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The Impact of Range Improvement on the Economic Success and Survivability of Ranches in the Eastern Rolling Plains of Texas

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The Impact of Range Improvement on the Economic Success and Survivability of Ranches in the Eastern Rolling Plains of Texas

by

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Overview

Uncertain forage production created by variation in climatic conditions and encroachment of undesirable brush species account for much of the business risk facing range livestock producers. This study focuses on evaluation of range improvement techniques which may decrease economic losses associated with operating in this complex and uncertain environment. The investment alternatives in question were the implementation of grazing systems and the control of mesquite infestations.

Nine scenarios were examined. They include the combination of three grazing strategies (conventional grazing, deferred rotational grazing, and rotational grazing) with three mesquite control alternatives (no treatment, aerial spraying with triclopyr, and aerial spraying followed by maintenance burning). A representative ranch developed for the eastern portion of the Texas Rolling Plains was used for the study. The simulation model developed for this analysis was stochastic, dynamic, and recursive. Using Monte Carlo techniques, several random variables were simulated over a 20-year planning horizon for 100 iterations. The random variables included climatic conditions, stocking rates, success of brush control, cattle weights, conception and death rates, supplementation rates, and labor requirements. Stochastic cattle prices were also developed by projecting the cattle cycle throughout the 20-year planning horizon via harmonic functions.

Stochastic dominance was used to determine efficient sets for ranchers who were risk averse, risk neutral, or risk loving. Two conventional grazing scenarios, aerial spraying and spraying plus burning, were equally preferred by the risk neutral and risk averse categories. The second most preferred strategy included a rotational grazing system and an aerial spraying practice. The risk lover's most efficient set included only the conventional grazing strategy coupled with aerial spraying.

Results showed it was economically prudent to control mesquite infestations. The grazing strategies studied obtained negative average net present values when combined with the no brush control option. Overall farm profitability and solvency were best when implementing a conventional grazing strategy and controlling mesquite using aerial spraying or spraying followed by maintenance burns. With brush control practices remaining constant, altering cattle production by deviating from conventional grazing was not profitable. These conclusions must be qualified, though, because of the limitations of the assumptions and data used in this study (e.g., the production levels of grazing systems, response of mesquite to treatment, and the economic environment assumed).

Introduction

Risks facing range livestock producers in the Texas Rolling Plains stem from both economic and environmental sources. Scifres (1985) summarized the major business risks challenging Texas ranchers by stating that excessive brush problems, scant and erratic rainfall, and fluctuating livestock prices constituted the major management issues facing range livestock producers in Texas and that "all other issues seem inconsequential compared to these management concerns...." These three major business risks are interactive and serve to make the decision environment uncertain and difficult.

To help alleviate the uncertainty in forage production levels associated with erratic precipitation levels and brush infestations, several grazing strategies and mesquite control programs have been developed. These alternatives vary in implementation and operating costs, and in their ability to increase total beef production. Each alternative also responds differently to changes in environmental conditions.

Objectives

The general objective of this research was to examine the feasibility of various range management-beef production alternatives, and to assess their effect on the stability and level of rancher's incomes. More specifically the objectives were the following: 1) to evaluate the economic advantages of three grazing systems, namely, rotational grazing, deferred rotational grazing, and yearlong continuous grazing, and 2) to examine the feasibility of controlling mesquite infestations by spraying with triclopyr, combined with the possibility of extending the benefits of the initial herbicide treatment by controlled burning.

Study Area

The eastern portion of the Rolling Plains of Texas, as defined by Bonnen (1960) (Figure 1), comprise more than 5 percent of Texas' land area or approximately 9 million acres. Farms and ranches comprise almost 91 percent of the area, with 76 percent of the land in farms and ranches consisting of pasture and rangeland. The cow-calf enterprise is the principal type of livestock production with wheat, cotton, oats, and grain sorghum being the primary crops (Texas Dept. of Agric. 1980-1984).

Clay loam range sites predominate the area, with mesquite being most prevalent. Vegetation is a mixture of mid- and shortgrasses. Climate is highly variable, with warm, wet springs and falls, hot summers, and mild winters. Rainfall is varied within and between years with an annual average of 27 inches (Heitschmidt, et al. 1985).

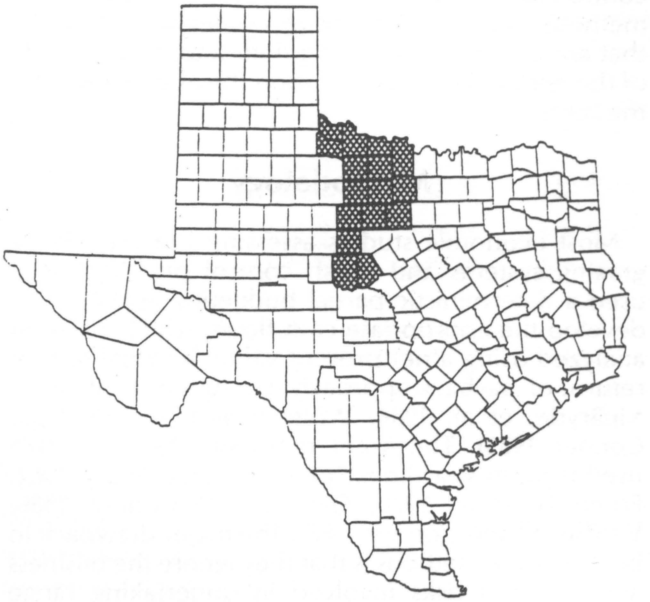

Figure 1. Eastern Rolling Plains of Texas.

