its flexibility for adaptation to other objectives, (2) identification of gaps of knowledge (Arcus, 1963) and (3) consideration of time (Gafsi, 1970). Limitations of simulation should be noted also. Ability of simulation to approximate a system is dependent upon extent of knowledge about the system, sufficient data for assignment of numerical values to effects, and biases by the model-builder (Arcus, 1963; Gafsi, 1970).

Diversity is one of the primary reasons for modeling a system. Numerous components affect the outcomes of an agricultural production enterprise. As the number of components increases, the number of possible interactions increases exponentially. Scientists use modeling to assimilate and evaluate these diverse inputs and conditions. However, diversity of inputs, which has spurred production of models, is responsible for their shortcomings. To include all factors affecting the outcome of a production process is impossible. Because of this diversity, models are often disappointing in their abilities to predict outcomes. Many inputs are inexact quantities based on past experience or "best guess" (Dent and Blackie, 1979). For this reason, modeling should be viewed as a tool which, at best, provides a guideline of possible outcomes and which is not an exact measuring device.

Modeling serves several purposes. It provides scientists with insights into relationships among components and poses new questions simultaneously. In addition to a detailed list of well understood effects, models provide information concerning these effects, relationships and concepts which require additional research for better understanding (Freer and Christian, 1981; Cartwright, 1977). Models and simulations furnish a bridge between scientists and producers. Complex ideas in models provide practical information useful for producer decision-making (Dougherty et al., 1985).

Models are simplistic equations or inequalities describing very complex realities. The fact that models are simplifications which can never completely describe a real system is easy to forget. Inability to fully describe a system separates a model from reality and makes it prone to error (Brockington, 1979).

Model Construction

Spreen and Laughlin, 1986 identified numerous types of models which can be constructed. The primary determinant of model type is the objective of the model constructor. Johnson and Rausser (1977) suggested five primary steps involved in model construction. These are

specification, parameter estimation, verification, validation, and revision.

Specification is a decision-making step where objectives of modeling efforts must be designated. This is one of the most neglected steps. The specification step establishes boundaries. Generality or specificity of the model are determined based upon objectives, amount of available information, and degree of precision required (Joandet and Cartwright, 1975).

Oltjen (1986) describes three basic levels of models based upon objectives of the modeler. Empirical models, using linear regression equations, are primarily for descriptive objectives. Brockington (1979) refers to these as "black-box" models (Figure 1). Causal or mechanistic relationships, involving nonlinear equations, are necessary for increased understanding of systems. Finally, differential and integral equations are used in mechanistic models when a wider array of inputs is desired. Empirical models, described by Oltjen (1986), operate at higher levels of aggregation than mechanistic models and have narrow range applicability. As level of aggregation decreases, understanding increases and range of applicability increases.

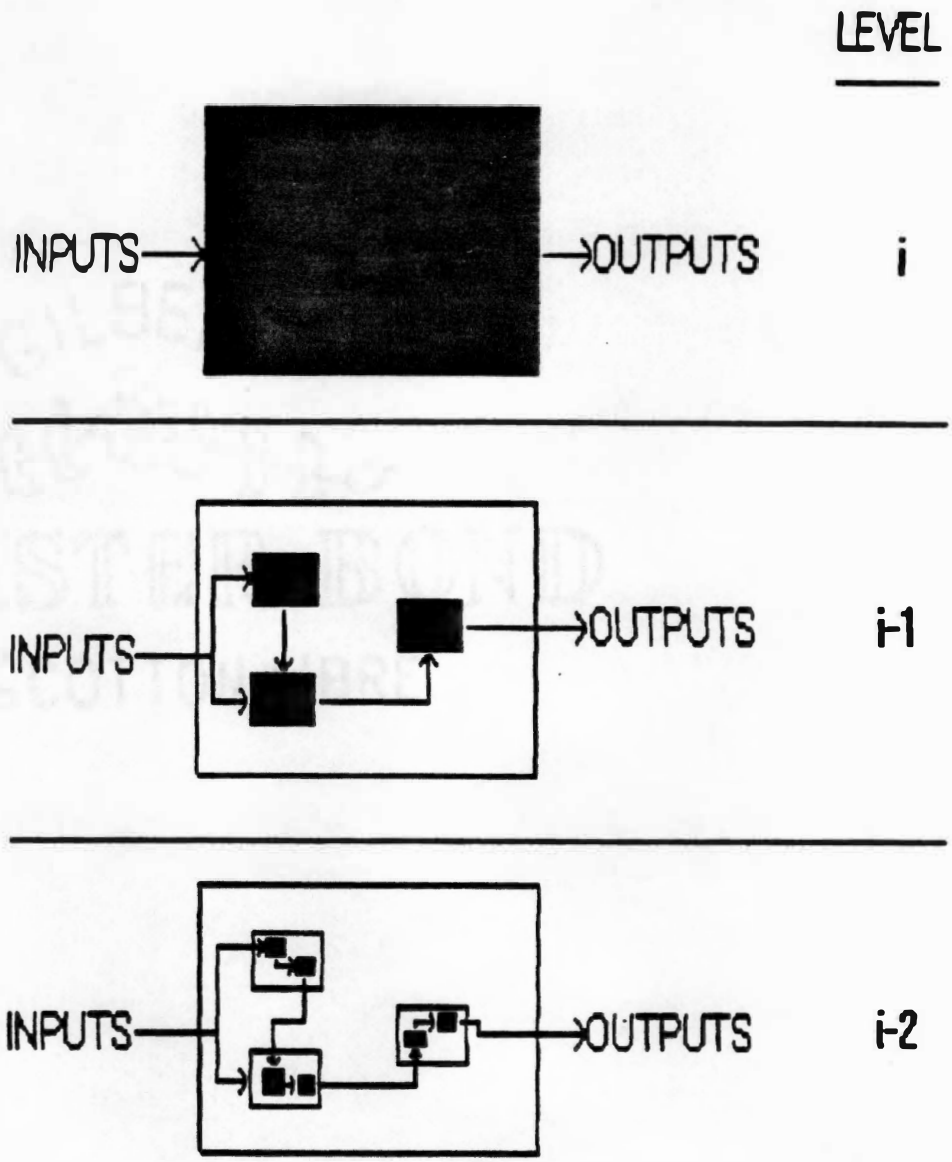

Figure 1. Diagram of modelling aggregation levels. Adapted from Brockington (1979) and Oltjen (1986).

Previously, research has been concerned with increasing levels of detail. Modelers have addressed this research emphasis by working at decreasing levels of aggregation. Lower levels of aggregation primarily provide a better understanding of processes which are responsible for outputs of various systems. MacNeil and Harris (1988) suggest that systems modeling may be utilized best by working toward higer levels of aggregation. If the processes described in lower levels are indexed or combined without loss of generality, the reduction in complexity would enable description of systems with larger boundaries (e.g. industries, macroeconomies). Oltjen et al. (1986) used this concept by applying a model of protein accretion of nine separate tissue and organ systems to whole body protein. The purpose of the model was to gain more accuracy than was possible with empirical models by operating at the whole animal level and to increase range of applicability by operating at a lower level of aggregation.

Parameter estimation is the process of analyzing relevant data to elucidate relationships determined in the specification step. Complete data, within bounds of the model, are rarely available from one source. Such a comprehensive study would be enormous and require large resources. Therefore, data from several different sources

and possibly from several different areas must be reconciled to estimate a given parameter. In many instances data may not be available and a "best guess" is necessary.

Verification, validation, and revision are necessary once the model is constructed. The ability of the model to perform correctly and in harmony with the initial objectives must be verified. The model must be validated against an independent source of data. The word independent is important since a model should perform well when compared to the data used in the parameter estimation step. Revision of the model is necessary if it does not properly emulate the intended system under specified objectives.

Model Expansion

One of the best opportunities for development of models of the animal-plant complex is integration of tested models of independent disciplines. Fick (1980) incorporated parts of several models to construct the Canterbury Pasture Production Model for production of irrigated ryegrass and white clover in New Zealand. The objective was to develop a model of pasture productivity that could be incorporated into a larger whole farm planning model for producers.

Rodriguez and Roath (1987) linked an empirical model describing forage and animal growth with a dynamic optimization model to evaluate alternative marketing and supplementation options. Similarly, Angirasa et al. (1981) coupled a biological simulation model with two economic linear programming (LP) models to evaluate the effects of integration and risk on an East Texas cow-calf operation. The biological simulation model (TAMU) was used to generate input-output coefficients for various beef production enterprises. These were used in the first economic LP program to maximize both long and short term total net revenue. Risk-constrained linear programming (MOTAD) then was used to incorporate risk into the short-term model. Bourdon and Brinks (1987) used the same biological model with a different economic LP program to evaluate efficiency of a cow-calf system with different cow types and compared yearling and weanling production systems. The result was that the most biologically efficient system (weanling) was not the most economically efficient system. The yearling system was more economically efficient than the weanling system because of the increased slaughter weight of the animals.

Forage and Animal Production Models

Forage-beef systems naturally lend themselves to systems analysis and modeling due to their inherent hierarchical subsystems. The two primary subsystems, forage and beef production may be considered as independent systems in the absence of the other. However, when the system boundary is expanded to include the two together, processes within the two subsystems become extremely complicated due to their effects on one another. Grazing systems are difficult to describe mathematically due to a lack of knowledge concerning the interface between the two systems (Sibbald et al., 1979). Factors controlling intake of grazing animals still are not well understood (Minson, 1983) although several theories have been proposed (Conrad et al., 1966; Holloway, 1984).

Forage Production Models

Clayton et al. (1983) used a simple linear regression model to predict production of range herbage in southwestern Idaho from a precipitation index. Wight et al. (1984) improved the model by including soil water content, mean air temperature, and solar radiation. From these input variables, the ratio of actual transpiration to potential transpiration was calculated. This

transpiration index was multiplied by potential yield to predict actual yield.

Overman et al. (1988, 1989) developed two models describing cumulative production of 'Coastal' bermudagrass (*Cynodon dactylon* (L) Pers.). The first model, an empirical model, was found to describe production very well when compared to data from Watkinsville and Tifton, Georgia and Gainesville, Florida. The model equation used time as the only input variable and mean time, time spread and total season production as the only three parameters. The derivative of the equation was the well-known Gaussian distribution indicating that production was greatest during the middle of the growing season. A method was developed for estimating the three parameters for various nitrogen levels so that N fertilization could be incorporated into the model. The second model used the same Gaussian function but also included the effects of irrigation, nitrogen level, and harvest interval on model parameters in a dynamic environment.

Animal Production Models

In animal science, non-grazing models have primarily developed in the areas of nutrition, metabolism and growth, and genetics as related to selection strategies. Reproductive models also have been developed (Sanders,

1974) although they usually are concerned with reproduction from a genetic aspect (Doren et al., 1985; Johnson and Notter, 1987). Models which evaluate various management alternatives are available. These system descriptions integrate genetics, nutrition, growth, and metabolism at a higher level of aggregation to simulate production at herd or ranch level.

Models have been developed to calculate energy requirements of animals (Geisler and Jones, 1979) and to simulate growth and body composition from energy and nitrogen inputs (Graham et al., 1976). Song and Dinkel (1978) modeled feed intake and growth of weaned beef cattle. Several equations were developed to consider chemostatic, thermostatic, and distension limitations on intake. Bywater (1984) and Forbes (1977) developed models of intake for lactating dairy cows over a range of feedstuffs. Both models used the assumption that a cow will eat to maintain energy balance provided feed quality and rumen capacity permit. These models generally performed well but could not account for the lag between milk production and feed intake.

Clarke et al. (1984) compared several selection strategies for genetic and economic gains. Maximum genetic progress was made by reducing maximum cow age and emphasizing male selection. Greatest economic progress

was made by culling cows not producing a live calf and those with poor progeny performance. This agrees with the results of Bourdon and Brinks (1987) who found that the most biologically efficient system is not necessarily the most economically efficient. Johnson and Notter (1987) used a simulation approach to identify factors which influence underlying genetic variation of reproductive traits in beef cattle.

One of the most prevalent beef production models was developed by Sanders and Cartwright (1979a, 1979b) at Texas A&M University. This model simulated reproductive performance and growth of herds of cattle using genetic, nutritional and management input data, with the objective of describing the biological processes involved. The general structure of the model operates at a high level of aggregation. Detailed components are incorporated to increase the range of applicability. Another well-known beef production model is the Kentucky Model (Spreen and Laughlin, 1986). However, one of the objectives of the developers was to construct the ultimate model. Therefore, the Kentucky model, although a very good research model, is too cumbersome for practical use. Blackburn and Cartwright (1987) developed a model of sheep production. The model operated at animal level for physiological processes and then accumulated sheep into

flocks to evaluate effects of genetic and environmental factors on flock productivity.

Grazing Models

Grazing models are typically most concerned with the interface between the plant and animal subsystems. Both forage production and quality, and animal growth are dynamic systems. Therefore, their interactive effects are not constant. Brorson et al. (1983), Olson et al. (1986) and Whitson et al. (1976) considered this when they incorporated changes in intake by cattle over time due to variations in quality of forage.

A model to evaluate various grazing management strategies of bermudagrass for beef production was developed by Senft and Tharel (1989). The model aided in determining stocking rate which maximizes production efficiency for different grazing regimes. Rodriguez and Roath (1987) used empirical equations to describe forage and animal growth under different management. Marketing alternatives were included to evaluate results of selling cattle at various points during the grazing season.

Angirasa et al. (1981), Pope and Shumway (1984) and VanTassell et al. (1987) developed models to evaluate risk and uncertainty of beef production as related to

unpredictability of environmental conditions and forage yield.

Forage Species

Tennessee is ideally located in the transition zone between northern and southern climates for the production of both warm-season and cool-season forages. With average annual rainfall of approximately 130 cm (National Oceanic and Atmospheric Administration, 1983), moisture is not a limiting factor for forage production in most years. However, prolonged periods of dry conditions are common and, depending on soil type, their effects on forage production can be severe. The majority of precipitation occurs in winter and early spring and results in rapid growth of cool-season grasses.

Tall fescue (*Festuca arundinacea* Schreb.) is the predominant cool season forage in Tennessee. An estimated 1.4 million hectares in the state contain tall fescue (Burns, 1984). The popularity of tall fescue is primarily due to ease of establishment, adaptation to a wide range of soil conditions, and hardiness under extreme weather conditions and mis-management (Buckner, 1985). Performance of animals grazing tall fescue has been less than expected from a forage with such excellent agronomic and chemical qualities (Bond et al., 1984; Hemken et al.,

1984). Researchers have identified an endophytic fungus (*Acremonium coenophialum* Morgan-Jones and Gams) present in tall fescue that is associated with poor animal performance (Hoveland et al., 1980; Hemken et al., 1984). New fescue cultivars with low percentage of endophyte-infected plants are now available. Animals grazing these cultivars approach the performance of those grazing orchardgrass (*Dactylis glomerata* L.) (McLaren et al., 1983). However, many of these cultivars are more difficult to establish and are less persistant under extreme temperatures and intense grazing pressure (West et al., 1988).

Orchardgrass is also a cool season forage commonly used in Tennessee. The nutritive value of orchardgrass is extremely good, approaching that of alfalfa, when in the vegetative stage (Jung and Baker, 1985). Unlike tall fescue, orchardgrass stands can be damaged permanently by overgrazing or other mis-management. Due to lack of tolerance for hot and droughty conditions, orchardgrass requires intense summer management.

Bermudagrass is the predominant warm-season forage in Tennessee, particularly in the western part of the state. Common bermudagrass (*C. dactylon* var. *dactylon*) is the principal ecotype found in the state although its prostrate growing habit results in lower yields than those

of improved cultivars. 'Midland' bermudagrass has become increasingly popular in Tennessee due to winter hardiness and greater yields and more erect growing position than common bermudagrass. Use of 'Tifton 44', another hybrid bermudagrass, has increased in the state. Tifton 44 is superior to Midland in yield and animal performance and is a winter-hardy cultivar (Burton and Hanna, 1985). Midland Bermudagrass grows well in spring and summer and fills the warm season forage production gap of cool-season species such as tall fescue and orchardgrass. However, stocker cattle grazing bermudagrass only maintain weight and condition during summer months due to low forage quality (Fribourg et al., 1979).

Incorporation of legumes in grass pastures increases total forage quality and animal performance (McLaren et al., 1983). White clover (*Trifolium repens* L.) is widely used for this purpose in the eastern United States. The large types or ladino clovers are the preferred legume for inclusion to improve tall fescue pastures because of relatively higher yields than smaller types (Fribourg, 1978). The word ladino refers to both the class of large type clovers and a specific large white cultivar (Carlson et al., 1985). Another commonly used large-type cultivar in Tennessee is 'Regal' ladino clover. These clovers act as perennials under low stress management but producers

may need to reseed each spring to maintain adequate clover content in pastures. Nitrogen from the nitrogen-fixing process of legumes is available to grasses. Legumes also aid in reducing effects of fescue toxicosis by diluting effects of the fescue endophyte (Fribourg et al., 1986)

Stockering vs Backgrounding

In Tennessee, the term backgrounding generally defines the growing of lightweight calves to heavier weights prior to the finishing phase, without respect to food source used (Gill and Neel, 1985). Stockering in this state is the term given to a specific type of backgrounding venture where low quality roughages are marketed through thin cattle (stockers). However, many authors on beef production define backgrounding and stockering as two different operations. While these authors (Ensminger, 1978; Neumann, 1977; Thomas, 1986) agree with the use of the word stockering in Tennessee, they define backgrounding as rapid growing of better fleshed cattle (feeders) on high quality roughage with possible use of an energy supplement in preparation for finishing. This paper refers to the post-weaning growth of beef calves on high quality pasture-based systems. This production phase is similar to stockering since thin, often mis-managed, cattle are used in a grazing situation.

However, it also has characteristics defined by the term backgrounding.

According to Neel (1986), the greatest potential for profits from cattle production is during this post-weaning growth phase. During this phase, weight increases in cattle are more efficient and economical than during other phases. Low quality forages and other low cost feeds can be utilized by animals to produce large gains during this rapid growth phase.

By incorporating the backgrounding phase into a cow-calf operation, the producer may realize many advantages. Of major importance is the fact that retaining ownership beyond weaning permits the cow-calf producer to collect a larger percentage of the mature value of the animal. In effect, by joining the two enterprises, the cow-calf producer collects income he would normally receive if the calves were sold at 6-8 months of age, and he collects any profit from the backgrounding phase. In addition, marketing and transportation costs are reduced and the incidence of morbidity and mortality is generally lower due to reduced marketing and shipping stress (Billingsley, 1979; McLaren, 1984).

Another advantage of backgrounding is the numerous associated marketing options. Greater cash flow flexibility and greater forage utilization can be achieved

by selling cattle at any time during this phase. By realizing this option, producers can alter marketing time and utilize market fluctuations to increase returns. Other possibilities include selling heifers as replacements if more profitable, or increasing vertical integration by feeding the backgrounded calves to slaughter (Neel, 1986).

Slow acceptance of backgrounding in Tennessee can be traced to several factors. Many Tennessee beef producers are unfamiliar with the various marketing options available for backgrounded cattle. The beef cattle industry of this state is geared to production of weaned calves and organized feeder calf sales make this the most convenient route for producers. Tennessee feeder calf sales attract many out-of-state growers and finishers because of the large number of lightweight weaned calves at these sales (Neel, 1985). These buyers recognize that the large economical increases in weight during this phase provide an opportunity to increase returns on their investments. Since lighter cattle provide opportunity for greater profit, heavier weight calves are sold at a lower price.

In the past producers could not understand why they should hold their cattle longer and receive a lower price per unit weight. By selling calves at weaning, producers

can realize a more immediate return. In addition, their costs are lower due to fewer inputs. Fortunately, farmers are now generally better educated in marketing procedures. This increased awareness of marketing options, no doubt, will spur the development of beef cattle backgrounding operations in the future.