Production Technologies

Three common grazing systems utilized today are rotational grazing (RG), deferred rotational grazing (DR), and yearlong continuous grazing (CG). The CG strategy is the least expensive and simplest of the three grazing strategies to implement, maintain, and manage. Livestock are simply allowed to roam at large in one pasture year-round. The four-pasture, three-herd DR strategy allows one pasture to be unoccupied for four months following a one-year grazing period (Merrill 1954). At moderate stocking rates, the DR system provides more weight gain per animal but less production per acre than the CG system (Heitschmidt, et al. 1985). The RG strategy uses a fencing design, whereby numerous grazing paddocks radiate outward from a central watering and handling facility (Savory and Parsons 1980). While this strategy permits up to a 50 percent increase in yearlong rates of stocking, individual animal performance is hindered as a result of reduced weight gains, conception rates, and weaned calf crops (Heitschmidt, et al. 1985). Facility and labor costs are also greater with the RG method than the CG grazing method (Conner and Chamberlain 1985).

Increased forage production from controlling mesquite is generally attributed to the increased availability of moisture and sunlight to range forage. Control of this invader also improves efficiency of livestock handling and increases the availability of grazing to livestock, especially if the plant is multistemmed (Scifres 1980). Two of the more promising methods for controlling mesquite infestations are spraying with triclopyr, and spraying combined with the possibility of extending treatment benefits by controlled burning. The effectiveness of both control methods depends upon environmental conditions that are conducive to absorption and translocation of the herbicide, as well as upon the effectiveness of the burn.

Methodology

Most economic studies assessing the viability of grazing systems and brush control practices have used a deterministic partial budgeting approach to develop the appropriate cash flows, which are then analyzed using a net present value, internal rate of return, or payback approach (Lundgren, et al. 1984; McBryde, et al. 1984; Whitson and Scrifres 1980; Conner 1985). The other methodology commonly used is multi-year linear programming (Sharp 1964; Freeman, et al. 1978; Garoian and Conner 1986; VanTassell and Conner 1986). The major drawback to both of these methods is that they ignore the business and financial risks involved in undertaking range improvement investments. Motad and quadratic programming have been used more sparingly to address these problems (Whitson, et al. 1982; Whitson 1974). While motad and quadratic programs address some risk issues, the lack of flexibility in specifying the model and the size of the matrix involved are major drawbacks.

To evaluate the objectives of this study, a proper accounting of several uncertain economic and physical forces acting upon a ranching enterprise was essential. The major sources of risk needed to be quantified and combined appropriately to adequately describe the interacting relationships which exist between the uncertain environment and the productive processes of a livestock operation in order to evaluate the relative risk involved with each proposed project.

The methodology chosen to examine this problem was simulation analysis. Simulation provides the flexibility for dealing with dynamics and stochastics that are too complex to be represented by more rigid mathematical models such as linear and quadratic programming (Anderson 1974). Although the flexibility and autonomous analytical structure of simulation modeling relinquishes the advantage of determining an optimal solution, it does provide an estimate of the true answer via probability distributions (Johnson and Rausser 1977). Therefore, a representation of possible outcomes which could result in actual performance is supplied.

Model Development

A simulation model, Ranch Simulator (RANSIM), was developed to examine the effect of several existing uncertain conditions upon the success and survivability of a representative ranch. The model was dynamic, stochastic, and recursive in nature. Using Monte Carlo techniques, random climatic conditions, stocking rates, cattle weights, weaning dates, cow conception rates, cow and calf death rates, supplementation rates, labor requirements, and cattle prices were simulated throughout a 20-year planning horizon for 100 iterations. These stochastic production parameters, input levels, and output prices were then combined with depreciation, taxes, and capital requirements to compute the firm's income, cash flow, and balance sheet statement. At the end of each year, a solvency test was made to determine if the firm was still viable. After each 20-year iteration, the model records information necessary to estimate the empirical probability distributions for several key output variables.

The model was basically driven by the simulated climatic environment which directly influenced supplementation levels, cow and calf weights, weaning dates, and range conditions (including the possibility of undertaking brush control practices and determining their success). March 15, June 15, August 15, and October 15 were identified as important dates in the decision-making process for ranchers in the Rolling Plains (Riechers 1986). The model assessed cumulative environmental conditions (e.g., precipitation and temperatures) at each decision date, generated production parameters, and made production decisions given the generated conditions.

Representative Ranch

Evaluation of the alternative production systems under consideration necessitated describing a representative ranching operation for the eastern portion of the Rolling Plains. It was desirable to define a ranch large enough to employ a full-time operator who would have the expertise and capital base necessary to invest in and manage the production practices under examination. Area financial consultants, bank managers, experiment station personnel, and ranchers were consulted in defining the representative ranch.

The representative ranch consisted of 10,240 acres of rangeland that was in fair condition. One-half of the acreage was operated on a long-term cash lease at $4 per acre. The lessee was responsible for repair of all fences and shared in one-third of the fence replacement costs. The lessee also paid for implementation of all brush control and grazing system improvements. At the end of the lease or in case of insolvency, the lessee was reimbursed a salvage value for such improvements.

In its original condition, the total acreage supported 515, 640, and 439 crossbred cow-calf pairs for the CG, RG, and DG systems, respectively. Cows were bred to calve from late December to early February. Dry cows were sold in June if an adjustment downward in stocking rates was needed. At weaning, open cows, 13-year-old cows, and a minimum of 1 percent of the bottom of the herd were automatically culled. If conditions necessitated a further reduction in livestock numbers, pregnant cows or cow-calf pairs were sold. Spring replacements were assumed to be purchased as cows with calves at side, and bred heifers were purchased for fall replacements. All calves were sold after weaning at the prevailing market prices. Bulls were purchased as 2-year-olds and sold after they reached 8 years old.

Beginning long-term debt to asset ratio was 0.70 and the intermediate-term debt to asset ratio was 0.50. Existing and current long- and intermediate-term debts were assumed to be financed with 30- and 5-year loans, respectively. Beginning net worth was $538,351. Minimum equity requirements for solvency were 0.20 for long-term assets and 0.30 for intermediate-term assets.

Family living expenses were set at a minimum of $18,000 and a maximum of $36,000, with a marginal propensity to consume 25 percent of disposable income. Personal income and self-employment taxes for each year of the planning horizon were computed under provisions of the Tax Reform Act of 1986.

The operator and his family provided a total of 40 hours of labor per week above the amount required for financial, marketing, and other management concerns. Additional labor was provided at a cost of $10 per hour.

Assumed inflation rates and interest rates for the 20-year planning horizon are found in Appendix 1. All rates for 1987 through 1990 were obtained from the Commodity Specific General Equilibrium Model (COMGEM) using a high federal budget deficit scenario (Hughes, et al. 1987). After 1990, interest and inflation rates were assumed to remain at their 1990 levels for the remainder of the planning horizon. Costs were increased annually to reflect the assumed inflationary environment.

Machinery complements and livestock facilities were valued on a current market basis and replaced at the end of their economic (useful) life. Replacement price was based on 1986 prices and inflation rates which reflect the assumed economic conditions. Depreciable items were recovered using a 5-year double declining balance schedule. First-year expensing was also assessed on purchased livestock and machinery.

Initial costs of production for each grazing system were adopted from enterprise budgets developed by Conner and Chamberlain (1985). The ranch was already cross-fenced, so no additional facilities were needed for the DR system. An investment of $58,518 was required for fences, corrals, and watering systems required to set up two circles (six paddocks each) for the RG system. Operating costs for repairs, insurance, etc., were assumed to be equal for the CG and DR systems, but were increased almost $2,100 for the RG system (Table 1). Operating inputs per cow were assumed to be equal for all systems. They included $6.85 for veterinary and medicine, $2.30 for salt, and $0.50 for miscellaneous expenses, for a total of $9.65 per head. Marketing costs were $11 per animal sold, and supplemental feed in the form of range cubes was priced at $11 per hundredweight of feed. Labor requirements were included on both a per acre (for facility and fence repair) and a per cow basis. Average production parameters for each grazing system are found in Table 2.

Table 1. Yearly operating fixed input costs for the Conventional (CG), Deferred (DG), and Rotational (RG) Grazing Systems.

	CG	DG	RG
Fence Repair	$ 128.30	$ 128.30	$ 128.30
Electric Fence Repair			63.36
Equipment, Fuel, and Lube	2,112.90	2,112.90	2,853.80
Water Facilities Repair	110.00	110.00	660.00
Equipment Repair	2,295.00	2,295.00	3,060.20
Accountant and Legal Fees	2,500.00	2,500.00	2,500.00
Insurance	600.00	600.00	600.00
Miscellaneous Costs	1,000.00	1,000.00	1,000.00
Total	$8,746.20	$8,746.20	$10,865.66

Table 2. Average production parameters for the Conventional (CG), Deferred Rotational (DG), and the Rotational (RG) Grazing Systems.

	CG	DG	RG
Acres/Animal Unit	12.00	14.00	9.50
Cows/Bull	25.00	25.00	30.00
Weaning Weight, Steers (lbs)	580.00	595.00	550.00
Death Rate, Calves (%)	7.80	7.00	8.50
Death Rate, Cows (%)	1.90	1.60	2.20
Conception Rate (%)	90.00	94.00	88.00
Labor/Acre (hours)	0.17	0.17	0.31
Labor/Cow (hours)[a]	1.40	1.70	2.40

[a] Increased as a function of brush infestations.

Estimated costs for brush control were $11.25 per acre for spraying, which included $7.25 for chemicals and $4 for application. Cost of the first burn was assumed to be $6 per acre, including the development of fire lanes. Cost of the second burning was estimated at $3 per acre. To accommodate the temporary decreases in carrying capacity due to brush treatment, additional acreage was leased at $6.67 per cow per month.

Climatic Conditions

Monthly precipitation and average minimum temperatures were determined by VanTassell, et al. (1987 to be the most crucial climatic variables in evaluating production relationships in the Rolling Plains, with each forage production year beginning in August of the previous year and extending to each decision month. Historical monthly data for the Texas Rolling Plains area covering 1936 through 1985 were obtained from the National Oceanic and

Atmospheric Administration (NOAA 1985). These data were checked for long-run cyclical trends, but none were significant.

To stochastically generate alternate sequences of monthly climatic data, multivariate empirical probability density functions (pdf's) for each month's precipitation and January through May temperatures were developed (Richardson and Condra 1978; Clements, et al. 1971). Stochastically drawing the monthly climatic variables in this manner for each year maintains the interyear correlations. Because data needed to be aggregated across years into production periods, two problems existed with this method. First, was the correlation problem. For example, the correlation coefficient between February and December in year t was -0.01, while the correlation coefficient between February in year t and December in year t-1 was 0.411. To maintain the intertemperal correlation, the correlation matrix was expanded to include the lagged (t-1) August through December climatic variables (August t-1 thru December t climatic variables were generated for each year.). A second problem then arose, because the precipitation generated in year t for August through December precipitation by definition must be the same level generated for the lagged August through December precipitation in year t+1. Therefore, to assure identity in the overlapping precipitation variables, the empirical correlation method used to obtain the correlated deviates was modified to include intertemperal correlation and provide identical overlapping data.[1]

Rangeland Stocking Capacity

Forage availability was a function of total precipitation accumulated during a forage production period which began in August of the previous year and extended to each decision point. To account for the variability in forage levels, subjective probability distributions for carrying capacity, conditional upon rainfall, were elicited from range scientists. Precipitation levels associated with percentages of 90, 70, 50, 30, and 10 percent of the maximum precipitation received for each forage production period throughout the 50 years of historical data examined were used as the elicitation points.