Increases in the number of 320- to 370-kilogram cattle entering the sale arena in recent years are evidence of increasing numbers of stocker operations in Tennessee. In 1989, approximately one-third of all steers sold in Fall Feeder Calf Sales weighed more than 272 kg (Rawls, 1990).

Conclusion

Beef cattle production in Tennessee has traditionally been oriented toward the production of weaned calves. The natural agronomic productivity and the abundant supply of light-weight weaned calves make Tennessee an ideal area for stocker cattle operations. By estimating productivity of such operations with various combinations of inputs, producers could evaluate and identify management systems which provide the greatest returns with available resources.

Modeling forage and animal growth offers an opportunity for researchers to concentrate on needed

information by addressing production systems in their entirety. Traditional approaches of working in a strictly defined area are useful for basic research problems. Practical knowledge of production requires a systems approach considering all factors which affect operation processes.

CHAPTER III

MODEL DEVELOPMENT

Introduction

This modelling effort was undertaken to describe the backgrounding of beef calves on various forages and forage combinations. Oltjen (1986) described such models as empirical, since they are concerned only with the observed relationships and not the underlying biological processes. Empirical models are generally characterized by linear equations and fewer parameters than more complicated mechanistic models. Empirical models tend to have greater precision than other model types but are limited to the observed systems. However, a logical modelling sequence is to begin with the most basic relationships, refered to by Oltjen as level i, and then proceed to lower levels by making the model more mechanistic.

Primary Data Source

Most models rely heavily on published results from experiments. Modelers attempt to combine results from many different experiments at many locations to describe a system. This study is somewhat different in that most parameters were estimated from data collected in one large multi-phase experiment conducted in the modelling area.

Other sources were used only when information was not available from this experiment.

Backgrounding systems used in this study are based on four phases of a grazing study conducted over a 16-year period at Ames Plantation, Grand Junction, Tennessee. The 1.2 ha pastures were established on a Memphis silt loam soil (fine-silty, mixed, thermic, Typic Hapludalfs) which had been used for hay or corn production prior to 1970. In each phase, forage treatments were established in a randomized complete block design with two replications. Each phase was implemented for three grazing seasons with a 1-year interval between phases for developing suitable pastures for the next phase. In each phase, one treatment consisted of orchardgrass-ladino clover. Forages and forage combinations included in this study are shown in Table 1 along with years in which each forage system was evaluated.

Forage growth and consumption were estimated by the cage and strip method (Linehan, 1952) using one cage and one strip for each 0.2 ha. A minimum of three medium frame 1 or 2 tester steers weighing 205 to 270 kg were used on each pasture to measure animal performance. Grazing began approximately April 1 each year or as forage availibility allowed. Individual weights of three tester steers on each pasture were taken at approximately 21-day

Table 1. Forage systems used and the years in which they were included in comparisons at Ames Plantation.

Forage Combination			Phase in Which Each Forage System was Evaluated[a]			
Model Code	Description	Alphameric Code	I	II	III	IV
1	Common bermudagrass + N[b]	CB	*	*		
2	Common bermudagrass + Kentucky 31 tall fescue + Legumes[c]	CB+HF+LEG			*	*
3	Kentucky 31 tall fescue + N[d]	HF				*
4	Kentucky 31 tall fescue + Legumes[c]	HF+LEG		*	*	*
5	Low endophyte Kentucky 31 tall fescue[e] + N	LF				*
6	Low endophyte Kentucky 31 tall fescue[e] + Legumes	LF+LEG				*
7	Midland bermudagrass + N[b]	MB	*	*		
8	Midland bermudagrass + Legumes[c]	MB+LEG		*		
9	Midland bermudagrass + Kentucky 31 tall fescue + 224 kg N/ha[b]	MB+HF		*	*	*
10	Midland bermudagrass + Kentucky 31 tall fescue + Legumes[c]	MB+HF+LEG			*	*
11	Midland bermudagrass + Low endophyte tall fescue[e] + 224 kg N/ha[b]	MB+LF				*
12	Midland bermudagrass + Low endophyte tall fescue[e] + Ladino clover	MB+LF+LEG				*
13	Orchardgrass + Ladino clover	OG+LC	*	*	*	*

[a]Phase I 1971-1973; Phase II 1975-1977; Phase III 1979-1981; Phase IV 1983-1985.

[b]Nitrogen applied in three equal installments in late March, late May and early July.

[c]Legumes include ladino clover and Kobe lespedeza.

[d]67 kg/ha of nitrogen applied in late March.

[e]Less than 5% endophyte infected.

intervals to coincide with harvesting of cages and strips. A modified put-and-take grazing system was used to minimize frequency of stocking rate changes and maximize forage utilization by steers. Bermudagrass and tall fescue pastures were managed so that available forage was maintained at a height of 3 to 10 cm. Orchardgrass pastures overseeded with ladino clover were maintained at a height of 7 to 15 cm.

General Structure

Since most data for this study were collected at Ames Plantation, the area of application is limited to southwest Tennessee. Based on climate, topography and soil types, Williams (1975) and McBride (1989) defined areas of application in southwest Tennessee similar to this. This area includes most of Shelby, Fayette, Hardeman, Tipton, Haywood, Madison, Lauderdale, Crockett, Dyer, and Gibson counties.

The model was developed as a tool for producers and extension extension personnel to provide an estimate of forage and animal production of stocker cattle systems for various management alternatives. In addition, an estimate of financial performance of the system is calculated. The model is relatively simple to use and understand due to the few input parameters required and the linear

regression equations used to calculate performance estimates. The model relies exclusively on regression equations to estimate productivity based on information provided by the model user.

Forage production and intake, animal performance and animal value were modelled for a five-month (April - August) grazing season on permanent pastures. The model has six components which utilize user input information and information calculated from other components of the model. Components are climate, forage growth, forage intake, cattle performance, and price and budget (Figure 2). Production outputs and cattle economic values were calculated for each month.

Output from the model includes kilograms of forage dry matter yield per hectare, kilograms of dry matter intake per animal, and number of animals the forage system will support based on forage production and animal intake. Weights for the beginning and end of each month are provided along with gain expressed on a monthly and daily basis. Monthly gain and user supplied stocking rate is used to provide an estimate of kilograms of beef production per hectare. An estimate of the price per hundredweight of the animals is made based on average weight and the month of the year. This estimate is then translated into gross value on a per animal and per

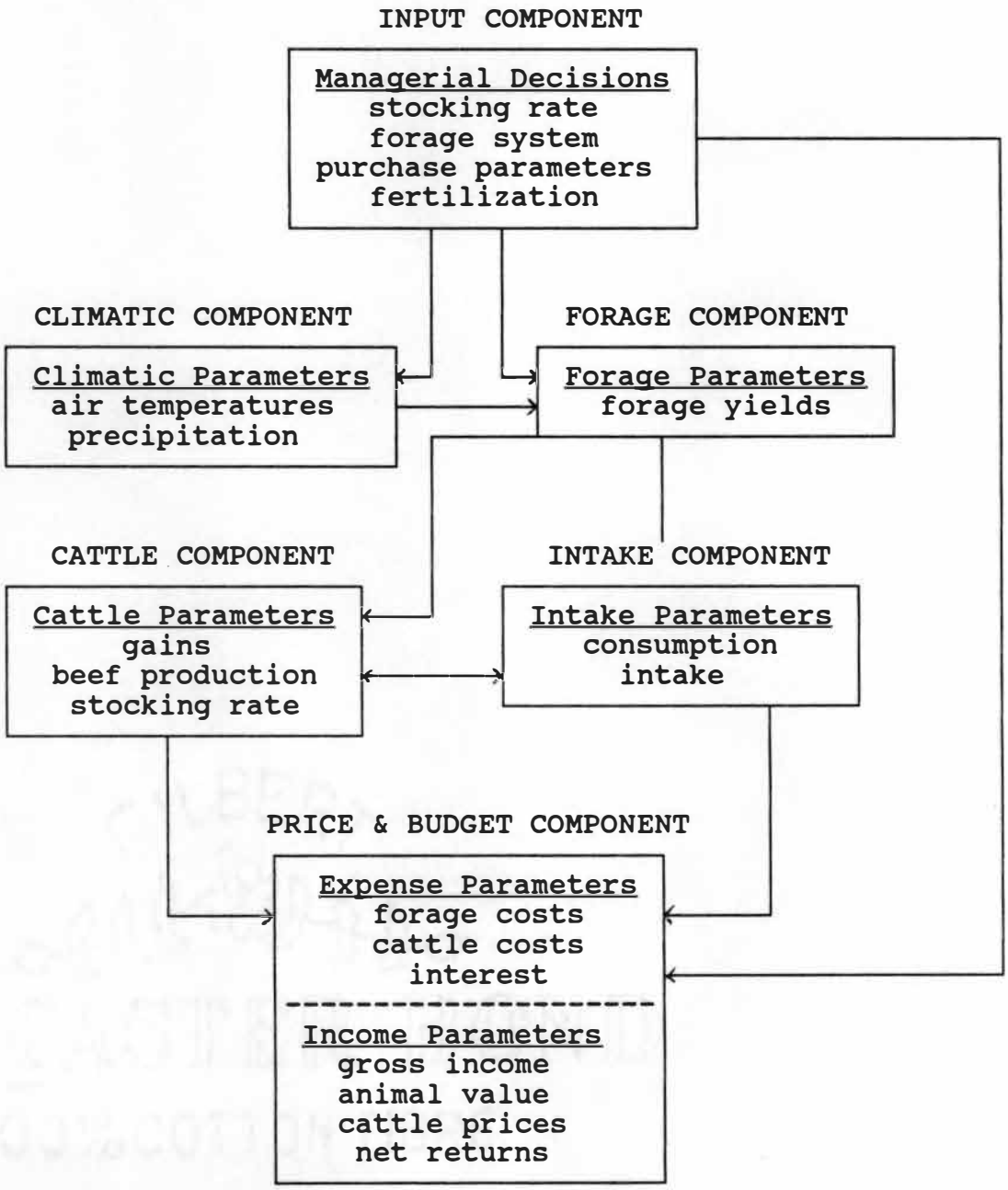

Figure 2. Diagram depicting the flow of information among various components of the model.

hectare basis. Expenses, including animal purchase, forage production, labor, and interest are then deducted to provide an estimate of net returns per hectare.

The model user begins by accessing the file User SAS which should be stored on a permanent mainframe mini-disk. Here the user provides information regarding eleven parameters necessary for the prediction equations. The file contains a banner in the first few lines of the file set off by stars. This banner explains each of the eleven variables and the units for each. When the neccessary information has been provided the user submits the job to the Statistical Analysis System (SAS) for processing. The output contains monthly production estimates for the selected input parameters.

The user may wish to run the model several times to evaluate productivity and returns with alternative input parameters. In this way, a producer has a basis for choosing a production system that matches available resources.

The model works through use of matrix algebra using the Interactive Matrix Language (IML) of the (SAS). Each forage system composes one row of the matrices. Dependent variables used in the prediction equations for each forage system make up the columns. Regression coefficients for each forage system comprise the matrix

elements. Each component contains one coefficient matrix which is used to store the regression coefficients for the calculation of the predicted variable in that component. User choice of a forage system results in extraction of one row from each coefficient matrix. The extracted vector is multiplied by a vector which includes climatic date values, user supplied inputs, and values predicted in previous components.

Inputs

The input file is an area designated for entering information necessary to perform calculations. Required variables include yearly precipitation, yearly average temperature, forage system, soil type, animal sex, muscling score, stocking rate, price paid for animals, animal purchase weight, and month of purchase.

Yearly precipitation was classified as either 'DRY', 'AVG' or 'WET'. For purposes of analysis, yearly precipitation was collapsed into one of these three classes to derive a distribution of rainfall for each class. Forage systems were assigned a numerical code as shown in Table 1, page 29. A numerical value from Table 2 was used to enter major soil type. This numerical value serves as an indexing scalar in the yield component of the model. Initial animal weight was average weight of

Table 2. Relative dry matter productivity of forage crops grown on six different soil series[a].

Model Code	Soil Series	Tall Fescue	Orchardgrass	Bermudagrass	Bermudagrass + Fescue
		%			
1	Lexington	56	95	90	149
2	Grenada	81	58	101	81
3	Memphis	100	100	100	100
4	Loring	102	85	104	91
5	Calloway	89	97	87	141
6	Henry	100	56	168	118

[a]Adapted from Fribourg et al 1989.

animals in kg on the day grazing began. Sex of the animals was coded as either 'S' or 'H' for steers or heifers, respectively. Possible muscling score values were either 1 or 2. These scores include animals that will grade "select" or higher. Stocking rate was entered as the number of animals per hectare of pasture. Since cattle are often purchased in fall and maintained through winter, information concerning the purchase was needed for the price and budget component. Purchase price, specified by the user, was dollars per hundredweight paid for the animals. Purchase month was the month in which animals were purchased and purchase weight was the average weight of cattle on which purchase price is based.

Climatic Component

Precipitation is almost impossible to predict. Shifts in the jet stream, changes in ocean currents, and many other variables can result in prolonged dry or wet periods (Baur, 1951). Climatic conditions are often simulated as stochastic functions which incorporate variability into the model (Hanson et al., 1982; McBride, 1989; VanTassell et al., 1989).

In this study, climatic component is actually composed of two modules. The first module generates precipitation values while the second module generates

average, maximum, and minimum air temperatures. Weather records from Ames Plantation from 1971 through 1988 were used to determine precipitation and temperature distributions. Although grazing was restricted to begin no earlier than April 1, climatic variables were predicted beginning on January 1 since climatic conditions in a given month can affect forage growth in subsequent months. Each year was classified as either dry, average, or wet based on January through August precipitation. Normal precipitation for the January through August period from Bolivar, Tennessee weather records is 90.70 cm (National Oceanic and Atmospheric Administration, 1983). Average precipitation for this eight-month period for the 18 years of data used was 90.69 cm with a standard error of 6.41 cm. Boundaries among the three classes of precipitation were chosen as two standard errors on either side of the overall mean. Six years were classified as "dry" with eight-month precipitation less than 77.87 cm. Four years were classified as "wet" with eight-month precipitation greater than 103.51 cm. The remaining eight years were in the "average" classification. Monthly means were then calculated for each of the three classifications and were used as estimates of monthly precipitation. The greatest differences in precipitation among the three classes occured prior to mid-year. January through August monthly

means for the three precipitation classes along with normal monthly rainfall are presented in Table 3.

Ambient temperatures follow similar patterns from year to year with the primary differences among years being the magnitude of the temperatures. Average yearly temperature was entered in degrees Celsius. Normal yearly temperature for this area is 15.3°C (National Oceanic and Atmospheric Administration, 1983). The magnitude of summer temperatures was directly related to the yearly average temperature. The variation in minimum and maximum monthly ambient temperatures for the period 1970 through 1988 was almost entirely explained by regression models containing average yearly temperature, average yearly temperature squared, climatic date, and climatic date squared. Climatic date is a number assigned to each day beginning with March 1 as climatic date 1 and ending with the last day of February as climatic date 365 or 366 in leap years. Regression coefficients are shown in Table 4. Average monthly temperatures were calculated as the mean of minimum and maximum monthly temperatures.

Forage Growth Component

General forage production distributions of several forages have been defined (Mueller and Green, 1980). Variation among years is primarily related to climatic

Table 3. Normal monthly precipitation and means and standard errors for dry, average, and wet classifications from January through August at Ames Plantation from 1971 through 1988.

Month	Normal[a]	Dry[b]		Average[b]		Wet[b]	
		Mean	SE	Mean	SE	Mean	SE
	cm						
January	12.52	7.50	2.69	9.20	0.95	18.92	1.60
February	11.35	5.95	2.37	10.81	2.86	19.21	3.26
March	14.12	9.59	1.79	14.61	2.99	20.71	5.39
April	13.16	7.97	1.18	15.17	2.40	15.91	4.46
May	11.76	10.55	2.64	15.43	2.59	18.26	1.67
June	8.81	8.79	2.09	10.85	1.79	13.36	3.72
July	10.21	8.03	1.43	9.65	1.99	9.46	0.90
August	8.76	3.97	0.50	8.45	1.41	10.42	2.67
Total	90.70	62.34	7.94	94.17	2.14	126.25	6.15

[a]1950 to 1980. National Oceanic and Atmospheric Administration, 1983. Bolivar, Tennessee Weather Station.

[b]Means of six, eight, and four years for dry, average, and wet classifications, respectively.

Table 4. Regression coefficients for prediction of minimum and maximum temperatures.

Independent Variable	Temperature, °C	
	Minimum	Maximum
Intercept	-10.1	-51.5
Yearly Average Temperature, °C	0.46	8.05
Yearly Average Temperature^2, °C		-0.2599
Climatic date	0.2974	0.2750
Climatic date^2	-0.000971	-0.000867
Mean square error	12.3357	15.1596
R-square	0.5902	0.5287

conditions and age of stand. However, forage production in any period is not exclusively determined by climatic conditions during that period. Effects of climate on forage production are cumulative due to availibility of soil moisture and heat stored in the soil. For this reason, cumulative climatic variables generated by the climatic component of the model were used to generate monthly cumulative forage production.

Stepwise and R-square procedures of the Statistical Analysis System (SAS, 1985e) were used to determine the best statistical model for explaining variation in cumulative forage production for each forage system. A combination of model adjusted R-squares, partial R-squares, significance levels, model mean square errors, and Mallow's C(p) statistics were used as criteria for selecting the best model (Draper and Smith, 1968; Rawlings, 1988). Regressor variables considered for inclusion in the models consisted of climatic date as a measure of elapsed time, climatic date squared, climatic date cubed, minimum and maximum monthly temperature, minimum and maximum monthly temperature squared, cumulative precipitation, cumulative precipitation squared, and climatic date x cumulative precipitation interaction.

For Midland bermudagrass (MB) and common bermudagrass (CB) forage systems, the amount of nitrogen used was included also. In all years, nitrogen was applied at the rate of 224 kg/ha to pastures containing MB in combination with high endophyte tall fescue (HF) or low endophyte tall fescue (LF). Nitrogen fertilization for these four forage systems occurred in three equal installments in late March, late May and early July. A single application of 67 kg/ha of nitrogen was made to HF and LF forage systems in March. This made it impossible to determine effects of varying levels of nitrogen on production of HF, LF, MB+HF, or MB+LF. Since nitrogen is subject to leaching and volatilization, forage production tends to be greater in periods following fertilization. Therefore, forage production estimates are valid only when a similar nitrogen fertilization scheme is followed. Regression coefficients retained for use in the model are presented for various forages in Table 5.

Properties of the soil on which forage is produced also affect forage production but in a more constant manner. Soils of this area of Tennessee are classified predominantly as Memphis, Lexington, Grenada and Loring series with some Calloway and Henry (Springer and Elder, 1980). The data collection area was mainly on Memphis silt loam. An index of relative dry matter production of

Table 5. Regression coefficients and standard errors[a] used to predict cumulative dry matter production of various forage systems.