A conditional cumulative distribution function (cdf) was estimated for each decision month using the five elicited density functions as observations (one for each precipitation level). The cdf's were estimated using a hyperbolic tangent transformation procedure described by Taylor (1984). The procedure estimates a cumulative distribution function as

$$(1)\quad F(Y \mid X) + .5 + .5\tanh\,[P(Y, X)].$$

Where Y is the stocking rate, X is accumulated precipitation throughout the production period, $F(Y \mid X)$ is the cdf of Y conditional on X, and P (Y, X) is a third degree polynomial function of Y and X. A program, SECANT, developed by Taylor (1983) was used to search for maximum likelihood (ML) estimates of (1). Stepwise regression procedures were used to specify which initial variables and coefficients from a third degree of polynomial were to be included in P(X, Y). A likelihood ratio test (Theil 1971) was used to determine which remaining polynomial terms were included in the ML estimates of P(X, Y).

Final ML estimations (and accompanying asymptotic t-statistics) for the CG strategy at the June, August, and October decision points, respectively are:

$$(2)\quad F(Y \mid X) = .5 + .5\tanh[\underset{(-8.44)}{-5.04} + \underset{(8.01)}{16.24Y^2} - \underset{(-6.91)}{2.13XY^2}]$$

$$(3)\quad F(Y \mid X) = .5 + .5\tanh[\underset{(-8.45)}{-4.95} + \underset{(7.93)}{16.08Y^2} - \underset{(-7.01)}{1.90XY^2}]$$

$$(4)\quad F(Y \mid X) = .5 + .5\tanh[\underset{(-0.115)}{-0.34} + \underset{(5.472)}{25.39Y^2} - \underset{(-2.143)}{1.94X} + \underset{(2.565)}{0.41X^2Y} - \underset{(-4.087)}{4.59XY^2}]$$

Final ML estimations (and accompanying asymptotic t-statistics for the RG strategy at the June, August, and October decision points, respectively, are:

$$(5)\quad F(Y \mid X) = .5 + .5\tanh[\underset{(-8.53)}{-8.47} + \underset{(6.36)}{20.93Y} - \underset{(-3.68)}{4.80XY} + \underset{(2.61)}{0.41X^2Y}]$$

$$(6)\quad F(Y \mid X) = .5 + .5\tanh[\underset{(-8.55)}{-7.64} + \underset{(6.05)}{26.18Y} - \underset{(-4.45)}{6.76XY} + \underset{(3.80)}{0.56X^2Y}]$$

$$(7)\quad F(Y \mid X) = .5 + .5\tanh[\underset{(-8.64)}{-8.31} + \underset{(5.79)}{32.83Y} - \underset{(-4.35)}{8.05XY} + \underset{(3.75)}{0.62X^2Y}]$$

The expected values of Y given X are then defined as:

$$(8)\quad E(Y \mid X) = \int_{-\infty}^{\infty} .5\, y\, P'(y,X)\, \mathrm{sech}^2[P(y,X)]\, dy.$$

Given the level of precipitation occurring during the production period, (8) was numerically integrated to obtain the carrying capacity for each decision period.

Twenty percent of the historic precipitation levels fell outside the range of the elicited density functions.

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[1] See Appendix 2 for a complete explanation of this method.

For most of the extreme levels of precipitation, the hyperbolic tangent functions did not remain stable, but gave stocking levels which were unrealistic. Stocking rates at levels outside the elicited range of precipitation were therefore assumed to be distributed empirically using the elicited density functions estimated at the 10 percent and 90 percent levels.

Because the DG strategy varies stocking rates only minimal amounts, carrying capacity was not conditional upon precipitation in the hyperbolic tangent functions. Carrying capacity was therefore assumed to be empirically distributed for the DG strategy, with the elicited density functions (dependent upon precipitation levels) being used as historical data.

Several factors usually cause a rancher to not completely utilize the full range of carrying capacity each grazing strategy affords. Among these are the expense of selling and buying cows, the disruption in the ranchers culling and breeding schemes, the availability of suitable replacements, and the lack of available funds for restocking. To partially account for the rigidity which exists in utilizing the full range of carrying capacity, stocking rates were obtained from a dampening function defined as:

(9) $SR = ASR - (ASR - CP)/ADJ$.

Where SR is the final stocking rate, CP is the carrying capacity obtained from the respective functions, ADJ is an adjustment factor, and ASR is the average stocking rate for each grazing strategy (12.0 for CG, 14.0 for DG, and 9.5 for RG). ADJ was assumed to be 2.0 unless accumulated precipitation was below (above) that which occurred 20 (80) percent of the time for the given decision point. For these later levels, the adjustment factor was changed to 1.75 to allow for more drastic stocking rate changes due to continual drought or excessive forage.

Brush Control

Two major sources of uncertainty exist when mapping changes in stocking rates over time via response curves. First, uncertainty exists about what the response from brush control will actually be. Second, is the effect the level of precipitation will have upon the carrying capacity of the range. To account for the first uncertainty, traditional response curves (Workman, et al. 1985; Whitson and Scifres 1980) were modified, after consultation with range scientists, to provide several response paths. Figure 2 presents the estimated response curve for spraying mesquite with triclopyr for normal precipitation levels. The range was assumed to be in fair condition with a mesquite canopy cover of 25 percent to 30 percent and a stocking rate of 20 acres per animal unit. Without treatment (Paths 1, 2, and 3), the stocking rate decreased to either 22, 24, or 26 acres per animal unit throughout the 20-year planning horizon, dependent upon several unmeasureable environmental factors. Each path was assigned a subjective probability of occurrence equal to 33.3 percent and a random draw determined which of the three lines were followed.

Paths 4, 5, and 6 map carrying capacity after spraying (Figure 2). No increase in forage production occurred the first year of spraying. By the second year, the majority of foliage was assumed to have been removed from the trees and maximum forage production was reached by the third year. The main source of forage variation from spraying was the rate of decline once maximum carrying capacity was reached. To account for this uncertainty, three paths of descent were assumed.

A major factor influencing the success of spraying mesquite was the physiological activity of the plant. Accumulated precipitation 3 months prior to spraying (April through June) was used as an indicator of plant viability. The decision about whether to spray and the subjective probabilities used for assigning a path of descent were changed depending upon the precipitation occurring prior to spraying. If precipitation was below 6.6 inches, which historically occurred 30 percent of the time, spraying was assumed to not be a successful investment and was not undertaken. If accumulated precipitation was above 8.7 inches, which historically occurred 50 percent of the time, probabilities of success for Paths 4, 5, and 6 were 20, 40, and 40 percent, respectively. If precipitation was between 6.6 and 8.7 inches, probabilities of success were changed to 25, 50, and 25 percent for Paths 4, 5, and 6, respectively. Once the range condition again deteriorated to 20 acres per animal unit, the range was eligible for respraying.

Sprayed land was eligible for burning in February during the sixth year after spraying, assuming sufficient fine fuel was available to carry the fire (Figure 3). To accumulate fuel, a grazing deferment of 5 months, from September until February, was required. Total precipitation during the deferment was used as a barometer for the amount of accumulated grass. If precipitation was below 6.6 inches, burning was not allowed. Since the amount of forage dictates the intensity of the fire, which in turn determines the extent of mesquite control, probabilities about the success of the burn were assigned to each path dependent upon the level of precipitation received during the deferment. Probabilities of following Paths 4, 5, or 6 were 25, 50, and 25 percent, respectively, when precipitation was under 8.7 inches; and 20, 50, and 30 percent, respectively, when precipitation was over 8.7 inches. A grazing deferment was continued for 3 months after the burn to allow proper regrowth of the forage.

Assuming the first burn occurred, the range was eligible for a second burn 6 years hence. The same rules used to determine eligibility and success of the first burn applied to the second burn except that probabilities were changed for Paths 7, 8, and 9, to

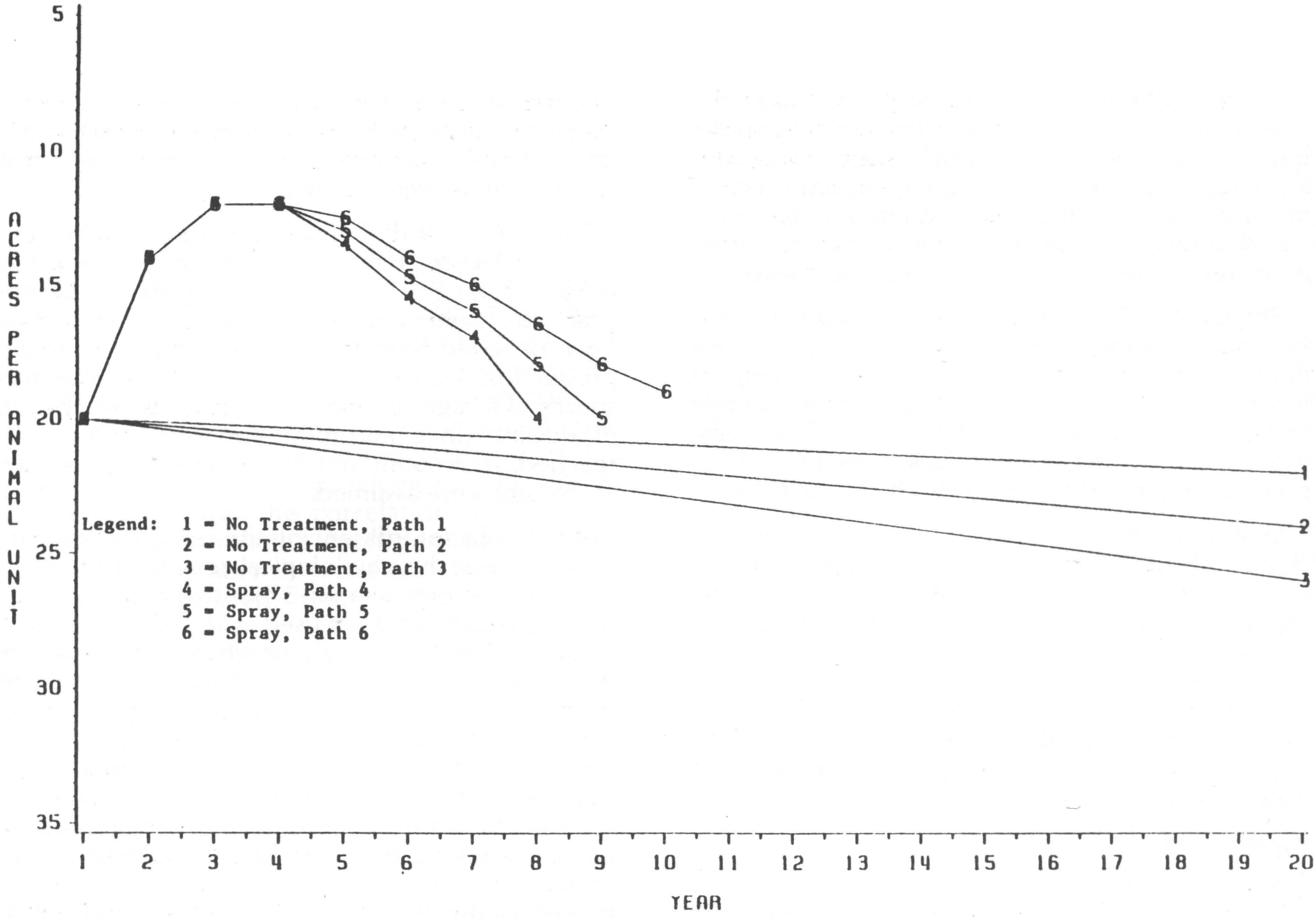

Figure 2. Response curves for the spray and and no treatment alternatives.