Forage[b]	Intercept, kg	Climatic Day, days	Climatic Day^2, days^2	Cumulative Precip., cm	Cumulative Precip.^{2}, cm^2	Day x Precip., dayxcm	Nitrogen Appl., kg	Maximum Monthly Temp., °C	Maximum Monthly Temp.^{2}, °C^2	Minimum Monthly Temp., °C	Minimum Monthly Temp.^{2}, °C^2	R^2
CB	-3495.7	57.675		111.094	-0.67731		-12.9847			-252.765	6.10831	.90
	(1234.2)	(4.264)		(36.327)	(0.20239)		(2.3829)			(61.514)	(2.3530)	
CB+HF+LEG	-1820.2	40.344										.64
	(470.4)	(3.730)										
HF	-6294.8	70.684	-0.18027	62.202								.81
	(1922.3)	(36.486)	(0.12951)	(25.869								
HF+LEG	3584.2	44.390	0.15069	-27.291	0.60684	-0.6768		-334.377		412.771		.72
	(1430.7)	(17.959)	(0.11214)	(26.152)	(0.35368)	(0.3516)		(109.402)		(109.988)		
LF	-4695.7	112.244	-0.26647									.56
	(3432.7)	(58.866)	(0.23048)									
LF+LEG	-5226.4	88.349	-0.29423	49.669								.74
	(2103.6)	(39.927)	(0.14172	(28.308)								
MB	-3452.7	-55.779	0.21012	208.182	-1.7940	0.6542	5.7715	-304.208	8.94415			.80
	(1811.0)	(31.835)	(0.14984)	(47.522)	(0.4252)	(0.3495)	(0.9778)	(157.099)	(3.15546)			
MB+LEG	-1931.2	-7.488	-0.18988	73.472	-0.7949	0.8849						.96
	(735.7)	(13.451)	(0.06483)	(34.320)	(0.3908)	(0.2550)						
MB+HF	-986.5	68.177	0.37890	-43.519	1.4764	-1.4650						.75
	(984.9)	(21.144)	(0.14852)	(34.439)	(0.4755)	(0.4654)						
MB+HF+LEG	675.6	28.171	0.05891	-15.257				-97.348		109.006		.85
	(931.0)	(10.738)	(0.03563)	(4.246)				(84.436)		(78.952)		
MB+LF	2936.8	88.336		-54.708								.85
	(834.2)	(15.703)		(30.269)								
MB+LF+LEG	1125.1	116.118		-143.395	2.0784	-1.1416		-269.865		346.064		.90
	(2867.4)	(50.180)		(79.593)	(0.9178)	(0.5575)		(142.921)		(165.139)		
OG+LC	-991.5	40.316		-29.876				69.231				.66
	(374.6)	(5.093)		(6.387)				(31.280)				

[a]Standard errors are shown in parentheses below regression coefficients.

[b]CB = common bermudagrass, HF = high endophyte tall fescue, LEG = legumes, LF = low endophyte fescue, MB = Midland bermudagrass, OG = orchardgrass, LC = ladino clover.

various forages on six different soil types (Fribourg et al., 1989) used to adjust forage productivity for soil type is presented in Table 2, page 33. The Memphis series was used as a base of 100.

Forage Intake Component

The primary factors governing forage intake by stocker cattle are size of animal, climatic conditions, and quality and availability of forage. Conrad et al. (1966) and Whitson et al. (1976) indicated that forage dry matter intake as a percent of live body weight increases as percent total digestible nutrients (TDN) of forage increases up to 67 percent. Above this point, which they define as 3 percent of live body weight, animal metabolism limits intake. Forage systems used in this study usually are less than 67 percent TDN.

Stepwise and R-square procedures of SAS were used to select independent variables that explain monthly intake of grazing stocker cattle. Regressors considered included weight of animals at beginning of the month, cumulative gain of the animals through the previous month, and minimum, maximum and average monthly temperatures. The quadratic term of each variable was included also for consideration. The best model was selected based on the same criteria as those used for forage production models.

Average temperature and minimum and maximum temperatures were not included in the same model since average temperature is a linear function of minimum and maximum temperatures and therefore would produce a singular sums-of-squares and cross-products matrix in the analysis. Regression coefficients of variables retained in the models are presented in Table 6 for each forage system. Monthly ambient temperatures did not explain a significant amount of the variation in intake. Intake of heifers was reduced to 90% of that of steers of the same weight (NRC, 1984). Since the cage-and-strip method actually measures forage disappearance, intakes were reduced 10% for losses due to insects, decay, and trampling.

Cattle Component

The primary objective of the cattle component is to calculate monthly weight changes. Cattle used in stocker operations are typically lightweight cattle which have not been managed to achieve maximum or near maximum performance. These cattle often are bought in late fall and fed through winter to gain no more than 0.5 kg per day. When placed on lush spring pastures, they tend initially to gain very rapidly. This phenomenom is referred to as compensatory gain. Horton and Holmes

Table 6. Regression coefficients and standard errors[a] used to predict monthly intake of stocker cattle grazing various forage systems.

Forage[b]	Intercept, kg	Elapsed Time, month	Elapsed Time^2, month^2	Animal Weight, kg	Animal Weight^2, kg^2	Animal Gain, kg	Animal Gain^2, kg^2	Nitrogen Appl., kg	R^2
CB	1.61	-1.5623		0.036751					.20
	(7.14)	(0.6943)		(0.025774)					
CB+HF+LEG	-38.52	4.9343	-0.520946	0.192895		-0.292765			.65
	(9.59)	(2.6312)	(0.392042)	(0.045157)		(0.050583)			
HF	0.81	-0.0673				0.656471	-0.01259071		.51
	(5.84)	(0.6976)				(0.436574)	(0.00663916)		
HF+LEG	125.39	-6.2939	0.882249	-0.950554	0.00193021	0.280322	-0.00301338		.57
	(36.66)	(2.7582)	(0.400225)	(0.278409)	(0.00050413)	(0.093494)	(0.00090858)		
LF	-190.33	10.9846	-1.304942	1.585262	-0.00332441	-0.139911			.58
	(88.92)	(5.3185)	(0.751847)	(0.717465)	(0.00143746)	(0.074861)			
LF+LEG	-15.94	-14.5118	1.698388	0.165995					.69
	(6.67)	(3.1619)	(0.382464)	(0.040852)					
MB	-3.27			0.029288		0.356293	-0.00570417	-0.0088	.30
	(4.87)			(0.017107)		(0.148780)	(0.00209518)	(0.0030)	
MB+LEG	-6.65	16.7126	-2.217588			-0.693739	0.00641729		.78
	(8.55)	(7.4705)	(0.957859)			(0.363880)	(0.00398393)		
MB+HF	175.45	-1.7570				0.204554	-0.00241929		.31
	(6.50)	(0.8910)				(0.086985)	(0.00079662		
MB+HF+LEG	-4.61			0.059224		-0.098636			.32
	(6.26)			(0.026055)		(0.028843)			
MB+LF	-31.79			0.197761		-0.424260	0.00250264		.78
	(8.93)			(0.041995)		(0.069798)	(0.00046274)		
MB+LF+LEG	-64.75			0.062727					.33
	(7.49)			(0.024755)					
OG+LC	5.11	2.0232	-0.368740						.02
	(3.58)	(2.6116)	(0.419628)						

[a]Standard errors are shown in parentheses below regression coefficients.

[b]CB = common bermudagrass, HF = high endophyte tall fescue, LEG = legumes, LF = low endophyte fescue, MB = Midland bermudagrass, OG = orchardgrass, LC = ladino clover.

(1978) found that cattle on a winter restricted diet had accelerated gains during the first eight weeks of unlimited spring grazing. Subsequently, daily gains begin decreasing as the animal nears the end of gain compensation. Brorson (1983) suggests that one-half of the increased gain may be attributable to increased intake while the other one-half may be due to increased digestibility of the feedstuff. Therefore, stocker cattle gains usually exhibit a logarithmic trend over time.

In the model, cattle are assumed to gain 0.34 kg/day from purchase until they begin grazing. Grazing begins on April 1 except for common bermudagrass (CB), Midland bermudagrass (MB), and Midland bermudagrass + legumes (MB+LEG). The cattle component begins with average weight of cattle on the day that grazing begins. This initial average weight is then the purchase weight plus gain made from purchase until initiation of grazing. Cumulative monthly gains are calculated using grazing month, weight at beginning of each month, and intake along with their quadratic forms as regressors. Procedures for selecting these variables for inclusion in models for each forage were similar to those described for forage production. Regression coefficients retained in models for predicting gains are presented in Table 7.

Table 7. Regression coefficients and standard errors[a] used to predict cumulative weight gain of stocker cattle grazing various forage systems.

Forage[b]	Intercept, kg	Elapsed Time, days	Elapsed Time^2, days^2	Animal Weight, kg	Animal Weight^2, kg^2	Animal Intake, kg	Animal Intake^2, kg^2	R^2
CB	16.06	35.9509	-3.089051	-0.108258				.70
	(19.47)	(10.0504)	(1.383983)	(0.055775)				
CB+HF+LEG	-112.08	17.5425	-2.090349	0.500530		3.852385	-0.245122	.80
	(188.50)	(13.9060)	(1.980547)	(1.406735)		(2.319150)	(0.145489)	
HF	-33.54	-16.1216	2.661640	0.386145		2.060279	-0.253943	.80
	(35.47)	(9.1834)	(1.395780)	(0.163885)		(2.319150)	(0.145489)	
HF+LEG	240.51	30.0102	-3.176052	-2.192476	0.004394068	7.015159	-0.309361	.76
	(171.66)	(11.2895)	(1.694842)	(1.244367)	(0.002223228)	(2.431831)	(0.116178)	
LF	-404.45	33.9960	-2.592150	3.864245	-0.008748852	-2.195243		.36
	(456.12)	(24.0004)	3.418965)	(3.769060)	(0.007715984)	(1.285794)		
LF+LEG	24.20	31.3721	-3.026083					.70
	(17.47)	(13.3137)	(2.177021)					
MB	-327.65	9.5598		2.331923	-0.003892010			.41
	((182.85)	(1.7997)		(1.168051)	)0.001843235)			
MB+LEG	45.74	63.2388	-6.462588	-0.461839				.45
	(96.76)	(40.4023)	(5.298109)	(0.419722)				
MB+HF	711.31	48.2000	-5.328070	-5.375568	0.009649496			.51
	(259.89)	(14.2660)	(2.075794)	(2.002440)	(0.003741376)			
MB+HF+LEG	410.19	47.4217	-6.053973	-2.974161	0.005654117	-8.864646	0.424315	.66
	(266.28)	(22.5976)	(3.296890)	2.005161)	(0.003472261)	(5.511991)	(0.337175)	
MB+LF	-70.64	1.6062		0.515403				.96
	(13.03)	(1.5831)		(0.059382).				
MB+LF+LEG	-46.53			0.617659	15.878946	1.347197		.95
	(20.30)			(0.049784)	(4.847665)	(0.388295)		
OG+LC	-30.05	12.3296		0.243701				.54
	(30.66)	(3.8952)		(0.126450)				

[a]Standard errors are shown in parentheses below regression coefficients.

[b]CB = common bermudagrass, HF = high endophyte tall fescue, LEG = legumes, LF = low endophyte fescue, MB = Midland bermudagrass, OG = orchardgrass, LC = ladino clover.

To estimate reduction in gain of heifers as compared to steers, gains of steers and heifers weighing from 180 to 400 kg (in 5 kg increments) were estimated using NRC equations (1984). These estimates were based on net energy values for bermudagrass, tall fescue, and orchardgrass presented in NRC (1982). Results indicated that heifers of the same weight and condition as steers and grazing similar forages gain approximately 15% less.

In the model, average end of month weights of cattle are calculated by the following equation:

$$W_t = W_{t-1} + (G_t - G_{t-1})$$

where:

W_t = calf weight at end of month t
W_{t-1} = calf weight at end of month t-1
G_t = cumulative calf gain at end of month t
G_{t-1} = cumulative calf gain at end of month t-1

Kilograms of beef produced per hectare per month is calculated as a measure of pasture productivity. Forage production of the system is considered as well as performance of cattle grazing the forage. Monthly beef production was specified as:

$$B_t = S_t (G_t - G_{t-1})$$

where:

B_t = beef production per hectare at end of month t
S_t = user supplied stocking rate in number of cattle per hectare

Price and Budget Component

To determine economic feasibility of a stockering program an estimate of costs and returns was generated. Cattle prices generally follow a seasonal pattern with highest prices occuring in spring, lowest prices during summer and winter, and intermediate prices in fall. Since this model evaluates a stocker operation on a yearly basis, no attempt is made to describe the cattle price cycle or other yearly variations. Knowledge of seasonal variation in cattle prices can aid producers in determining the time to find the "best" buy on stocker cattle. It is also important to estimate the value of the stocker cattle at various points in time to provide an economic basis for deciding optimum selling time.

To provide an estimate of monthly value of the cattle, a price index was calculated which is used in conjunction with user supplied purchase price to establish a monthly market price. Monthly average prices from Tennessee livestock auctions from 1972 through 1988 (Tennessee Agricultural Statistics, 1989) were used to establish the index. Index values were determined for

four groups by sex and muscling score. To remove among year variation, monthly index values were calculated across weights by group and year. Regression procedures were used to determine the relationship of price index to animal weight and time for each of the four sex and muscling score combinations. Regression coefficients used to predict monthly price index are shown in Table 8.

Price per weight unit of calf is determined as follows:

$$P_t = P_p (I_t) / I_p$$

where:

P_t = price per weight unit of calf at end of grazing month t
P_p = price per weight unit of calf at purchase
I_t = index value for calve at end of month t
I_p = index value for calve at purchase

Finally, monthly value of cattle per hectare or possible gross income is calculated by:

$$V_t = P_t (W_t / 100) * S_t$$

where:

V_t = value of cattle per hectare at month t

Forage and livestock budgets used in the analysis are standard budgets adapted from McBride (1989), Ray and Walch (1986), and Halbrook et al. (1987). All pasture

Table 8. Regression coefficients and standard errors for the prediction of monthly stocker cattle price index for four classes of cattle.

Dependent Variable	Heifer Muscle Score 1 Mean	Heifer Muscle Score 1 SE	Heifer Muscle Score 2 Mean	Heifer Muscle Score 2 SE	Steer Muscle Score 1 Mean	Steer Muscle Score 1 SE	Steer Muscle Score 2 Mean	Steer Muscle Score 2 SE
Intercept	96.04	9.26	100.59	10.72	107.34	10.46	105.22	11.57
Weight, kg	-0.07455	0.00014	-0.07900	0.00017	-0.12336	0.00016	-0.10750	0.00018
Time, Month[a]	34.6472	15.2647	28.0297	0.3441	38.2265	17.2550	34.4966	19.0934
$Time^2$, $Month^2$	-23.28582	8.76165	-20.09489	10.10686	-26.64437	-9.90787	-24.59939	10.96348
$Time^3$, $Month^3$	6.921187	2.328684	6.209498	2.684010	8.058163	2.633827	7.579640	2.914407
$Time^4$, $Month^4$	-0.983489	0.312596	-0.898895	0.360127	-1.161044	0.353595	-1.106003	0.391268
$Time^5$, $Month^5$	0.066082	0.020558	0.060937	0.023677	0.078964	0.023256	0.075934	0.025734
$Time^6$, $Month^6$	-0.001692	0.000526	-0.001568	0.000606	-0.002043	0.000595	-0.001980	0.000658
R^2	0.20		0.19		0.29		0.21	

[a]For economic purposes October was set as Month 1.

costs other than expenses due to nitrogen fertilization of CB and MB are absolute. Pasture costs differ among forages due to differences in establishment costs, proration periods, fertilization, overseeding, and seed costs. Cost/ha of each forage system is presented in Table 9.

With these budgets, net income is derived each month for comparison of selling cattle at the end of each month and terminating grazing. Net income is expressed in dollars per hectare and is calculated as the difference between value of cattle per hectare and the sum of expenses per hectare and cost of cattle per hectare:

$$I_t = V_t - (F + C_t)$$

where:

I_t = income possible in month t

F = expenses per hectare of forage production

C_t = expenses per hectare of cattle through month t

Table 9. Annual expenses per hectare for production of various forage combinations grown in southwest Tennessee[a].

Forage[b]	Establishment Costs[c], $	Machinery Costs, $	Annual Costs, $			Total Cost, $
			N	P, K, Lime, & Machinery	Legume Overseeding	
CB	13.26	15.51	0	47.18	0	69.53[d]
CB+HF+LEG	32.65	15.51	0	47.18	23.51	118.85
HF	15.29	15.51	32.60	47.18	0	110.58
HF+LEG	24.87	15.51	0	47.18	23.51	111.07
LF	29.62	15.51	32.60	47.18	0	124.91
LF+LEG	32.06	15.51	0	47.18	23.51	118.26
MB	17.24	15.51	0	47.18	0	79.93[d]
MB+LEG	36.41	15.51	0	47.18	23.51	122.61
MB+HF	24.97	15.51	112.00	47.18	0	199.66
MB+HF+LEG	39.37	15.51	0	47.18	23.51	125.57
MB+LF	47.72	15.51	112.00	47.18	0	222.41
MB+LF+LEG	50.14	15.51	0	47.18	23.51	136.34
OG+LC	29.51	15.51	0	47.18	23.51	115.71

[a]Based on information presented by Halbrook et al. (1987), McBride (1989), and Ray and Walch (1986).

[b]CB = common bermudagrass, HF = high endophyte tall fescue, LEG = legumes, LF = low endophyte fescue, MB = Midland bermudagrass, OG = orchardgrass, LC = ladino clover.

[c]Establishment costs are prorated.

[d]Cost does not include cost of nitrogen. Nitrogen costs are charged at $0.50/kg for nitrogen amount supplied by user.

CHAPTER IV

SAS AS COMPUTER MODELLING SOFTWARE

Introduction

Conversion of a mathematically described system to a series of computer commands has become standard. This step is actually separate from systems analysis and is usually one of the final actions taken in describing the system. Theoretically, systems analysis could be performed and the system described by means of text and tables without a computer program. However, conversion of the system analysis to a computer model is essential to carry out calculations for checking accuracy rapidly and for practical use. This is especially true for use of "what if" type models where the user is interested in determining outcomes by altering an input or several inputs in a methodical fashion.

Numerous computer languages and software packages are available for modelling system behavior with digital computers. These languages are divided into two major classes as either high-level or low-level languages (Charlton, 1971; Dent and Blackie, 1979). Programs provide instructions to the computer in a series of single operation steps. Programs using low-level languages necessarily provide each of the most basic instructions.

High-level languages group several of these single operation steps into one command and therefore are usually more desirable. High-level languages use logical English-like statements and mathematical notation making them easier to both learn and use.

One of the most popular programming languages is FORTRAN due to its wide availibility and flexibility. FORTRAN is a high-level language but it is also a very basic or general-purpose language allowing the programmer or model builder to perform a wide variety of tasks (Brockington, 1979). In contrast to this are special-purpose simulation languages such as CSMP (de Wit and Goudriaan, 1974;), SIMSCRIPT and GPSS (Dent and Blackie, 1979) which are designed to handle particular types of programming problems such as dynamic models and time sequencing.

With the increase in micro-computer speed, memory and storage, there has been an increase in model development using commercially available personal computer software packages. These are popular because of high accessibility and friendliness of the software. Gill (1983) demonstrated the simplicity of such software and the ease of building simple computer models of livestock production using Visa-calc. Forcherio and Waller (1988) used Lotus to develop a simple whole herd nutrition model

incorporating annual forage production cycles in Tennessee and nutrient requirements of various classes of livestock found in a cow-calf operations. Prediction models based on such software will become more popular, especially for extension personnel and producer use, due to the advent of laptop and portable computers.

Statistical Analysis System

The Statistical Analysis System (SAS) is a software-language program which has not been widely used for modelling, primarily due to cost. Like FORTRAN, SAS uses basic individual instructions permitting its use in building programs to perform many operations. It also is widely available and used extensively by researchers. Therefore, programs can be deciphered and understood by most interested persons. Since it is a popular statistical analysis language, its use for modelling eliminates the need to learn adequately new programming languages. This would allow the researcher to concentrate more on the accuracy of the components of the model and less on programming language and techniques. The model constructed in this study used SAS for data analysis and modelling phases. Due to expertise of the modeller, the widespread acceptance of SAS by the academic community,

and the portability of PC SAS, SAS was chosen for computer representation of the model.

Features

Many features of SAS make it especially useful for model building. First, SAS has the capability of running in either batch mode or interactive mode in mainframe and PC environments (SAS, 1985e). Interactive mode proved especially useful in the model construction and testing steps (Armstrong, 1971) since it permitted modification of the program and checking of results without leaving the SAS environment. Interactive dynamic models could utilize the interactive mode to allow the model user to view early results and make new decisions.