30, 50, and 20 percent, respectively, for precipitation between 6.6 and 8.7 inches; and 25, 50, and 25 percent, respectively, for precipitation levels over 8.7 inches for the same paths. The decreased success of the second burn was due to increased size and foliage of the mesquite plants.

The range was only eligible for burning during the sixth and seventh years following the previous treatment. After the seventh year, mesquite foliage was assumed to be sufficiently dense and the stems large enough to reduce the effectiveness of burning below its marginal value. If financing was not available or if drought had prevented implementing a burn prior to the seventh year, the range was resprayed when carrying capacity reached 20 acres per animal unit or more. The rancher also had to resort to spraying as the only means of treatment the fourth or fifth year following a successful second burn because of the increased size and viability of the mesquite plants.

The ranch was assumed to be divided into parcels one section in size for brush treatment. In the first year of every iteration, each section was randomly assigned a stocking rate path to follow. Sections were then evaluated separately on brush control needs. Spraying was allowed in a maximum of four sections each year and burning was permitted in three sections, depending on environmental conditions and the rancher's financial condition. Sections qualifying for the first maintenance burn were given first priority for financing. Second burn sections were given second priority, and spray or respray sections were given last priority.

A secondary advantage of controlling mesquite infestations was the reduction in labor required for gathering, handling, feeding, and inspecting the cattle. To account for these increased economies, labor requirements per cow were altered depending on the degree of mesquite infestation. Labor requirements for relatively clean pastures were assumed to be 1.4, 1.7, and 2.4 hours per cow for the CG, DG, and RG strategies, respectively (Conner and Chamberlain 1985). As carrying capacity was reduced to between 16 and 19 acres per animal unit, labor requirements increased to 1.89, 2.61, and 2.66 for the CG, DG, and RG strategies, accordingly. For infestations which reduced carrying capacity to more than 19 acres per animal unit, labor requirements were assumed to increase to 2.37, 3.51, and 2.78 for the CG, DG, and RG strategies, respectively.

Response curves were consolidated with the stochastic stocking rates developed for each grazing system via the hyperbolic tangent or empirical distributions discussed earlier using:

(10) $SR_i = 1 / [\, (1 / SA_j * BSR) / CC_i]$.

Where SR_i is the final stocking rate for the i^{th}

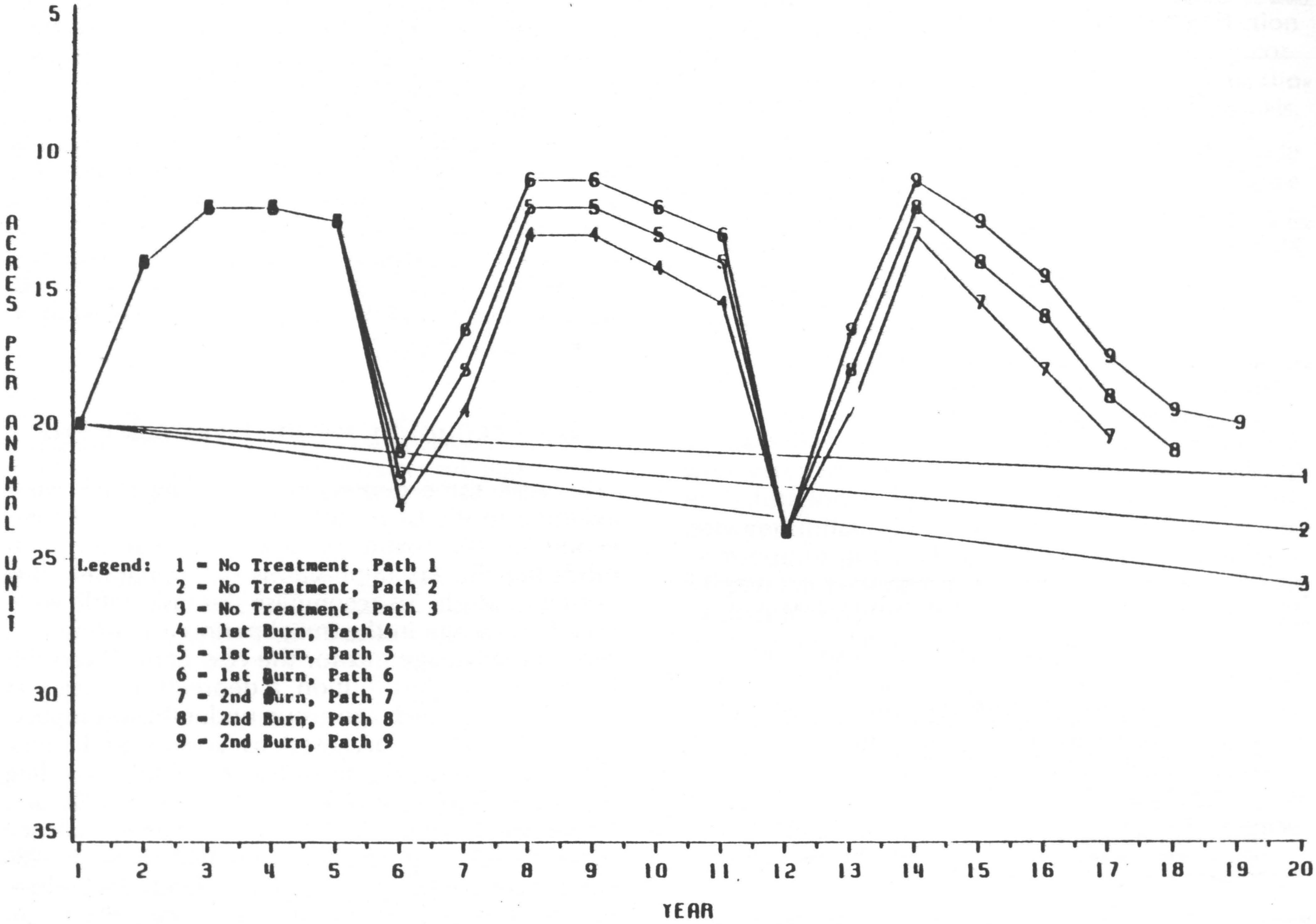

Figure 3. Response curves for the no treatment and burn-after-spray alternatives.