Because SAS can be used for the data analysis steps and the model programming steps, it is not necessary to switch between languages. In fact, these steps can be combined so that output from the data analysis is sent to a file in a pre-defined format to be used by the model program (SAS, 1985e and 1985c). In this study, errors possible in generating, printing and re-entering parameter estimates were reduced by use of the OUTEST= and OUTSSCP options of PROC REG and the FILE PRINT statement. In general, it would not be efficient to include data analysis as a step in the computer model due to increased

CPU time and expense. However, it may be useful in model construction and for cases where data are being collected continuously and added to an existing database. In this way the model is updated continuously and improved by drawing on a larger database.

Customized statements also can be programmed into SAS. To simplify the entering of input variables, these customized statements can be used for prompts or forms for interactive users. Similarly, statements can be used for report writing to give SAS output a more customized appearance and more descriptive labels. Output can be tailored also to make reading and interpretation simpler. An example of model output is shown in Figure 3. Headings which are matrix elements themselves are used to describe the rows and columns of each vector. Charts, graphs and tables can be generated also as part of the modelling program to aid in interpreting output. In addition, output can be written to a file on some form of permanent storage format, such as floppy disks, PC hard disks, magnetic tape or magnetic disks.

Data Handling Capabilities

Various type of data and program storage and retrieval can be used with SAS (SAS, 1985d). Modelling often requires large programs and many datasets consisting

ORCHARDGRASS + LADINO CLOVER

STOCKING RATE = 3.8000

	PRECIP	CUM PRECIP	MAX TEMP	MIN TEMP	AVG TEMP
APRIL	15.170	49.790	21.603	8.578	15.090
MAY	15.430	65.220	26.822	14.096	20.459
JUNE	10.850	76.070	30.286	17.658	23.972
JULY	9.650	85.720	32.226	19.504	25.865
AUGUST	8.450	94.170	32.500	19.483	25.991

	YIELD, KG/HA	INTAKE, KG/HD	CARRYING CAPACITY, HD/HA	INTAKE, % BODY WEIGHT
APRIL	1215.785	6.181	5.901	0.024
MAY	1150.147	7.276	4.589	0.026
JUNE	1125.165	7.888	4.279	0.026
JULY	1095.823	8.016	3.969	0.025
AUGUST	1016.309	7.660	3.852	0.023

	BEGIN WEIGHT	END WEIGHT	GAIN	BEEF PROD	ADG
APRIL	243.220	274.223	31.003	117.810	1.033
MAY	274.223	294.107	19.885	75.563	0.641
JUNE	294.107	311.283	17.176	65.267	0.573
JULY	311.283	327.798	16.515	62.758	0.533
AUGUST	327.798	344.153	16.354	62.147	0.528

	PRICE	VALUE/HD	VALUE/HA	NET RETURN /HA	NET RETURN /HD
MAY 1	83.659	505.767	1921.913	-22.414	-5.898
JUNE 1	79.018	512.351	1946.933	-9.904	-2.606
JULY 1	76.743	526.657	2001.295	31.949	8.408
AUGUST 1	77.054	556.849	2116.025	134.169	35.308
SEPTEMBER 1	74.355	564.151	2143.773	149.407	39.318

Figure 3. Model output using SAS/IML print operators and labels.

of parameter estimates and coefficients. The ability to store these on tape, magnetic disk or cards that can be stored at a central processing site makes it possible for many users to access the program easily and quickly without using limited personal storage space. For the model to work, the user must have six files on his mainframe personal mini-disk. These six files are user sas, input sas, climate sas, yield sas, gainintk sas, and econ sas. For instance, the files which compose this model occupy 16.4% of a standard 450 block University of Tennessee Computing Center (UTCC) mini-disk. A user of the model requires editing access to one of the smaller of these files. Therefore, this component of the model may be stored in a micro-computer environment or on a mainframe user mini-disk while larger components reside on mainframe storage media (SAS, 1985b). When multiple program and data files are used SAS can locate and open the files to perform various operations. For this model seven files are used as separate model components. Once a component is processed, pertinent output data are stored in a temporary SAS data library to be used in a future component. By storing data in a SAS library, they can be retrieved as input data when the file for the next component is opened and processed. After all components are processed, the output data in the library are written

to a file in a report formatted style. The option of routing output to permanent libraries is another feature that aids in model construction. Once a component is finished, the output necessary for calculations in future components can be stored in permanent libraries. The sums of squares and crossproducts matrix for the economic regression equations is stored in SAS library on the user's permanent minidisk. This matrix holds the information necessary to calculate variances of economic estimates. The storing of these data in permanent libraries makes it unnecessary to run finished components of the model during testing stages of component development. This can result in considerable time savings.

PC SAS

Perhaps one of the best features of SAS is the recently released PC SAS. Micro-computer users who do not have access to mainframe computers can use PC SAS to access the power of SAS. Permanent personal storage of SAS datasets and programs are simplified with PC SAS. This has introduced portability to the SAS system. The limiting factors of PC SAS are time and memory requirements. Since micro-computers are much slower than mainframe computers, programs submitted to PC SAS require

much more time to complete than programs submitted to SAS in a mainframe environment. Memory availabe on many personal computers may not be sufficient to complete calculations for some large programs.

Since the model was developed as a production model consideration was taken to make it workable in the PC SAS environment. "What if" type models such as the one developed in this study, which may be run several times with different inputs, are necessarily concerned with speed. The model was developed originally for mainframe SAS, and only required minor editing to run in the PC SAS environment. In mainframe SAS version 5.18 running under the CMS operating system on an IBM 3090 machine, the model runs in approximately 3 seconds CPU time. In PC SAS on an IBM PS/2 Model 60 with an 80286 micro-processor chip without a math co-processor, the model runs in approximately 2 minutes 8 seconds CPU time.

Stochastic Modelling

Another important feature of SAS is that the ability to generate several standard distributions is available when estimates of necessary parameters are supplied. Random values can then be "drawn" from these distributions (SAS, 1985d). This process permits introduction of variability or stochasticity into components. However,

the limitation here is that the distribution must be a standard predefined distribution such as normal, gamma, or rectangular.

The handling of distributions is made more difficult because SAS is a non-integrating language. Instead of integration, it is necessary to calculate the change in x from time t to time t+a by subtraction. If only the values at the beginning or at the end of discrete periods are of interest, this method is adequate. No information concerning the production curve is gained from this type of calculation. If the discrete time intervals chosen are small enough there is little problem associated with assuming linearity between adjacent points.

SAS Interactive Matrix Language

Interactive Matrix Language (IML) software is a sub-package of SAS for performing matrix operations (SAS, 1985a). This sub-package can operate as a high-level language, a low-level language, or a combination of the two within the same program. Matrix operators such as SQRT and VECDIAG in line 643 of the program (shown in Appendix) can be used to perform routine functions, or custom functions can be programmed. Information can be converted between datasets and matrices in IML. Therefore, the input form of the data is not limiting.

Lines 59 and 60 of the computer representation (shown in Appendix) of the model show how the input dataset is read into a vector. Output from IML can be customized with descriptive row and column names. Descriptive row and column names can make matrices look like tables. An example of the model output with row and column names is shown in Figure 3 . Each table is composed of matrices, concatenated matrices, or partitioned matrices. The arrangement of the output on the page with row and column headings was accomplished by use of special print operators as shown in lines 571 through 590 of the computer code in the appendix.

Like the base SAS program, IML can perform iterative and conditional iterative operations through the use of "do loops". Module definition is another method of performing repetitive types of computer operations. Modules in IML are comparable to macros in the SAS base program. Use of modules for printing (lines 586-596 and 597-606) was made to handle forage systems which had to be printed in a slightly different format.

CHAPTER V

MODEL PERFORMANCE

To determine whether the model output was realistic, the model was evaluated under normal temperatures and average rainfall for each of the forage systems. Two passes were made for each forage. The first pass was made to determine the Maximum carrying capacity of each forage system for the given conditions. Maximum carrying capacity was defined as the maximum number of animals/ha possible during the month of lowest carrying capacity. A minimum value of 3 steers/ha was used. Due to deterministic specification of model output, statistical comparisons were not made.

Forage Production

Forage growth for each forage system under normal conditions is presented in Table 10. Model output suggests that combinations of Midland bermudagrass (MB) and tall fescue alone or in combinations produce more forage dry matter than other combinations when fertilized with nitrogen. Low endophyte tall fescue (LF) overseeded on MB had the greatest production at 10,257 kg of dry matter. This production was from sustained high production throughout the grazing season. The summer

Table 10. Predicted monthly and annual forage yields for a year with average precipitation of 94 cm and an average temperature of 15.3° C on a Memphis silt loam soil in southwest Tennessee.

Forage[a]	Month					Annual Yield
	April	May	June	July	August	
	kg/ha					
CB		1670	1688	1755	1697	6810
CB+HF+LEG	1210	1251	1210	1251	1251	6173
HF	2567	2296	1638	1255	834	8590
HF+LEG	1500	1274	1026	863	691	5354
LF	2632	2216	1657	1208	696	8409
LF+LEG	1644	1508	1084	865	624	5725
MB		1907	2046	2273	2329	8555
MB+LEG		1212	1038	1010	924	4184
MB+HF	1444	1519	1464	1611	1778	7816
MB+HF+LEG	906	1011	1109	1240	1331	5597
MB+LF	1820	1894	2057	2210	2276	10257
MB+LF+LEG	2399	2194	1667	1198	658	8116
OG+LC	1216	1150	1125	1096	1016	5603

[a]CB = common bermudagrass, HF = high endophyte tall fescue, LEG = legumes, LF = low endophyte tall fescue, MB = Midland bermudagrass, OG = orchardgrass, LC = ladino clover.

production is only slightly lower than MB with 224 kg N/ha. High endophyte fescue (HF) and LF forage systems with 67 kg N/ha had yields similar to MB although the MB grazing season consisted of four rather than five months. HF and LF had high production during the spring and greatly decreased production in summer while MB dry matter production continued to increase throughout the season.

The seven forage combinations utilizing LEG or ladino clover (LC) as a nitrogen source produced less forage dry matter than those receiving nitrogen fertilization, in general. Forage systems overseeded with legumes (LEG) typically experienced lower production than their nitrogen fertilized counterparts during the last three months of the grazing season. MB+LEG had the lowest production of the thirteen systems, producing only 4184 kg of dry matter during the season. In contrast to MB with 224 kg N/ha, MB+LEG production declined as the season progressed. This indicates that legumes are unable to furnish sufficient nitrogen to provide constant levels of production of MB.

As shown in Table 5, page 43, common bermudagrass (CB) had a negative relationship to nitrogen fertilization. Normally, this would not be expected to occur. However, CB was evaluated during two phases of the experiment and each time under a different nitrogen fertilization level. Negative regression coefficient may

actually be due to effects of different phases and not to level of nitrogen fertilization.

Combinations of warm and cool season forages tended to produce more forage than cool season systems alone. Increased productivity of these combinations is primarily due to sustained production throughout the five month grazing season.

Forage Intake

Predicted monthly intakes of stocker cattle grazing the various forage systems are shown in Table 11. Generally, cattle grazing orchardgrass overseeded with ladino clover (OG+LC) or forage systems containing LF had greatest intakes. Intake of LF+LEG was reduced during June and July. Cattle grazing HF+LEG had similarly low intakes during these two months when viewed as percent of average monthly body weight (1.4%). Although their intakes are numerically greater, weights of these cattle were approximately 40 kg less than those of cattle grazing LF+LEG during this period.

Addition of either LEG or MB, or a combination of the two, increased intake of cattle grazing HF during summer months. Dilution of the fescue endophyte by incorporation of other forage species is considered responsible for improved intake (Ball, 1984).

Table 11. Predicted daily forage dry matter intake for grazing stocker steers in southwest Tennessee.

	Month				
Forage[a]	April	May	June	July	August
	----------		$kg \cdot hd^{-1} \cdot d^{-1}$		----------
CB		7.02	6.57	5.72	4.72
CB+HF+LEG	8.75	9.20	9.03	8.40	7.40
HF	5.64	6.16	5.26	5.46	4.64
HF+LEG	5.03	3.99	4.59	6.56	9.48
LF	7.89	6.90	8.95	6.95	4.84
LF+LEG	10.46	8.26	6.17	6.24	8.46[b]
MB		4.71	7.57	6.66	4.73
MB+LEG		8.37	6.23	5.56	4.97
MB+HF	4.59	3.95	6.22	7.27	6.87
MB+HF+LEG	7.88	7.63	6.62	5.91	5.44
MB+LF	9.06	5.52	6.96	8.89	10.51
MB+LF+LEG	7.73	9.04	9.40	9.09	8.49
OG+LC	6.18	7.28	7.89	8.02	7.66

[a]CB = common bermudagrass, HF = high endophyte tall fescue, LEG = legumes, LF = low endophyte tall fescue, MB = Midland bermudagrass, OG = orchardgrass, LC = ladino clover.

[b]Intake was actually limited to 5.50 kg due to inadequate forage availability for 3 steers/ha.

Carrying Capacity

Carrying capacity is defined as maximum stocking rate consistent with maintaining or improving vegetation or related resources under a variable stocking rate grazing system. Carrying capacity is a measure of pasture productivity which also considers ad libitum intake of grazing animals.

The monthly and 5-month average carrying capacities of each forage system are presented in Table 12. In general, those forage systems with greatest forage dry matter production were also capable of sustaining more animals/ha. The least average carrying capacities were on CB+HF+LEG, LF+LEG, and OG+LC pastures (4.2, 4.3 and 4.5 steers/ha, respectively) while MB with 224 kg/ha of nitrogen had the greatest (11.0 steers/ha). The seven pasture systems overseeded with LEG or LC had the lowest carrying capacities. Carrying capacity of most forage systems containing LEG decreased during July and August due to reduced forage yields. Exceptions were CB and MB overseeded with with HF and LEG. Forage yields of CB+HF+LEG remained constant during the summer and MB+HF+LEG forage yields increased during the same period. Increased yields along with decreased intakes of cattle grazing these forages resulted in increased carrying

Table 12. Predicted monthly carrying capacity of forage systems for a year with average precipitation of 94 cm and an average temperature of 15.3° C on a Memphis silt loam soil in southwest Tennessee.

	Month					
Forage[a]	April	May	June	July	August	Avg.
	steers/ha					
CB		6.9	7.7	8.9	10.4	8.5
CB+HF+LEG	4.1	3.9	4.0	4.3	4.9	4.2
HF	13.6	10.8	9.3	6.7	5.2	9.1
HF+LEG	8.9	9.3	6.7	3.8	2.1	6.2
LF	10.0	9.3	5.6	5.0	4.2	6.8
LF+LEG	4.7	5.3	5.3	4.0	2.1	4.3
MB		11.7	8.1	9.9	14.3	11.0
MB+LEG		4.2	5.0	5.3	5.4	5.0
MB+HF	9.3	10.7	7.0	6.9	11.9	9.2
MB+HF+LEG	3.5	3.8	5.0	6.1	7.1	5.1
MB+LF	6.0	10.0	8.9	7.2	6.3	7.7
MB+LF+LEG	9.3	7.2	5.5	3.8	2.0	5.6
OG+LC	5.9	4.6	4.3	4.0	3.9	4.5

[a]CB = common bermudagrass, HF = high endophyte tall fescue, LEG = legumes, LF = low endophyte tall fescue, MB = Midland bermudagrass, OG = orchardgrass, LC = ladino clover.

capacity. Carrying capacities of MB, MB+HF, and HF were greater than other forage systems reflecting the high productivity of MB and the low intakes of cattle grazing HF.

Carrying capacity for CB and MB increased through the summer, as a reflection of their warm season growth. Most of the higher quality cool season forages provided feed for more animals during April and May.

Animal Performance

Animal Gain

Cattle grazing HF gained an average of approximately 0.10 kg/day over the final four months. This included negative gains in June (Table 13). Animal gains were greatest for forage systems containing LF and the OG+LC system. The LF+LEG and OG+LC systems produced over 95 kg of gain per animal during the 153 day grazing season although different gain distributions are shown in Figure 4. Cattle grazing LF+LEG produced approximately two-thirds of their gains during the first two months while cattle grazing OG+LC had more linear weight gains during the entire grazing season.

Less than 60 kg of gain per animal was produced by HF and MB forage systems (Figures 4 and 5). A portion of the decreased seasonal gains of cattle grazing MB can be

Table 13. Predicted monthly and seasonal average daily gains of grazing stocker steers in southwest Tennessee.

Forage[a]	Month					Annual Gain
	April	May	June	July	August	
	----------	----------	$kg \cdot hd^{-1} \cdot d^{-1}$	----------	----------	
CB		0.93	0.56	0.39	0.21	0.52
CB+HF+LEG	0.96	0.81	0.66	0.44	0.19	0.61
HF	0.98	0.08	-0.02	0.06	0.30	0.28
HF+LEG	0.43	0.52	0.63	0.64	0.45	0.54
LF	1.20	0.26	0.40	0.21	0.22	0.46
LF+LEG	1.40	0.72	0.54	0.33	0.13	0.62
MB		0.74	0.47	0.33	0.29	0.46
MB+LEG		0.68	0.78	0.34	0.14	0.49
MB+HF	0.23	0.90	0.46	0.41	0.16	0.43
MB+HF+LEG	0.23	0.92	0.67	0.43	0.03	0.46
MB+LF	1.53	0.81	0.49	0.29	0.20	0.66
MB+LF+LEG	1.54	1.35	1.02	0.48	0.07	0.89
OG+LC	1.03	0.64	0.57	0.53	0.53	0.66

[a]CB = common bermudagrass, HF = high endophyte tall fescue, LEG = legumes, LF = low endophyte tall fescue, MB = Midland bermudagrass, OG = orchardgrass, LC = ladino clover.

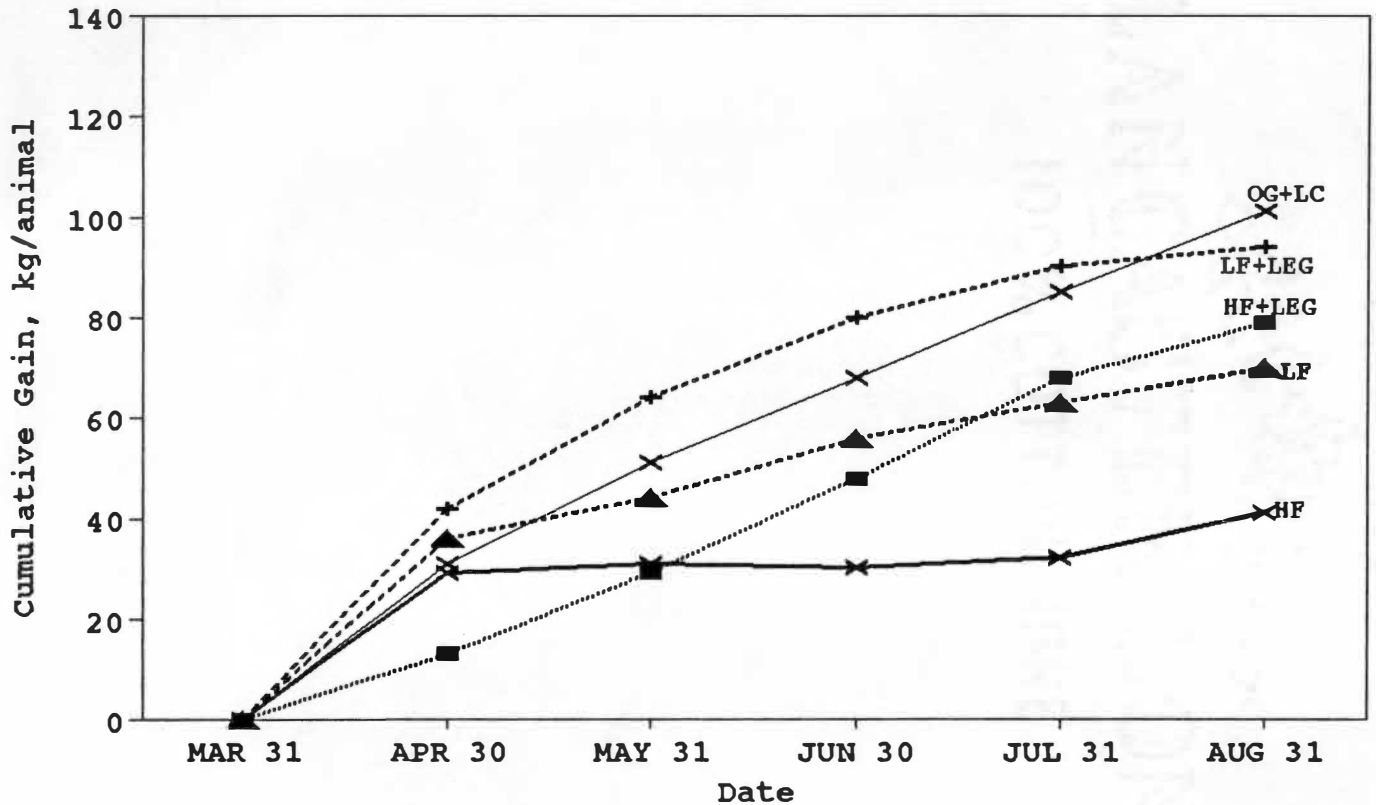

Figure 4. Cumulative gain per animal for steers grazing high or low endophyte tall fescue with nitrogen or legumes or orchardgrass overseeded with ladino clover (HF = high endophyte tall fescue, LEG = legumes, LF = low endophyte tall fescue, OG = orchardgrass, LC = ladino clover).

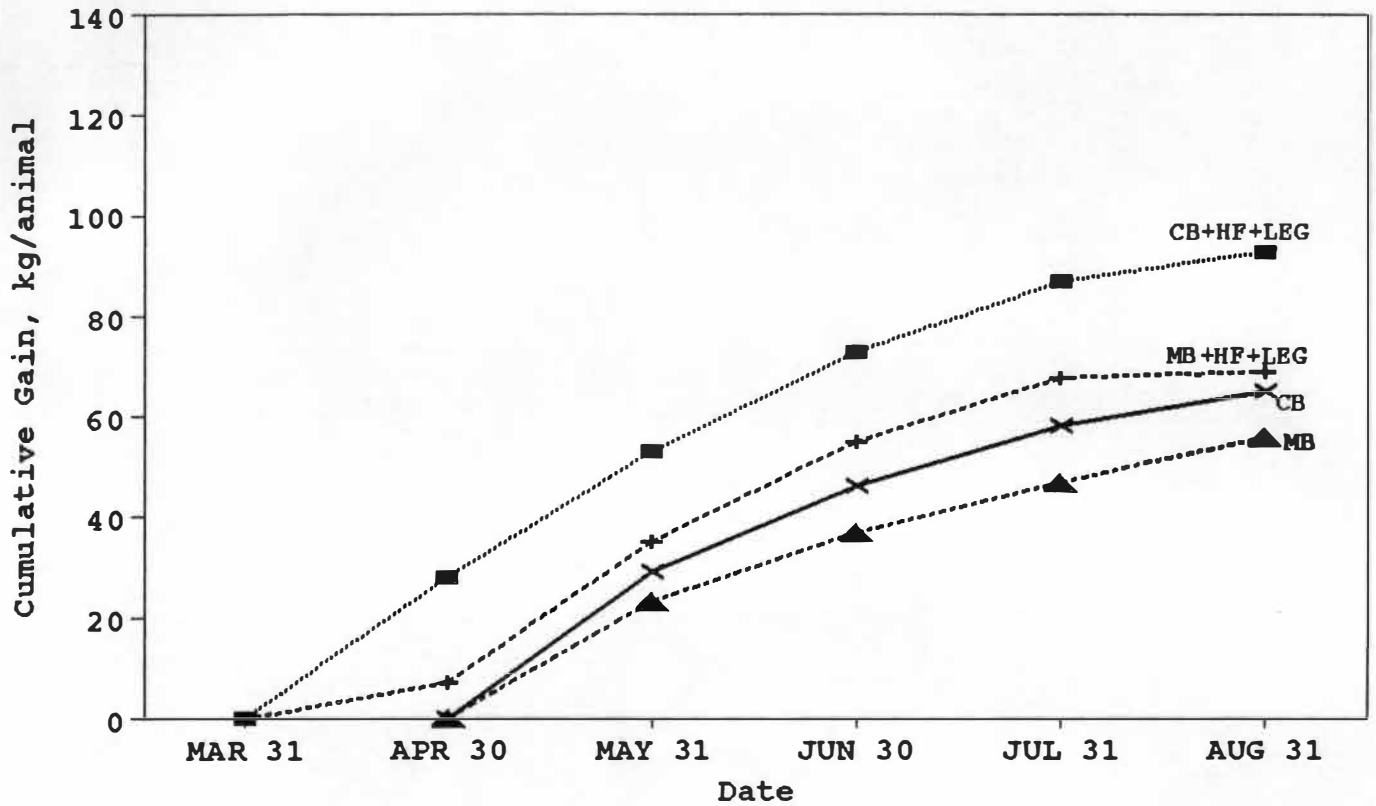

Figure 5. Cumulative gain per animal for steers grazing bermudagrass pastures fertilized with nitrogen or bermudagrass pastures overseeded with tall fescue and legumes (CB = common bermudagrass, HF = high endophyte tall fescue, LEG = legumes, MB = Midland bermudagrass).

attributed to the 4-month instead of the 5-month grazing season for the other forage systems. Cumulative gain distribution of cattle grazing HF+LEG was different from that of other forage systems. Cattle grazing HF+LEG maintained almost constant gains throughout the grazing season. Cattle grazing other forage systems experienced their greatest gains early in the grazing season and had decreased gains toward the latter part of the season (Figure 6). When combinations of CB or MB with HF were used, gains were improved. Even greater gains were made when LEG were incorporated in HF pastures.

Beef Production

Beef production is a measure of pasture productivity which includes animal performance. Beef production is directly related to stocking rate and animal gain. Although LF+LEG pastures produced the largest seasonal animal gains, forage yields limited stocking rate to three animals per hectare. This low stocking rate resulted in less beef production per hectare than most of the other forage systems.

Predicted beef production/ha and stocking rates are presented in Table 14. The MB+HF and MB forage systems produced the greatest amount of beef (458 and 456 kg/ha, respectively). Although steers grazing OG+LC and MB+LF

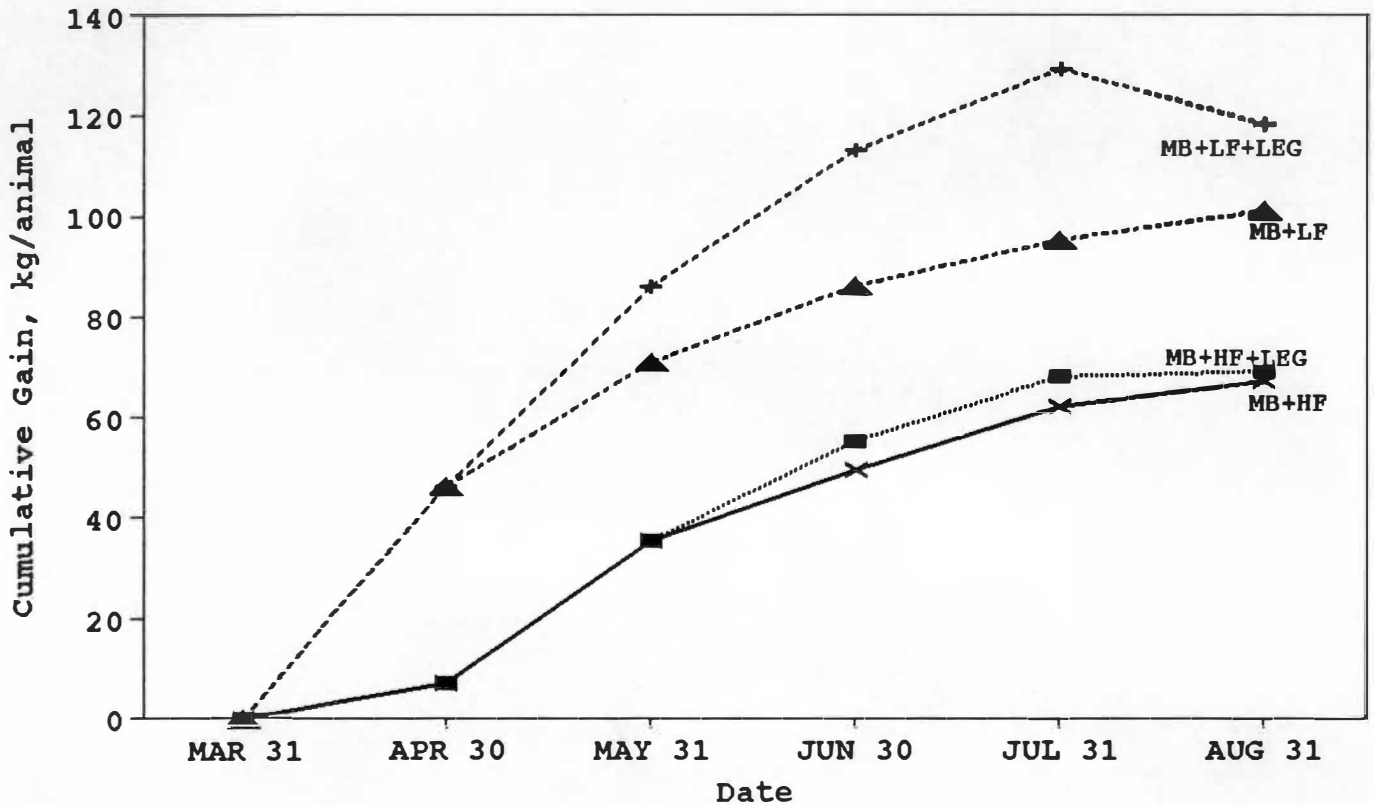

Figure 6. Cumulative gain per animal for steers grazing Midland bermudagrass alone or overseeded with high or low endophyte tall fescue and fertilized with nitrogen or overseeded with legumes (MB = Midland bermudagrass, LEG = legumes, HF = high endophyte tall fescue, LF = low endophyte tall fescue).

Table 14. Predicted monthly and seasonal beef produced per hectare by grazing stocker steers on various forage combinations in southwest Tennessee.

Forage[a]	Stocking Rate	Month					Annual Production
		April	May	June	July	August	
	str/ha	kg/ha					
CB	6.9		199	116	84	45	444
CB+HF+LEG	3.9	112	98	78	53	23	364
HF	5.2	152	13	-4	11	49	221
HF+LEG	3.0	39	48	57	60	33	237
LF	4.1	148	34	49	27	28	286
LF+LEG	3.0	126	67	49	31	12	285
MB	8.0		183	113	81	71	448
MB+LEG	4.2		88	99	44	19	250
MB+HF	6.6	46	184	91	83	33	437
MB+HF+LEG	3.4	24	97	68	45	4	238
MB+LF	6.0	275	151	88	55	38	607
MB+LF+LEG	3.0	139	120	81	49	-34	355
OG+LC	3.8	118	76	65	63	62	384

[a]CB = common bermudagrass, HF = high endophyte tall fescue, LEG = legumes, LF = low endophyte fescue, MB = Midland bermudagrass, OG = orchardgrass, LC = ladino clover.

pastures had over 50% greater gains during the grazing season than steers grazing MB+HF, OG+LC and MB+LF pastures produced slightly more than 400 kg/ha of beef. Pastures containing LF and LF+LEG forage combinations produced more beef/ha and steers grazing these pastures had greater weight gains than their HF counterparts. Less beef was produced (212 kg/ha) on MB+HF+LEG than any other forage combination.

Income From Sale of Cattle

Income from sale of cattle for each of the forage systems is presented in Table 15. Variances for monthly income estimates were derived by matrix calculations described by Searle (1971) and Weisberg (1985). These variances are calculated on the assumption that weight of the animals is known. In fact, animal weight is derived from previous prediction equations as an estimate with its own variation. Therefore, standard errors presented in Table 15 probably underestimate the true standard errors of income and should be used with caution. Variances for net income are functions of variances calculated for animal value. Therefore, standard errors are greatest for forage systems with greater numbers of animals per hectare. In general, forage systems producing more beef/ha provided greater incomes/ha.

Table 15. Predicted net returns to land and management and standard errors of the predictions from selling cattle at the end of each month.

		Month									
		April		May		June		July		August	
Forage[a]	Stocking Rate	Return	SE	Return	SE	Return	SE	Return	SE	Return	SE
	str/ha	$/ha									
CB	6.9			-72.07	403.39	8.62	427.48	167.20	446.18	143.53	456.40
CB+HF+LEG	3.9	-44.02	219.39	-8.27	240.06	43.54	256.26	137.10	267.99	117.80	273.32
HF	5.2	16.21	293.02	-64.72	295.90	-99.70	295.04	-39.01	297.98	-31.51	308.57
HF+LEG	3.0	-96.33	158.91	-91.79	168.99	-47.29	180.77	46.19	193.86	48.15	201.04
LF	4.1	2.70	236.80	-37.32	243.97	-10.97	254.17	59.92	260.44	48.00	266.72
LF+LEG	3.0	-3.94	176.98	8.16	191.10	35.05	201.27	97.84	208.22	77.80	211.15
MB	8.0			-112.36	457.65	-37.09	481.05	130.81	499.30	126.45	515.05
MB+LEG	4.2			-92.94	238.69	-11.56	259.26	77.37	269.05	54.84	273.36
MB+HF	6.6	-228.38	341.36	-122.55	379.91	-63.26	398.83	92.19	417.32	61.99	424.96
MB+HF+LEG	3.4	-142.61	175.86	-86.25	196.07	-34.15	210.21	47.46	220.15	17.66	221.23
MB+LF	6.0	34.84	358.68	72.11	390.60	113.82	408.89	233.77	421.47	203.56	430.11
MB+LF+LEG	3.0	-7.08	179.71	51.91	205.02	97.86	222.09	174.14	233.18	116.34	226.19
OG+LC	3.8	-22.41	215.47	-9.90	231.40	31.95	244.99	134.17	258.82	149.41	272.35

[a]CB = common bermudagrass, HF = high endophyte tall fescue, LEG = legumes, LF = low endophyte tall fescue, MB = Midland bermudagrass, OG = orchardgrass, LC = ladino clover.

Although nitrogen fertilization can be a large out-of-pocket expense, income/ha of nitrogen fertilized MB and MB+HF forages was greater than that from MB and MB+HF forages overseeded with LEG.

Distribution of income derived from selling cattle at various times during the grazing season are presented in Figures 7 through 9. Pasture and cattle costs have been subtracted from these income distributions. Income from stockering most forage combinations was maximized by selling cattle at the end of July. Lower August gains and interest costs on cattle decreased returns when cattle were held through August.

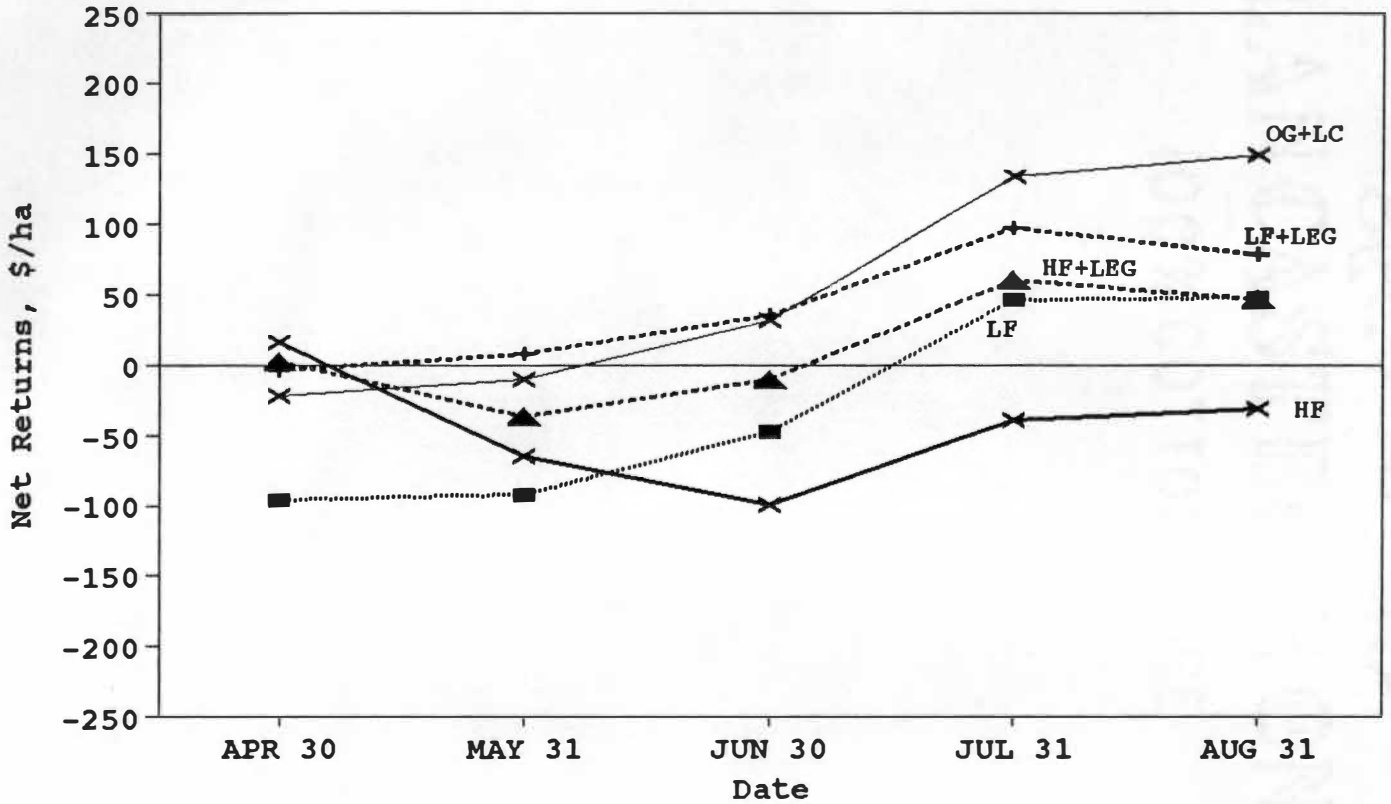

Figure 7. Net return to land and management by terminating grazing of high or low endophyte tall fescue with nitrogen or legumes or orchardgrass overseeded with ladino clover and selling steers at various times during the grazing season (HF = high endophyte tall fescue, LEG = legumes, LF = low endophyte tall fescue, OG = orchardgrass, LC = ladino clover).