section, SA_j is the stocking rate (conditional upon precipitation) derived for the j^{th} grazing system, BSR is the stocking rate for the response curve (assuming low brush infestations and average precipitation, e.g., 12 acres per animal unit), and CC is the carrying capacity determined from the response curve for the i^{th} section.

Discounted terminal values were used to assess the productive potential of the range at the end of the planning horizon, or in case of insolvency, by valuing each animal unit available above the untreated carrying capacity level at $60. This rate corresponded to a yearly per head grazing fee associated with a conservative $3 per acre lease.

Cattle Production Parameters

To account for the variability in cattle production levels, steer and heifer calf weights, cull and dry cow weights, cow and calf death rates, and conception rates were developed for each grazing system. These data were developed using historical production data collected at the Texas Experimental Ranch in Throckmorton County, Texas.

Cattle weights were developed for both the June and weaning decision periods. Table 3 contains the weight equations used in the study, along with their accompanying statistics. The calf weight equations were obtained from VanTassell, et al. (1987), while the cow weight equations were developed using these same data and methods. All weights were stochastically simulated by adding the respective standard deviation multiplied by a random normal deviate to each equation.

Differences between steer and heifer weights (adjusted for age differences) were independent of all other variables, and thus were determined by their mean difference (34 pounds) plus their standard deviation (20 pounds) times a normal random deviate. This difference was added to the estimated average calf weights to obtain steer weights and subtracted to obtain the final heifer weights. Purchased replacement heifers and young cows were assumed to weigh 850 pounds and cull bulls were assumed to weigh 1,750 pounds.

VanTassell, et al. (1987) showed that cumulative probability distributions of the historical calf weights

Table 3. Cow and calf weight (lbs) ordinary least square equations for the June and weaning decision periods.

$$\mathrm{WT2} = \underset{(-5.21)^{**\Phi}}{-242.35} + \underset{(12.80)^{**}}{1.97}\,\mathrm{AGE} + \underset{(4.20)^{**}}{0.26}\,\mathrm{SUP} - \underset{(-5.09)^{**}}{19.86}\,\mathrm{CG} - \underset{(-4.22)^{**}}{46.29}\,\mathrm{RG} + \underset{(19.86)^{**}}{81.92}\,\mathrm{CB} +$$

$$\underset{(6.99)^{**}}{15.19}\,\mathrm{A11} - \underset{(-6.42)^{**}}{0.27}\,\mathrm{A11}^2 + \underset{(1.76)^{*}}{0.58}\,\mathrm{J4} + \delta$$

$$R^2 = .83 \quad \sigma = 19.38$$

$$\mathrm{WT3} = \underset{(0.47)}{-226.20} + \underset{(10.73)^{**}}{0.65}\,\mathrm{WT2} + \underset{(8.67)^{**}}{1.09}\,\mathrm{DAY} + \underset{(1.11)}{0.081}\,\mathrm{SUP} - \underset{(2.03)^{**}}{9.10}\,\mathrm{CG} - \underset{(1.80)^{*}}{22.08}\,\mathrm{RG}$$

$$+ \underset{(9.84)^{**}}{62.71}\,\mathrm{CB} + \underset{(2.51)^{**}}{14.75}\,\mathrm{F7} - \underset{(2.53)^{**}}{0.44}\,\mathrm{F7}^2 + \underset{(3.44)^{**}}{1.26}\,\mathrm{J5} + \delta$$

$$R^2 = .89 \quad \sigma = 20.25$$

$$\mathrm{WC2} = \underset{(21.74)^{**}}{959.12} + \underset{(1.72)^{*}}{0.18}\,\mathrm{WT2} + \underset{(9.46)^{**}}{111.85}\,\mathrm{DRY} + \underset{(2.69)^{**}}{0.87}\,\mathrm{SUP} - \underset{(-4.52)^{**}}{62.28}\,\mathrm{CG} - \underset{(-3.76)^{**}}{70.73}\,\mathrm{RG}$$

$$+ \underset{(3.82)^{**}}{87.57}(\mathrm{DRY}*\mathrm{DG}) - \underset{(-2.94)^{**}}{0.11}(\mathrm{DG}*\mathrm{WT2}) + \delta$$

$$R^2 = .76 \quad \sigma = 41.24$$

$$\mathrm{WC3} = \underset{(-0.99)}{-21.69} + \underset{(4.39)^{**}}{0.78}\,\mathrm{CFG} + \underset{(3.52)^{**}}{3.79}\,\mathrm{DRY} - \underset{(-3.66)^{**}}{1.15}\,\mathrm{DAY} + \delta$$

$$R^2 = .25 \quad \sigma = 42.26$$

$^{\Phi}$t-values for each parameter are in parenthesis below the parameter estimate.

* and ** imply significantly different from zero at the 90% and 95% level, respectively.