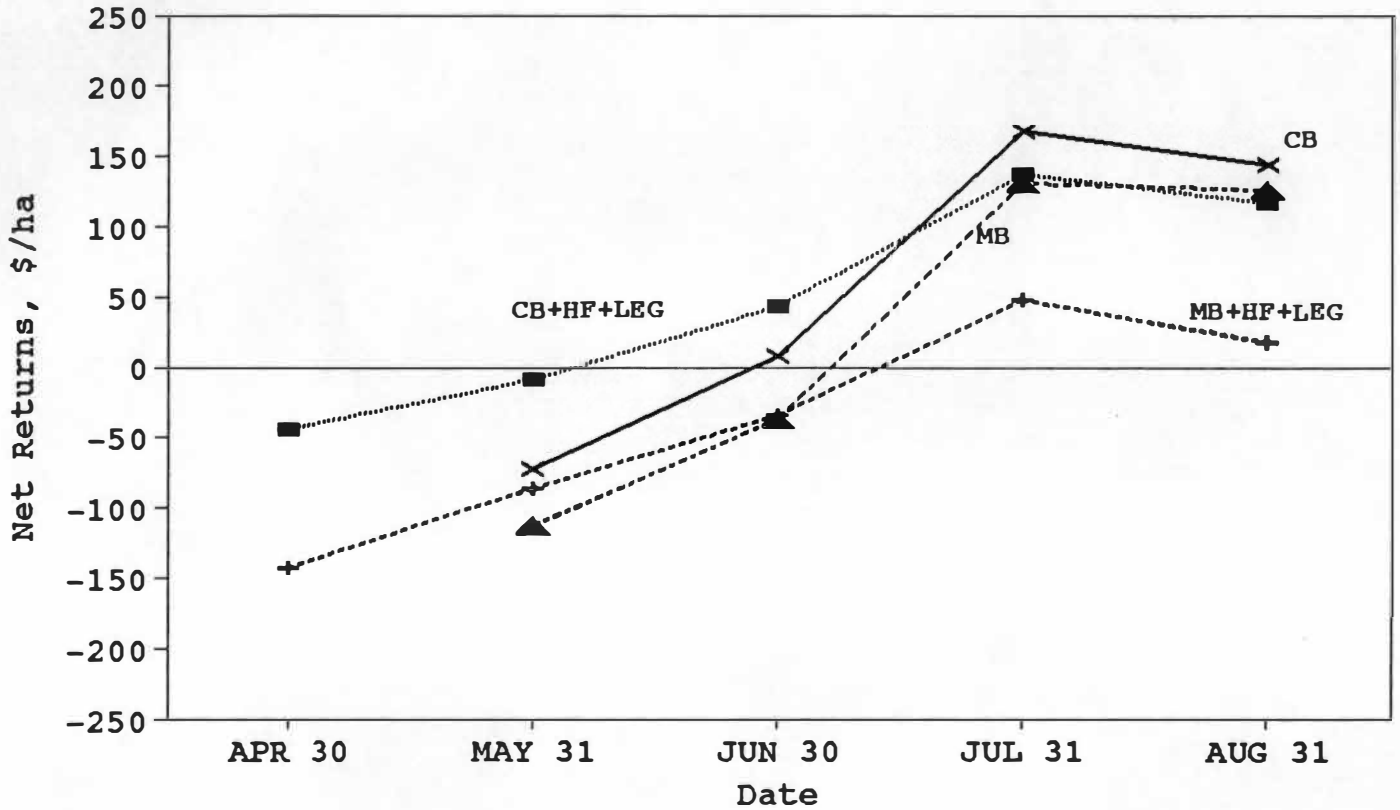

Figure 8. Net return to land and management by terminating grazing of bermudagrass pastures fertilized with nitrogen or bermudagrass pastures overseeded with tall fescue and legumes (CB = common bermudagrass, HF = high endophyte tall fescue, LEG = legumes, MB = Midland bermudagrass).

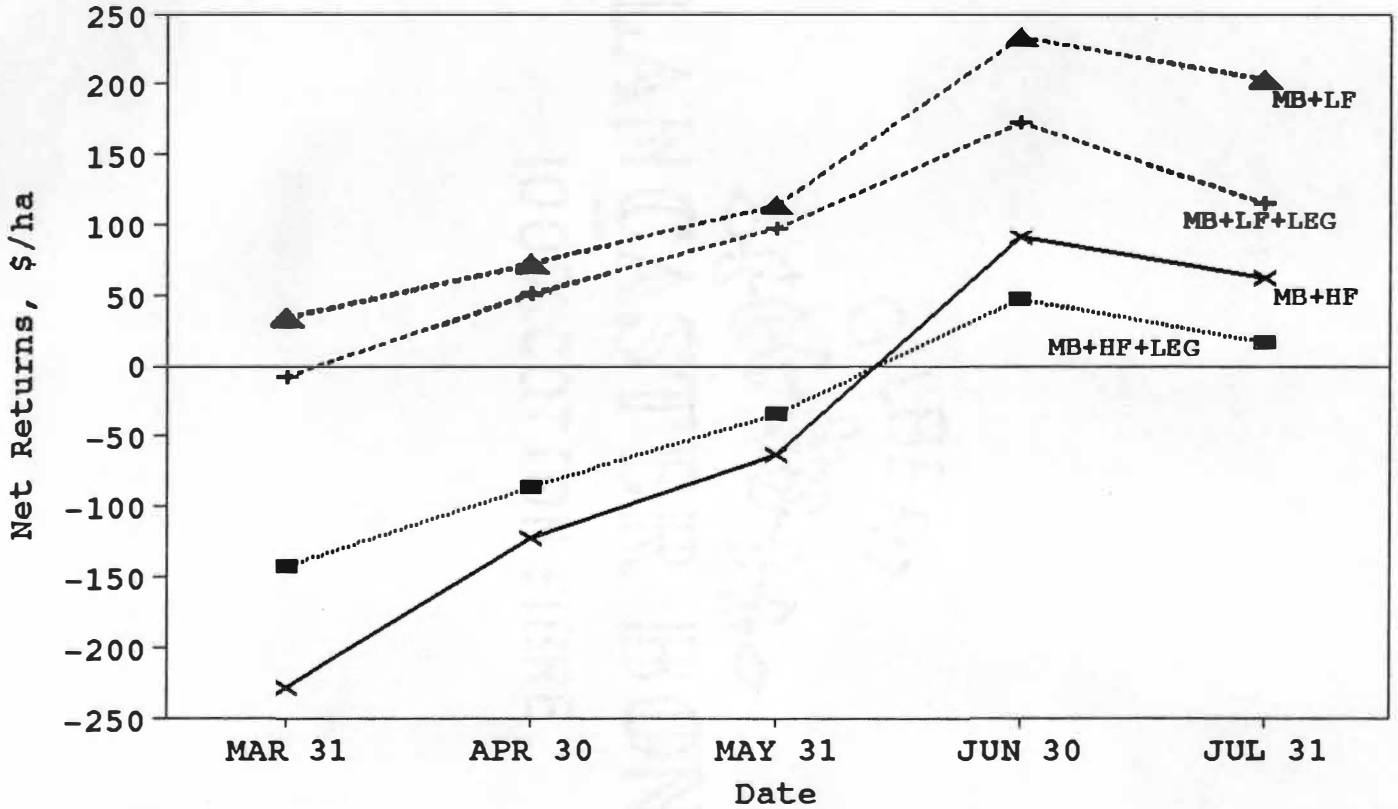

Figure 9. Net return to land and management by terminating grazing of Midland bermudagrass alone or overseeded with high or low endophyte tall fescue and fertilized with nitrogen or overseeded with legumes (MB = Midland bermudagrass, LEG = legumes, HF = high endophyte tall fescue, LF = low endophyte tall fescue).

CHAPTER VI

SUMMARY AND CONCLUSIONS

Four three-year experiments were conducted using 1.2 ha pastures to evaluate the productivity of various forage species combinations and the performance of stocker steers grazing them. Forage systems used were (1) Common bermudagrass (*Cynodon dactylon* L. var. *dactylon*) + 112 or 224 kg N/ [CB]; (2) Common bermudagrass overseeded with high endophyte (*Acremonium coenophialum* Morgan-Jones and Gams) tall fescue (*Festuca arundinacea* Schreb.), ladino clover (*Trifolium repens* L.) and Kobe lespedeza (*Lespedeza striata* (Thunb.) H & A) [CB + HF + LEG]; (3) HF + 67 kg N/ha [HF]; (4) HF + LEG; (5) Low endophyte tall fescue + 67 kg N/ha [LF]; (6) LF + LEG; (7) Midland bermudagrass + varying rates of N [MB]; (8) MB + LEG; (9) MB + HF + 224 kg N/ha [MB + HF]; (10) MB + HF + LEG; (11) MB + LF + 224 kg N/ha [MB + LF]; (12) MB + LF + LEG; and (13) Orchardgrass (*Dactylis glomerata* L.) overseeded with ladino clover [OG + LC].

The primary objective of this study was to assimilate twelve years of stocker cattle research and develop prediction equations which would provide estimates of expected performance of various forage systems with varying input parameters. Systems analysis was used to

determine relationships among climate, forage dry matter production, dry matter intake, and animal performance. This information was incorporated into a mathematical model which would provide estimates of productivity with varying inputs in southwest Tennessee. Data from Tennessee Feeder Calf Sales (1972-1988) were incorporated in the model to estimate animal value. Forage production budgets and stocker cattle budgets were included to provide an estimate of the economic viability of stockering cattle on various forage species combinations.

Six components comprising the model were user input area, climatic characteristics, forage yield, forage intake, cattle gain, and price and budget. User supplied inputs included expected yearly precipitation, yearly average temperature, forage system, soil type, animal sex, muscling score, stocking rate, and animal purchase price, weight, and month. Monthly output variables were forage dry matter yield, dry matter intake, pasture carrying capacity, cattle weights, gains, average daily gains, beef production, cattle value per animal and per hectare, and net income per ha.

Output for each forage system modelled under normal climatic conditions was compared. Pastures containing HF were the least productive in terms of animal performance and estimated net income. Bermudagrass pastures receiving

nitrogen fertilization produced the greatest amounts of forage and supported the most animals. However, animal performance was similar to that of HF forage systems. Steers grazing pastures with LF and OG gained more weight than steers grazing any other forage system. These gains resulted in a large economic advantage for these forage systems.

Limitations

Although the model provides estimates which appear realistic, caution should be exercised not to rely on them exclusively. Several areas of the plant-animal complex are still not well understood and additional research is necessary to understand better relationships in this complex. Therefore, estimates provided by the model must be interpreted carefully.

One area of concern in modeling grazing systems is the estimation of forage yield and intake. Measurement of dry matter yield and intake in a grazing situation lacks accuracy needed for modeling efforts. Many of the interactions which may exist in a forage production environment were not available. Secondary data on the effects of soil type on forage yields were employed in the form of an index. The data in this secondary study resulted from plots which were not subjected to grazing

pressure. Therefore, the effects of varying stocking rates on forage dry matter production could not be discerned from this study. Yields in the grazing study conducted at Ames Plantation were measured by the cage and strip method. Although the cage and strip method does provide an adequate relative measurement of dry matter yield, Linehan (1952) suggests this method overestimates forage growth.

The linear regression equations used to estimate precipitation during the grazing season may not accurately describe actual weather conditions. Prolonged temperature extremes and precipitation extremes cannot be described by these models. It may be possible that actual environmental conditions may favor optimum and less than optimum forage production months during the same grazing season. Alternatively, stochastic functions of climate variables with smaller intervals could aid in providing estimates of forage yield, but would probably increase the variability of yields. The greater variance found in forage yields estimated in such a manner may be more realistic.

Effects of relative species composition on forage yields were not addressed in the model. Species composition can be highly variable due to climate, overseeding practices, and competition from other forage

species. Animal intake and performance may also be effected by composition of forage dry matter.

The experimental pastures used in this study were extremely well managed. Conditions of both cattle and pastures were monitored daily such that corrective measures could be made if imbalances existed. Users of the model should be aware that estimates were derived from pastures where forage was maintained in a vegetative state. Results would be expected to be different from those of the model if forage and/or animals were not properly managed.

No provision is made for carrying excess forage into subsequent months. Carrying capacity of some forage systems could be greater than described in the model if some small stockpiling occured during periods of more rapid growth. This is especially true for cool season forages which typically exhibit greatest dry matter production during spring months. In addition, deviations from the fertilization schedule would invalidate the model results. Therefore, the model is somewhat restrictive in its interpretation.

Similarly, results of the animal component can deviate from "real world" situations if management practices are inadequate. The assumption is made that cattle are implanted with some growth promotant such as

Ralgro, have ample access to water, shade, and minerals, and are maintained in healthy condition. If feed availability or quality is limited, cattle cannot be expected to perform similarly to those modelled. Therefore, it is essential that recommended forage and animal management practices be followed. Since forage was maintained in a high quality vegetative state, estimates of cattle performance may be greater than if forages were allowed to become more mature.

No specification was made for differences in genetic make-up of cattle in the model. Most of the cattle from which the experimental data were collected were Angus, Hereford, Simmental, or combinations of these breeds. Improvement in prediction estimates could be made with reliable descriptions of relationships between forage systems, mature size, and maturing rate.

The price component of the model also should be used with caution since factors such as supply, demand, and weather were not included in the model for estimating prices. In addition, market prices may be affected by color patterns of cattle. Under stable market conditions, the modelled prices should provide a reasonable estimate of cattle prices. However, users may wish to add a "safety factor". Due to the deterministic specification of the model, estimates of true variance were not

calculated. However, an estimate of the variance of expected returns to land and management was made under the assumption that weight of the cattle was known. Although these variances may appear large, they probably underestimate the true variances.

Some of the inadequacies of the model are the result of inadequate or non-existent data concerning relationships within this plant-animal complex. The greatest improvements could be made with greater model detail describing these relationships. Forage yield data under grazing conditions that consider climate and soil conditions are needed to improve forage yield estimation. In addition, factors that affect species composition should be identified.

The development of improved methods of measuring intake by grazing cattle would aid in describing variables that influence intake. The model would probably benefit by describing animal performance as functions of energy intake and utilization. Again, increased accuracy in measuring intake as well as more information regarding animal behavior would aid such a specification.

Increased attention to these research concerns would benefit cattle producers. However, research to generate sufficient quantities of quality data for grazing systems requires vast resources and long range planning with few

immediate returns for the research scientists. More interaction and cooperation among scientists involved in each area of these production systems would make better use of each study and allow for more complete description.

Conclusions

The model is adequate for the purpose of the study and provides a suitable starting point for more detailed specifications. The narrow range of applicability can be expanded by moving beyond the black-box to a lower level of aggregation. A more detailed explanation of the biological processes described in the present model would increase model complexity but would permit the application of results to a broader array situations.

Due to the narrow range of the model and the assumptions identified, extreme caution must be exercised in transferring results from the model to an actual production situation. Results of the model are valid only under the strict assumptions listed earlier. An understanding of the limitations discussed previously is vital for proper interpretation of the results. With this in mind, the model does produce results that appear similar to some actual production systems. Therefore, the model should allow users to investigate alternative

production strategies and to aid in making production decisions.

The computer representation of the model was written to enhance modification. This allows the model to be improved as additional information is collected and permits modification to meet the objectives of the user. The general structure of the computer code can be maintained and provide support for increased model detail. When information concerning some of the complex interactions becomes available, additional matrices of relationship coefficients and the statements to incorporate them in the calculations can be added to the program.

The model would benefit from validation and verification. The comparison of model performance to actual production systems may suggest areas where the model is inadequate and would benefit from further refinement.

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APPENDIX

```
1 ****************************************************************
2 **********  SOUTHWEST TENNESSEE STOCKER CATTLE MODEL  **********
3 ****************************************************************
4
5 OPTIONS LS=72;

6 ****************************************************************
7 ** YOU WILL NEED TO ENTER THE FOLLOWING INFORMATION:          **
8 ** CHARACTER VALUES SHOULD BE ENTERED IN UPPER CASE.          **
9 ** YRPPT    -- CLASS VARIABLE VALUES = DRY, AVG OR WET         **
10 ** AVGTEMP  -- ANNUAL AVERAGE TEMPERATURE IN DEGREES CELSIUS  **
11 ** FORAGE   -- THE MODEL CODE OF THE FORAGE YOU ARE USING     **
12 ** SOILTYPE -- THE MODEL CODE OF SOIL TYPE FOR YOUR PASTURES  **
13 ** SX       -- SEX OF THE ANIMALS (S=STEER H=HEIFER)          **
14 ** MUSCLE   -- MUSCLE SCORE OF THE ANIMALS (1 OR 2)           **
15 ** STOCRATE -- STOCKING RATE IN ANIMALS/HECTARE               **
16 ** BUYPRICE -- PRICE PAID FOR THE ANIMALS IN $/CWT            **
17 ** NITROGEN -- N FERTILIZATION FOR COMMON AND MIDLAND ONLY    **
18 ** BUYMONTH -- FIRST 3 LETTERS OF ANIMAL PURCHASE MONTH       **
19 ** BUYWT    -- PURCHASE WEIGHT OF THE ANIMALS IN KG            **
20 ****************************************************************;

21 DATA USER;
22 INPUT YRPPT $ AVGTEMP FORAGE SOILTYPE SX $ MUSCLE
23 STOCRATE BUYPRICE NITROGEN BYMONTH $ BUYWT;
24 CARDS;
25 AVG
26 15.3
27 13
28 3
29 S
30 1
31 3.8
32 90
33 224
34 OCT
35 181
36 ;

37 ** INPUT SUBROUTINE IS CALLED **;
38 %INC INPUT;


39 ****************************************************************
40 ******              INPUT SUBROUTINE                      ******
41 ****************************************************************;

42 ** CONVERT USER INPUT CHARACTER VALUES TO NUMERIC VALUES **;
43 DATA INPUT;SET USER;
44 IF YRPPT='DRY' THEN YLYPPT=1;
45 IF YRPPT='AVG' THEN YLYPPT=2;
46 IF YRPPT='WET' THEN YLYPPT=3;
47 if sx='S' then sex=1;
```

```
48 if sx='H' then sex=2;
49 IF BYMONTH='OCT' THEN BUYMONTH=1;
50 IF BYMONTH='NOV' THEN BUYMONTH=2;
51 IF BYMONTH='DEC' THEN BUYMONTH=3;
52 IF BYMONTH='JAN' THEN BUYMONTH=4;
53 IF BYMONTH='FEB' THEN BUYMONTH=5;
54 IF BYMONTH='MAR' THEN BUYMONTH=6;
55 IF BYMONTH='APR' THEN BUYMONTH=7;
56 IF BYMONTH='MAY' THEN BUYMONTH=8;
57 IF BYMONTH='JUN' THEN BUYMONTH=9;
58 IF BYMONTH='JUL' THEN BUYMONTH=10;
59 IF BYMONTH='AUG' THEN BUYMONTH=11;
60 IF BYMONTH='SEP' THEN BUYMONTH=12;

61 ** INVOKE IML AND READ USER INPUTS INTO VECTOR INPUT **;
62 PROC IML;
63 USE INPUT;
64 READ INTO INPUT ALL;

65 ** SET UP VECTOR OF FORAGE NAMES **;
66 FORAGEPT={
67  "                    COMMON BERMUDAGRASS",
68  "          COMMON BERMUDAGRASS + TALL FESCUE + LEGUMES",
69  "                TALL FESCUE + 67 KG/HA NITROGEN",
70  "                     TALL FESCUE + LEGUMES",
71  "         LOW ENDOPHYTE TALL FESCUE + 67 KG/HA NITROGEN",
72  "              LOW ENDOPHYTE TALL FESCUE + LEGUMES",
73  "                MIDLAND BERMUDAGRASS + NITROGEN",
74  "                MIDLAND BERMUDAGRASS + LEGUMES",
75  "         MIDLAND BERMUDAGRASS + TALL FESCUE + NITROGEN",
76  "         MIDLAND BERMUDAGRASS + TALL FESCUE + LEGUMES",
77  "   MIDLAND BERMUDAGRASS + LOW ENDOPHYTE TALL FESCUE + NITROGEN",
78  "   MIDLAND BERMUDAGRASS + LOW ENDOPHYTE TALL FESCUE + LEGUMES",
79  "                ORCHARDGRASS + LADINO CLOVER"};

80 ** DATE MATRIX CONTAINS MONTH ENDING DATES, SQUARES AND CUBES **;
81 DATE={0    31     61     92     122     153     184     214,
82       0   961   3721   8464   14884   23409   33856   45796,
83       0 29791 226981 778688 1815848 3581577 6229504 9800344};

84 ** INPUT, FORAGEPT VECTORS AND DATE MATRIX STORED IN LIBRARY **;
85 STORE INPUT DATE FORAGEPT;

86 ** CLIMATE SUBROUTINE IS CALLED **;
87 %INC CLIMATE;


88 ******************************************************************
89 ******                CLIMATE SUBROUTINE                    ******
90 ******************************************************************;

91 ** USER SUPPLIED YEARLY PRECIPITATION IS READ INTO YPPT MATRIX **;
92 YPPT=INPUT(|1,9|);
```

```
** PPTBETA IS A MATRIX OF MEAN PRECIPS FOR DRY, AVG AND WET YEARS **;
PPT={7.5 5.95 9.59 7.97 10.55 8.79 8.03 3.97,
     9.2 10.81 14.61 15.17 15.43 10.85 9.65 8.45,
     18.92 19.21 20.71 15.91 18.26 13.36 9.46 10.42};

** CUMULATIVE MONTHLY PRECIP IS CALCULATED **;
MONTHPPT=PPT(|YPPT,|);
MONTHPPT=MONTHPPT`;
C1=MONTHPPT(|1,|);
C2=C1+MONTHPPT(|2,|);
C3=C2+MONTHPPT(|3,|);
C4=C3+MONTHPPT(|4,|);
C5=C4+MONTHPPT(|5,|);
C6=C5+MONTHPPT(|6,|);
C7=C6+MONTHPPT(|7,|);
C8=C7+MONTHPPT(|8,|);
CUMPPT=C3//C4//C5//C6//C7//C8;
MONTHPPT=MONTHPPT(|3:8,1|)||CUMPPT;

** YEARLY AVERAGE TEMPERATURE IS READ INTO AVGTEMP MATRIX **;
AVGTEMP=INPUT(|1,1|);

** SET DATE TDATE AS DATE AT MIDDLE OF MONTH **;
TDATE=DATE(|1,2:7|)-15;
TDATE2=TDATE##2;

** SIX COLUMN VECTORS ARE FORMED BY AVG TEMP AND ITS SQUARE **;
AVGT=J(1,6,AVGTEMP);
AT2=AVGT##2;

** MATRIX IS FORMED TO SERVE AS REGRESSORS FOR PREDICTING TEMPS **;
TEMP=J(1,6,1)//AVGT//AT2//TDATE//TDATE2;

** TEMPBETA - VECTOR OF BETAS TO CALCULATE MIN AND MAX TEMPS **;
** ROW 1 IS MAX TEMP BETAS AND ROW 2 IS MIN TEMP BETAS **;
TEMPBETA=
 {-51.456848 8.045372 -0.259944 0.275001 -0.000867,
  -10.112063 0.461700  0        0.297416 -0.000971};

** MAX, MIN AND AVG TEMPERATURES ARE CALCULATED **;
MAXTEMP=TEMPBETA(|1,|)*TEMP;
MINTEMP=TEMPBETA(|2,|)*TEMP;
AVGTEMP=(MAXTEMP+MINTEMP)*.5;

** TEMP MATRIX IS CONSTRUCTED **;
TEMP=MAXTEMP`||MINTEMP`||AVGTEMP`;

** WEATHER MATRIX IS FORMED FROM PRECIP AND TEMP MATRICES **;
WEATHER=MONTHPPT||TEMP;

** WEATHER MATRIX IS STORED IN LIBRARY **;
STORE WEATHER;
```

```
** FORAGE YIELD SUBROUTINE IS CALLED **;
%INC YIELD;

*****************************************************************
******        FORAGE DRY MATTER YIELD SUBROUTINE        ******
*****************************************************************;

** REGRESSION COEFFICIENTS ARE ENTERED INTO DATA SETS **;
DATA YLDBETA;
INPUT INTERCEP DATE DATE2 YRCPPT YRCPPT2 DATEYRPT N;
CARDS;
-3495.69  57.6750  0          111.0941  -0.677314  0          -12.984727
-1820.16  40.3435  0            0        0          0            0
-6294.81  70.6842 -0.180267   62.2017   0          0            0
 3584.21  44.3901  0.150692  -27.2908   0.606848 -0.676755     0
-4695.67 112.2440 -0.266472    0        0          0            0
-5226.39  38.3486 -0.094229   49.6694   0          0            0
-3452.57 -55.7789  0.210122  208.1817  -1.794007  0.654239     5.771512
-1931.20  -7.4880 -0.189880  73.47170  -0.794931  0.884937     0
 -986.52  68.1773  0.378904  -43.5195   1.476466 -1.464952     0
  675.60  28.1708  0.058905  -15.2567   0          0            0
-2936.80  88.3360  0          -54.7077   0          0           .0
 1125.15 116.1177  0         -143.3952   2.078352 -1.141588     0
 -991.51  40.3164  0          -29.8762   0          0            0

DATA YLDTEMPB;
INPUT MAX MAX2 MIN MIN2;
CARDS;
   0        0        -252.7652  6.108310
   0        0           0       0
   0        0           0       0
-334.3765   0         412.7707  0
   0        0           0       0
   0        0           0       0
-304.2077  8.944148     0       0
   0        0           0       0
   0        0           0       0
 -97.3480   0         109.0062  0
   0        0           0       0
-269.8654   0         346.0643  0
  69.2311   0           0       0

** IML IS INVOKED AND COEFFICIENTS ARE READ INTO MATRIX YLDBETA **;
PROC IML;

** BETA VALUES ARE READ INTO THE YLDBETA MATRIX**;
USE YLDBETA;
READ INTO YLDBETA ALL;
USE YLDTEMPB;
READ INTO YLDBETA2 ALL;
YLDBETA=YLDBETA||YLDBETA2;
```

```
** LOAD NECESSARY MATRICES FROM LIBRARY **;
LOAD INPUT WEATHER DATE;

** THE CHOSEN FORAGE IS READ INTO MATRIX FORAGE **;
FORAGE=INPUT(|1,2|);

** THE PRIMARY SOIL TYPE IS READ INTO MATRIX SOILTYPE **;
SOILTYPE=INPUT (|1,3|);

**PUT FORAGE TYPE INTO CLASS FOR CALCULATIONS BY SOILFACT MATRIX **;
IF FORAGE=1 | FORAGE=7 | FORAGE=8 THEN FORCLASS={3};
IF FORAGE>2 & FORAGE<7 THEN FORCLASS={1};
IF FORAGE>8 & FORAGE<13 | FORAGE=2 THEN FORCLASS={4};
IF FORAGE=13 THEN FORCLASS={2};

** MATRIX OF FORAGE PRODUCTIVITY ON VARIOUS SOILS (FRIBOURG) **;
** ROWS ARE FESCUE ORCHARDGRASS BERMUDA BERMUDA+FESCUE **;
SOIL={ 56  81 100 102  89 100,
       95  58 100  85  97  56,
       90 101 100 104  87 168,
      149  81 100  91 141 118};

** ONE ROW OF YLDBETAS IS CHOSEN BY CHOICE OF FORAGE **;
FORBETA=YLDBETA(|FORAGE,|);

** ONE COLUMN OF SOIL MATRIX IS CHOSEN BY SOIL TYPE **;
SOILA=SOIL(|,SOILTYPE|);

** ONE ELEMENT OF SOILA VECTOR IS CHOSEN BY FORAGE FROM SOILA **;
SOILFACT=SOILA(|FORCLASS,|);

** AVERAGE TEMPERATURE SQUARED CALCULATED **;
AVGTEMP2=WEATHER(|,5|)##2;

** CUMULATIVE PRECIPITATION SQUARED IS CALCULATED **;
CPPT2=WEATHER(|,2|)##2;

** DATE X CUMULATIVE PRECIPITATION IS CALCULATED **;
DATECPPT=DATE(|1,2:7|)`#WEATHER(|,2|);

** NITROGEN VECTOR IS CONSTRUCTED **;
NA=INPUT(|1,7|);
N=J(1,6,NA);
ONE=J(1,6,1);

** MATRIX OF INPUTS IS CONSTRUCTED **;
YLD=ONE//DATE(|1:2,2:7|)//WEATHER(|,2|)`//CPPT2`//
    DATECPPT`//N//WEATHER(|,3|)`//WEATHER(|,3|)`##2//
    WEATHER(|,4|)`//WEATHER(|,4|)`##2;

** MONTHLY CUMULATIVE FORAGE YIELD IS CALCULATED **;
YIELD=FORBETA*YLD;
```

```
** MONTHLY FORAGE YIELDS ARE CALCULATED BY SUBTRACTION **;
APRYLD=YIELD(|,2|)-YIELD(|,1|);
MAYYLD=YIELD(|,3|)-YIELD(|,2|);
JUNYLD=YIELD(|,4|)-YIELD(|,3|);
JULYLD=YIELD(|,5|)-YIELD(|,4|);
AUGYLD=YIELD(|,6|)-YIELD(|,5|);

** A VECTOR OF MONTHLY FORAGE YIELDS IS FORMED **;
MONTHYLD=APRYLD||MAYYLD||JUNYLD||JULYLD||AUGYLD;
MONTHYLD=MONTHYLD';

** BERMUDAGRASS PASTURES ARE LIMITED TO NO YIELD IN APRIL **;
IF FORCLASS=3 THEN MONTHYLD(|1,1|)={0};

** MATRICES AND VECTORS FOR FUTURE CALCULATIONS ARE STORED **;
STORE FORAGE AVGTEMP2 MONTHYLD FORCLASS;

** GAIN & INTAKE SUBROUTINE IS CALLED **;
%INC GAININTK;


*****************************************************************
******          GAIN AND INTAKE SUBROUTINES              ******
*****************************************************************;

** REGRESSION COEFFICIENTS FOR PREDICTING GAIN **;
DATA BETAS;
INPUT @1 INTERCEP 6.2 @7 MO 11.8 @18 MO2 10.8 @28 BWT 10.8 @38 BWT2 8.9
@46 I 11.8 @57 I2 9.8;
CARDS;
  1206 3595094717-308905144-012825753  0           0        0
-11208 1754252508-209034912 050053049  0       385238456-24512224
 -4354-1612160979 266163968 038614480  0       206027883-25394295
 24051 3001023653-317605227-219247587 4394068  701515905-30936069
-41545 3399599033-239215131 386424482-8448852 -109524310    0
  2420 3137213147-302608270   0        0           0        0
-31965  925980111   0       233192266-3999010      0        0
  4574 6333881829-601258760-046183932  0           0        0
 71131 4819995599-532807047-537556766 9649496      0        0
 41019 4742165827-605397289-297416086 5654117 -886464557 42431517
 -7064  160616098   0       051540261  0           0        0
 -5653    0         0       061765941  0     -1587894561134719744
 -3005 1232963838   0       024370062  0           0        0

** REGRESSION COEFFICIENTS FOR PREDICTING INTAKE **;
DATA INTBETA;
INPUT @1 INTERCEP 10.6 @11 MO 11.8 @22 MO2 10.8 @32 BWT 10.8 @42 BWT2 8.9
@50 LCGN 9.8 @59 LCGN2 9.9 @68 N 6.7;
CARDS;
   1607604 -156227299   0       003675099   0       0        0        0
 -38515142  493424936-052094649 019289527   0    -29276468   0        0
   0810687 -006726604   0         0         0     65647066-12590710   0
 125391300 -629390348 088224902-095055350 1930209 28032173-03013385   0
```

```
265 -190127470 1098457164-110494156 158526250-3304411-10191054   0         0
266  -15937979-1451181906 169838759 016599460   0        0        0         0
267   -3267310    0          0      002928796   0     35629325-05704117-87607
268   -9648087 1671256730-201758780   0         0    -69373879 06417390   0
269  174449320 -175700425    0        0         0     20455355-02419289   0
270   -4613114    0          0      005922425   0    -09863565   0         0
271  -33790597    0          0      019776069   0    -42425965 02102638   0
272  -64749394    0          0      006272709   0        0        0         0
273    5113473  202320514-026874012   0         0        0        0         0

274 PROC IML;

275 ** BETA VALUES ARE READ INTO THE GAINBETA MATRIX**;
276 USE BETAS;
277 READ INTO GAINBETA ALL;

278 ** LOAD STORED MATRICES FROM LIBRARY **;
279 LOAD INPUT WEATHER DATE FORAGE FORCLASS MONTHYLD;

280 ** ANIMAL WEIGHTS AT START OF GRAZING ARE CALCULATED **;
281 IWT=INPUT(|1,8|)+((7-INPUT(|1,11|))*30.5*.34);
282 IF FORAGE=1 | FORAGE=7 | FORAGE=8
283 THEN IWT=INPUT(|1,8|)+((8-INPUT(|1,11|))*30.5*.34);

284 ** STOCKING RATE AND SEX ARE CONVERTED TO SCALARS **;
285 STOCRATE=INPUT(|1,5|);
286 SEX=INPUT(|1,10|);

287 ** A VECTOR IS FORMED FROM INITIAL GRAZING WEIGHT **;
288 IWT=J(1,5,IWT);

289 ** ONE ROW OF GAIN BETAS IS CHOSEN BY CHOICE OF FORAGE **;
290 FORGBETA=GAINBETA(|FORAGE,|);

291 ** READ INTAKE BETA VALUES INTO INTBETA MATRIX **;
292 USE INTBETA;
293 READ INTO INTBETA ALL;

294 ** ONE ROW OF INTAKE BETAS IS CHOSEN BY CHOICE OF FORAGES**;
295 FORINTBT=INTBETA(|FORAGE,|);

296 ** COEFFICIENTS FOR EFFECT OF AVG TEMP ON INTAKE OF STEERS GRAZING **
297 ** MB+HF AND MB+LF+LEG ARE USED TO CALCULATE CONSTANTS **;
298 A=((WEATHER(|,3|)*1.8)+32);
299 IF FORAGE=9 THEN MHFFACT=A*-4.51449961+A##2*.02997821;
300 IF FORAGE=12 THEN MLFLFACT=A*1.69867113+A##2*-.01239848;

301 ** APRIL INTAKE IS CALCULATED **;
302 ONE={1};

303 ** MARCH GAIN IS CONVERTED TO SCALAR **;
304 MARCGN={10.55};
```

```
305 ** NITROGEN APPLICATION RATE IS CONVERTED TO SCALAR **;
306 N=INPUT(|1,7|);
307 IF FORCLASS ^= 3 THEN N={0};

308 ** MATRIX OF MONTHS IS INPUT (1=APRIL, ETC.) **;
309 MO={1 2 3 4 5,1 4 9 16 25};

310 ** MATRIX OF REGRESSORS FOR ESTIMATING APRIL INTAKE IS FORMED **;
311 APRINTIP=ONE//MO(|,1|)//IWT(|1,1|)//IWT(|1,1|)##2
312          //MARCGN//MARCGN##2//N;

313 ** APRIL INTAKE IS CALCULATED **;
314 EAPRINT=FORINTBT*APRINTIP;
315 IF FORAGE=9 THEN EAPRINT=EAPRINT+MHFFACT(|2,|);
316 IF FORAGE=12 THEN EAPRINT=EAPRINT+MLFLFACT(|2,|);
317 APRINT=EAPRINT;

318 ** INTAKE IS LIMITED BY FORAGE DRY MATTER PRODUCTION **;
319  IF (EAPRINT*STOCRATE*30)>MONTHYLD(|1,1|) THEN
320   APRINT=(MONTHYLD(|1,1|)/STOCRATE)/30;

321 ** ADJUSTMENT FOR SEX **;
322 IF SEX=2 THEN APRINT=APRINT*.90;

323 ** APRIL GAIN AND WEIGHT IS CALCULATED **;
324 APRGANIP=ONE//MO(|,1|)//IWT(|1,1|)//IWT(|1,1|)##2
325          //APRINT//APRINT##2;
326 CAPRGAIN=FORGBETA*APRGANIP;
327 APRGAIN=CAPRGAIN-MARCGN;

328 ** GAIN FOR BERMUDAGRASS PASTURES (BEGIN GRAZING MAY 1) IS CALCULATED **;
329 IF FORCLASS=3 THEN APRGAIN=10.21;

330 ** ADJUSTMENT FOR SEX **;
331 IF SEX=2 THEN APRGAIN=APRGAIN*.85;

332 ** CUMULATIVE GAIN CALCULATED **;
333 CAPRGAIN=APRGAIN+MARCGN;
334  IF FORCLASS=3 THEN CAPRGAIN={10.21};

335 ** WEIGHT AT BEGINNING OF APRIL AND MAY CALCULATED **;
336 APR1WT=IWT(|1,1|);
337 MAY1WT=APR1WT+APRGAIN;
338 IF FORCLASS=3 THEN MAY1WT=IWT(|1,1|);

339 ** MAY INTAKE IS CALCULATED SIMILAR TO APRIL INTAKE **;
340 MAYINTIP=ONE//MO(|,2|)//MAY1WT//MAY1WT##2
341          //CAPRGAIN//CAPRGAIN##2//N;
342 EMAYINT=FORINTBT*MAYINTIP;
343 IF FORAGE=9 THEN EMAYINT=EMAYINT+MHFFACT(|3,|);
344 IF FORAGE=12 THEN EMAYINT=EMAYINT+MLFLFACT(|3,|);
345 MAYINT=EMAYINT;
```

```
346 ** INTAKE IS LIMITED BY FORAGE PRODUCTION **;
347 IF (EMAYINT*STOCRATE*31)>MONTHYLD(|2,1|) THEN
348   MAYINT=(MONTHYLD(|2,1|)/STOCRATE)/31;

349 ** ADJUSTMENT FOR SEX **;
350 IF SEX=2 THEN MAYINT=MAYINT*.90;

351 ** MAY GAIN IS CALCULATED **;
352 MAYGANIP=ONE//MO(|,2|)//MAY1WT//MAY1WT##2
353          //MAYINT//MAYINT##2;
354 CMAYGAIN=FORGBETA*MAYGANIP;
355 MAYGAIN=CMAYGAIN-CAPRGAIN;

356 ** ADJUSTMENT FOR SEX **;
357 IF SEX=2 THEN MAYGAIN=MAYGAIN*.85;

358 ** CUMULATIVE MAY GAIN AND JUNE 1 WEIGHT IS CALCULATED **;
359 CMAYGAIN=CAPRGAIN+MAYGAIN;
360 JUN1WT=MAY1WT+MAYGAIN;

361 ** JUNE INTAKE IS CALCULATED SIMILAR TO APRIL **;
362 JUNINTIP=ONE//MO(|,3|)//JUN1WT//JUN1WT##2//
363          CMAYGAIN//CMAYGAIN##2//N;
364 EJUNINT=FORINTBT*JUNINTIP;
365 IF FORAGE=9 THEN EJUNINT=EJUNINT+MHFFACT(|4,|);
366 IF FORAGE=12 THEN EJUNINT=EJUNINT+MLFLFACT(|4,|);
367 JUNINT=EJUNINT;

368 ** INTAKE IS LIMITED BY FORAGE PRODUCTION **;
369 IF (EJUNINT*STOCRATE*30)>MONTHYLD(|3,1|) THEN
370   JUNINT=(MONTHYLD(|3,1|)/STOCRATE)/30;

371 ** ADJUSTMENT FOR SEX **;
372 IF SEX=2 THEN JUNINT=JUNINT*.90;

373 ** JUNE GAIN IS CALCULATED **;
374 JUNGANIP=ONE//MO(|,3|)//JUN1WT//JUN1WT##2
375          //JUNINT//JUNINT##2;
376 CJUNGAIN=FORGBETA*JUNGANIP;
377 JUNGAIN=CJUNGAIN-CMAYGAIN;

378 ** ADJUSTMENT FOR SEX **;
379 IF SEX=2 THEN JUNGAIN=JUNGAIN*.85;

380 ** CUMULATIVE JUNE GAIN AND JULY 1 WEIGHT IS CALCULATED **:
381 CJUNGAIN=CMAYGAIN+JUNGAIN;
382 JUL1WT=JUN1WT+JUNGAIN;

383 ** JULY INTAKE IS CALCULATED SIMILAR TO PREVIOUS MONTHS **;
384 JULINTIP=ONE//MO(|,4|)//JUL1WT//JUL1WT##2//
385          CJUNGAIN//CJUNGAIN##2//N;
386 EJULINT=FORINTBT*JULINTIP;
387 IF FORAGE=9 THEN EJULINT=EJULINT+MHFFACT(|5,|);
```

```
388 IF FORAGE=12 THEN EJULINT=EJULINT+MLFLFACT(|5,|);
389 JULINT=EJULINT;

390 ** INTAKE IS LIMITED BY FORAGE PRODUCTION **;
391 IF (EJULINT*STOCRATE*31)>MONTHYLD(|4,1|) THEN
392   JULINT=(MONTHYLD(|4,1|)/STOCRATE)/31;

393 ** ADJUSTMENT FOR SEX **;
394 IF SEX=2 THEN JULINT=JULINT*.90;

395 ** JULY GAIN IS CALCULATED **;
396 JULGANIP=ONE//MO(|,4|)//JUL1WT//JUL1WT##2
397          //JULINT//JULINT##2;
398 CJULGAIN=FORGBETA*JULGANIP;
399 JULGAIN=CJULGAIN-CJUNGAIN;

400 ** ADJUSTMENT FOR SEX **;
401 IF SEX=2 THEN JULGAIN=JULGAIN*.85;

402 ** CUMULATIVE JULY GAIN AND AUGUST 1 WEIGHT IS CALCULATED **;
403 CJULGAIN=CJUNGAIN+JULGAIN;
404 AUG1WT=JUL1WT+JULGAIN;

405 ** AUGUST INTAKE IS CALCULATED SIMILAR TO PREVIOUS MONTHS **;
406 AUGINTIP=ONE//MO(|,5|)//AUG1WT//AUG1WT##2
407          //CJULGAIN//CJULGAIN##2//N;
408 EAUGINT=FORINTBT*AUGINTIP;
409 IF FORAGE=9 THEN EAUGINT=EAUGINT+MHFFACT(|6,|);
410 IF FORAGE=12 THEN EAUGINT=EAUGINT+MLFLFACT(|6,|);
411 AUGINT=EAUGINT;

412 ** INTAKE IS LIMITED BY FORAGE PRODUCTION **;
413 IF (EAUGINT*STOCRATE*31)>MONTHYLD(|5,1|) THEN
414   AUGINT=(MONTHYLD(|5,1|)/STOCRATE)/31;

415 ** ADJUSTMENT FOR SEX **;
416 IF SEX=2 THEN AUGINT=AUGINT*.90;

417 ** AUGUST GAIN IS CALCULATED **;
418 AUGGANIP=ONE//MO(|,5|)//AUG1WT//AUG1WT##2
419          //AUGINT//AUGINT##2;
420 CAUGGAIN=FORGBETA*AUGGANIP;
421 AUGGAIN=CAUGGAIN-CJULGAIN;

422 ** ADJUSTMENT FOR SEX **;
423 IF SEX=2 THEN AUGGAIN=AUGGAIN*.85;

424 ** CUMULATIVE AUGUST GAIN AND SEPTEMBER 1 WEIGHT IS CALCULATED **;
425 CAUGGAIN=CJULGAIN+AUGGAIN;
426 SEP1WT=AUG1WT+AUGGAIN;

427 ** MONTHLY INTAKE VECTOR FORMED **;
428 INTAKE=APRINT//MAYINT//JUNINT//JULINT//AUGINT;
```

```
429 ** ADJUSTMENT FOR FORAGE LOSSES (TRAMPLING, INSECTS, DECAY, ETC.) **;
430 INTAKE=.9*INTAKE;

431 ** INTAKE VECTOR IF FORAGE PRODUCTION IS NOT A LIMITING FACTOR **;
432 EINTAKE=EAPRINT//EMAYINT//EJUNINT//EJULINT//EAUGINT;

433 ** MONTHLY GAIN VECTOR FORMED **;
434 GAIN=APRGAIN//MAYGAIN//JUNGAIN//JULGAIN//AUGGAIN;

435 ** BEGINNING AND ENDING MONTHLY WEIGHTS **;
436 STWEIGHT=APR1WT//MAY1WT//JUN1WT//JUL1WT//AUG1WT;
437 EDWEIGHT=MAY1WT//JUN1WT//JUL1WT//AUG1WT//SEP1WT;

438 ** VECTOR OF DAYS OF MONTHS (APR-AUG) **;
439 MODAYCT={30,31,30,31,31};

440 ** MONTHLY CONSUMPTION CALCULATED **;
441 CONSUMP=INTAKE#MODAYCT*STOCRATE;

442 ** MONTHLY CONSUMPTION IS FORAGE IS NOT LIMITING **;
443 ECONSUMP=EINTAKE#MODAYCT*STOCRATE;

444 ** EXCESS FORAGE **;
445 EXFORAGE=MONTHYLD(|1:5,|)-CONSUMP;

446 ** CARRYING CAPACITY **;
447 CARRCAP=MONTHYLD(|1:5,|)/(EINTAKE#MODAYCT);
448 PRINT EINTAKE ECONSUMP;

449 ** VECTOR OF MONTHLY WEIGHT GAIN **;
450 GAIN=APRGAIN//MAYGAIN//JUNGAIN//JULGAIN//AUGGAIN;

451 ** BEEF PRODUCTION **;
452 BEEFPROD=GAIN*STOCRATE;

453 ** MATRIX OF BEGINING AND ENDING WEIGHTS,GAIN AND BEEF PRODUCTION **;
454 BEEF=STWEIGHT||EDWEIGHT||GAIN||BEEFPROD;

455 ** TOTAL GRAZING SEASON GAIN **;
456 TOTGAIN=SUM(BEEF(|,2|));

457 ** TOTAL GRAZING SEASON BEEF PRODUCTION **;
458 TOTBEEF=SUM(BEEF(|,3|));

459 ** MATRICES STORED FOR LATER USE **;
460 STORE BEEF INTAKE CARRCAP EXFORAGE MODAYCT EINTAKE;

461 **CALL ECONOMIC SUBROUTINE**;
462 %INC ECON;
```

```
463 ****************************************************************
464 ******                    ECONOMIC SUBROUTINE                ******
465 ****************************************************************;

466 ** REGRESSION COEFFICIENTS FOR SEASONAL PRICES **;
467 DATA ONE;
468 INPUT @1 INTERCEP 7.4 @8 WT 9.7 @17 MONTH 10.8
469 @27 MONTH2 11.8 @38 MONTH3 9.8 @47 MONTH4 10.8 @57 MONTH5 7.8
470 @64 MONTH6 8.9;
471 CARDS;
472 0960439-338142943464715896-2328585845692118726-0983488566608195-1691796
473 1005920-358319032802970653-2009489361620949848-0898894566093718-1567796
474 1073376-559558823822647507-2664436755805816282-1161044217896425-2042601
475 1052185-487603433449655372-2459939414757964020-1106003127593358-1979913

476 PROC IML;

477 ** READ DATASET OF BETA VALUES INTO PRICBETA MATRIX **;
478 USE ONE;
479 READ INTO PRICBETA ALL;

480 ** LOAD INPUT AND BEEF MATRICES **;
481 LOAD FORAGE INPUT BEEF WEATHER MONTHYLD INTAKE FORAGEPT
482      CARRCAP EXFORAGE MODAYCT FORCLASS EINTAKE;

483 ** SET SCALAR MATRICES FROM INPUT MATRIX **;
484 BUYPRICE=INPUT(|,6|);
485 BUYMONTH=INPUT(|,11|);
486 BUYWT=(INPUT(|,8|)*2.204622622)/100;
487 SEX=INPUT(|1,10|);
488 MUSCLE=INPUT(|,4|);

489 ** CREATE WEIGHT VECTOR IN LBS. FROM BEEF MATRIX **;
490 WT=(BEEF(|,2|)*2.204622622)/100;

491 ** CHOOSE ONE ROW OF PRICBETA MATRIX BASED ON SEX AND MUSCLE **;
492 IF ALL(SEX) = 1 THEN SEXINDEX=PRICBETA(|3:4,|);
493 IF ALL(SEX) = 2 THEN SEXINDEX=PRICBETA(|1:2,|);
494 BETA=SEXINDEX(|MUSCLE,|);

495 ** CREATE ELEMENTS OF A MATRIX TO BE MULTIPLIED BY PRICBETA **;
496 ** THIS IS THE REGRESSOR MATRIX **;
497 ONE=J(5,1,1);
498 BUYWT2=BUYWT##2;
499 WT2=WT##2;
500 BWTMONTH=BUYWT#BUYMONTH;
501 BWTMONT2=BUYWT#BUYMONTH2;

502 ** SET MONTHS AS MAY THROUGH SEPTEMBER AND THEIR HIGER ORDER TERMS **;
503 MONTH={8,9,10,11,12};
504 MONTH2=MONTH##2;
505 MONTH3=MONTH##3;
506 MONTH4=MONTH##4;
```

```
MONTH5=MONTH##5;
MONTH6=MONTH##6;
ALLMONTH=MONTH||MONTH2||MONTH3||MONTH4||MONTH5||MONTH6;

** BUYMATRX WILL BE MULTIPLIED BY PRICBETA TO **
** ESTABLISH PURCHASE INDEX VALUE **;
BUYMATRX=ONE(|1,1|)||BUYWT||BUYMONTH||BUYMONTH##2||BUYMONTH##3||
         BUYMONTH##4||BUYMONTH##5||BUYMONTH##6;

** VALMATRX WILL BE MULTIPLIED BY PRICBETA TO ESTABLISH INDEX **
** VALUES FOR CATTLE FOR EACH MONTH ***;
VALMATRX=ONE||WT||ALLMONTH;

** ESTABLISH INDEX VALUE FOR CATTLE PURCHASE **;
BUYINDX=(BETA*BUYMATRX`);

** ESTABLISH INDEX VALUES FOR CATTLE FOR MAY THROUGH SEPTEMBER **;
VINDEX=(VALMATRX*BETA`);

** CALCULATE PRICE/CWT FOR CATTLE FOR EACH MONTH **;
VALUE=(BUYPRICE*VINDEX)/BUYINDX;

** CALCULATE VALUE ON AN ANIMAL BASIS **;
ANVAL=VALUE#WT;

** CALCULATE VALUE ON A HECTARE BASIS **;
INCOME=ANVAL*INPUT(|1,5|);

** PASTURE COSTS **;
PASTCOST={70 132 104 105 125 118 74 123 196 126 219 136 118};

** NITROGEN COSTS FOR MB AND CB PASTURES **;
NCOST=0;
IF FORAGE=1 | FORAGE=7 THEN NCOST=INPUT(|,7|)*.5;

** VARIABLE AND FIXED EXPENSES MINUS CATTLE, PASTURE AND FEED **;
STOKCOST={28.45};

** CATTLE COST PER HEAD **;
INANVAL=BUYPRICE*BUYWT;

** DEATH LOSS **;
DETHLOSS=.015*INANVAL;

** WINTER FEED COSTS 10LB/DAY * #DAYS * $50/TON **;
WINTFEED= 10 *((7-BUYMONTH)*30.5)*1/2000*50;

** VECTOR OF MONTHS APRIL=7 **;
MONTH={7 8 9 10 11};
BUYMTH=J(1,5,BUYMONTH);

** INTEREST ON CATTLE 11% **;
INTEREST=.11/12 * (MONTH - BUYMTH) * INANVAL;
```

```
** PASTURE COSTS FOR CHOSEN FORAGE **;
FORGCOST=PASTCOST(|1,FORAGE|);

** COST OF CATTLE LABOR PER HEAD **;
CATLABOR={22.14};

** TOTAL COST PER HA FOR STOCKERING **;
CTCSTHA=INPUT(|,5|)*(INANVAL+STOKCOST+DETHLOSS+WINTFEED+CATLABOR);
CTCSTHAJ=J(1,5,CTCSTHA)+(INPUT(|1,5|)*INTEREST);
PASTCOST=FORGCOST+NCOST;
ALLCOSTJ=J(1,5,PASTCOST) + CTCSTHAJ;

** NET RETURN PER HECTARE AND PER HEAD **;
NETRETHA= INCOME-ALLCOSTJ';
NETRETHD= NETRETHA/INPUT(|,5|);

** MONTHLY INTAKE AS PERCENT OF BODY WEIGHT **;
PINTAKE=INTAKE/((BEEF(|,1|)+BEEF(|,2|))/2);

** AVERAGE DAILY GAIN **;
ADG=BEEF(|,3|)/MODAYCT;
BEEF=BEEF||ADG;

** MATRIX OF ECONOMIC OUTPUT **;
ECON=VALUE||ANVAL||INCOME||NETRETHA||NETRETHD;

** MATRIX OF FORAGE OUTPUT **;
MONTHYLD=MONTHYLD||INTAKE||CARRCAP||PINTAKE;

** ADJUSTMENTS FOR PASTURES WHERE GRAZING BEGINS MAY 1 **;
IF FORCLASS=3 THEN MONTHYLD=MONTHYLD(|2:5,|);
IF FORCLASS=3 THEN INTAKE=INTAKE(|2:5,|);
IF FORCLASS=3 THEN BEEF=BEEF(|2:5,|);
IF FORCLASS=3 THEN ECON=ECON(|2:5,|);
STOCRATE=INPUT(|,5|);

** FORAGE NAME TO BE PRINTED ON OUTPUT **;
TITLE=FORAGEPT(|FORAGE,|);

** PRINT APRIL-AUGUST WEATHER DATA **;
WEATHER=WEATHER(|2:6,|);

** COLUMN NAMES FOR OUTPUT **;
YLDCOL={"     YIELD,       KG/HA" "     INTAKE,      KG/HD"
        "    CARRYING   CAPACITY,       HD/HA"};
WEATCOL={"     PRECIP" " CUM PRECIP" "   MAX TEMP"
         "   MIN TEMP" "   AVG TEMP"};
BEEFCOL={"BEGIN WEIGHT" "  END WEIGHT" "        GAIN" "   BEEF PROD"
         "         ADG"};
ECONCOL={"     PRICE" "  VALUE/HD" "  VALUE/HA" "NET RETURN/HA"
         "NET RETURN/HD"};
```

```
** MONTHS TO BE USED AS ROW NAMES **;
MONTH={"APRIL" "MAY" "JUNE" "JULY" "AUGUST"};
ECMONTH={"MAY 1" "JUNE 1" "JULY 1" "AUGUST 1" "SEPTEMBER 1"};

** ROW NAMES FOR FORAGES THAT BEGIN GRAZING MAY 1 **;
CLAS3MTH=MONTH(|,2:5|);
CLAS3ECM=ECMONTH(|,2:5|);

** MODULE TO PRINT OUTPUT INFORMATION **;
START NOCLASS3;
RESET NONAME;
PRINT /TITLE,
'STOCKING RATE =' STOCRATE;
PRINT
WEATHER(|ROWNAME=MONTH COLNAME=WEATCOL FORMAT=11.3|),
MONTHYLD(|ROWNAME=MONTH COLNAME=YLDCOL FORMAT=12.3|),
BEEF(|ROWNAME=MONTH COLNAME=BEEFCOL FORMAT=12.3|),
ECON (|ROWNAME=ECMONTH COLNAME=ECONCOL FORMAT=10.3|);
FINISH;

** MODULE TO OUTPUT INFORMATION FOR GRAZING BEGINNING MAY 1 **;
START CLASS3;
RESET NONAME;
PRINT /TITLE, 'STOCKING RATE =' STOCRATE;
PRINT
WEATHER(|ROWNAME=CLAS3MTH COLNAME=WEATCOL FORMAT=11.3|),
MONTHYLD(|ROWNAME=CLAS3MTH COLNAME=YLDCOL FORMAT=12.3|),
BEEF(|ROWNAME=CLAS3MTH COLNAME=BEEFCOL FORMAT=12.3|),
ECON (|ROWNAME=CLAS3ECM COLNAME=ECONCOL FORMAT=10.3|);
FINISH;

** PRINT COMMANDS **;
IF FORCLASS ^= 3 THEN RUN NOCLASS3;
IF FORCLASS = 3 THEN RUN CLASS3;


*************************************************************
** THE FOLLOWING COMPUTER CODE MAY BE USED OPTIONALLY TO **
** CALCULATE STANDARD ERRORS FOR ECONOMIC OUTPUT.        **
** VARIANCES CALCULATED WITH THIS CODE WILL PROBABLY     **
** UNDERESTIMATE THE TRUE VARIANCES.                     **
*************************************************************;

** ACCESS THE SUMS OF SQUARES AND CROSSPRODUCTS MATRIX **;
DATA SSCP; SET ADISK.SSCP;

** SET UP SSCP MATRIX FOR CALCULATION OF SE'S **;
USE SSCP;
READ INTO SSCP ALL
VAR{INTERCEP WT MONTH MONTH2 MONTH3 MONTH4 MONTH5 MONTH6};
SSCPH1=SSCP(|1:8,|);
SSCPH2=SSCP(|10:17,|);
SSCPS1=SSCP(|19:26,|);
```

```
630 SSCPS2=SSCP(|28:35,|);

631 ** CALCULATE VARIANCES FOR VINDEX FOR EACH SEX & MUSCLE SCORE **;
632 VARH1= 90.37961*(1+VALMATRX*INV(SSCPH1)*VALMATRX`);
633 VARH2=119.62989*(1+VALMATRX*INV(SSCPH2)*VALMATRX`);
634 VARS1=115.71433*(1+VALMATRX*INV(SSCPS1)*VALMATRX`);
635 VARS2=141.68475*(1+VALMATRX*INV(SSCPH1)*VALMATRX`);

636 ** SET UP VARIANCE FOR CHOSEN SEX AND MUSCLE SCORE **;
637 IF ALL(SEX) = 1 & ALL(MUSCLE)=1 THEN VARINDEX=VARS1;
638 IF ALL(SEX) = 1 & ALL(MUSCLE)=2 THEN VARINDEX=VARS2;
639 IF ALL(SEX) = 2 & ALL(MUSCLE)=1 THEN VARINDEX=VARH1;
640 IF ALL(SEX) = 2 & ALL(MUSCLE)=2 THEN VARINDEX=VARH2;

641 ** CALCULATE VARIANCES FOR PRICE/CWT FOR CATTLE EACH MONTH **;
642 VARVALUE=BUYPRICE**2*VARINDEX/BUYINDX**2;

643 ** CALCULATE VARIANCES FOR TOTAL MONTHLY ANIMAL VALUE **;
644 VARANVAL=VARVALUE#WT##2;

645 ** CALCULATE VARIANCES FOR MONTHLY NET RETURNS/HA **;
646 VARINCOM=VARANVAL*INPUT(|1,5|)##2;

647 ** SE'S CALCULATED AS ROOT OF VARIANCE MATRIX DIAGONALS **;
648 VALUESE=SQRT(VECDIAG(VARVALUE);
649 ANVALSE=SQRT(VECDIAG(VARANVAL);
650 INCOMSE=SQRT(VECDIAG(VARINCOM);

651 ** PRINT STANDARD ERRORS **;
652 PRINT VARINDEX VARVALUE VARANVAL VARINCOM;
```

VITA

David Glenn Keltner was born in Brownsville, Tennessee on October 5, 1961 to Mr. and Mrs. David Neal Keltner. He grew up in Bells, Tennessee, where he attended public primary and secondary schools. He graduated valedictorian from Bells High School in 1979. In September 1979, he entered The University of Tennessee, Martin. In May, 1983, he graduated with high honors with a Bachelor of Science degree in Agriculture. In September 1983, he began graduate studies as a graduate research assistant at The University of Tennessee, Knoxville in the Department of Animal Science. In 1985, he entered the Intercollegiate Graduate Statistics Program which enabled him to earn a Master of Science degree in Statistics in December 1989. He was employed as an instructor by the College of Agriculture in January 1990. In December 1990 he was awarded a Doctor of Philosophy degree in Animal Science with a concentration in Breeding and Genetics.

In December 1984, he married the former Elaine Marie Kennedy of Nashville, Tennessee. They are the parents of one son, David Andrew.