Where, σ = standard deviation, WT2 = average calf weight in June; WT3 = average calf weight at weaning; WC2 = average cow weight in calf between June and weaning; AGE = age of calf in days at weighing; DAY = days between the June and weaning weigh dates; SUP = supplementation level of cow herd in pounds of total crude protein; CG = 1 if CG strategy, 0 o.w.; RG = 1 if RG strategy, 0 o.w.; DG = 1 if DG strategy, 0 o.w.; CB = 1 if crossbred, 0 o.w.; DRY = 1 if cow was dry, 0 o.w.; A11 = accumulated precipitation from August in the previous year through June; F7 = accumulated precipitation from February through August; and J4(J5) = accumulated average minimum monthly temperatures from January through April (May).

were relatively steep at the upper and lower tails (i.e., a ceiling and floor on the range of weights), while distributions created from simulating the respective equations tailed off more slowly. All weights were therefore bounded, with the range dependent upon the grazing system involved. The ranges for calf weights were 450 to 590, 475 to 625, and 480 to 630 pounds for the RG, CG, and DG strategies, respectively. The ranges for June dry and weaning cow weights, respectively, were 990 to 1,215 and 890 to 1,140 pounds for RG; 1,000 to 1,225 and 900 to 1,150 pounds for CG; and 1,050 to 1,275 and 950 to 1,200 pounds for DG. Weight range limits were increased by 0.75 pounds per year to allow for any technical progress which may have occurred.

Cows were supplemented a 20 percent crude protein range cube at varying levels for up to 120 days during the winter depending on the assumed forage levels as determined by accumulated precipitation. The difference in supplementation rates between the grazing strategies corresponded to the stocking pressures on the rangeland. For the simulated data, average yearly supplementation rates were 164.50, 50.15, and 164.50 pounds for the CG, DG, and RG strategies, respectively.

Probability distributions were developed for conception rates and death rates for cows and calves by combining the historical observations (1981 through 1985) with subjective probability distributions obtained from range scientists working at the Texas Experimental Ranch. No historical correlations were found among these performance variables, or with other variables such as supplementation, weight, or weather. The distributions were therefore modeled as independent empirical, from which stochastic conception and death rates were obtained. Ninety percent of the yearly death loss for calves was assumed to occur prior to the June decision period, while 75 percent of the cow death loss was assumed to occur by this period.

Tax Accounting for the Livestock Herd

Because some depreciable breeding stock were assumed to die or be sold before the end of their economic life, extra consideration was given in modeling the tax implications of prematurely disposing of assets. To accomplish this task, cattle were classified by age in the initial period according to a representative age mix for the cow herd. Given this initial cow age distribution, a depreciable basis was established for each age group under the assumption that cows were purchased as 2-year-old heifers. Cows purchased prior to 1980 were valued according to historical prices, given a salvage value of $200, and depreciated using a 150 percent declining balance schedule. Cows purchased from 1980 through 1986 were recovered using a 5-year accelerated schedule, electing first-year expensing, and taking a 10 percent investment tax credit. Investment tax credit recapture was taken on all qualified breeding stock disposed of prematurely. Bulls purchased during these same time periods received the same tax treatment.

Casualty loss was taken on the remaining depreciation and salvage value (if applicable) of any cows or bulls which died during the year. Depreciation recapture was accumulated on all open cows sold using their respective remaining depreciable basis.

For accounting and salvage value purposes, breeding herd value was determined at the end of each year. Cows were priced at an average of utility and replacement cow prices. Bulls were valued at 80 percent of their current replacement price. Federal income taxes were calculated using the provisions for the 1986 Tax Reform Act, assuming the livestock producer was a sole proprietor.

Cattle Prices

Cyclical price paths were projected for 400-500, 500-600, and 600-700 pound steer and heifer calves; cull cows and bulls; and replacement heifers, cows, and bulls using harmonic regressions (Franzmann and Walker 1972; Gutierrez 1985). Data were collected on a monthly basis for the years 1972 through 1985[2] (Texas Dept. of Agric. 1972-1985; American *Hereford Journal* 1972-1986; USDA 1972-1985). Table 4 contains the ordinary least squares equations for each class of cattle using the following cyclical trend model:

$$(11)\quad P_{it} = B_0 + B_1 2\pi t - B_2 SIN(2\pi t/L1) + B_3 COS(2\pi t/L1) + B_4 SIN(2\pi t/L2) + B_5 COS(2\pi t/L2) + \delta$$

Where P_{it} is the predicted price for the i^{th} class of cattle in time period t, B's are parameter estimates, L is the specified cycle length, and δ is the residual error term. Following Franzmann and Walker, a 12 month seasonal component was specified for L1, and a 120-month cycle was used for L2. The prediction equations were stochastically simulated using correlated random normal deviates developed from the covariance matrix of the harmonic function residuals.

Table 4. Ordinary least square equations for the cyclical trend cattle price model[a].

$$H4 = 37.39 + 0.030T + 1.661S1 - 1.470C1 - 10.149S2 + 8.704C2 + \delta$$
$$(24.70)^{**} \quad (12.31)^{**} \quad (1.58) \quad (-1.39) \quad (-9.51)^{**} \quad (7.99)^{**}$$
$$R^2 = .67 \qquad \sigma = 9.49$$

$$H5 = 36.04 + 0.028T + 1.624S1 - 0.733C1 - 9.079S2 + 8.330C2 + \delta$$
$$(28.64)^{**} \quad (13.98)^{**} \quad (1.85)^{*} \quad (-0.84) \quad (-10.23)^{**} \quad (9.21)^{**}$$
$$R^2 = .71 \qquad \sigma = 7.89$$

$$H6 = 34.69 + 0.029T + 1.574S1 - 0.565C1 - 8.239S2 + 7.931C2 + \delta$$
$$(30.71)^{**} \quad (16.14)^{**} \quad (2.00)^{**} \quad (-0.72) \quad (-10.34)^{**} \quad (9.76)^{**}$$
$$R^2 = .75 \qquad \sigma = 7.08$$

$$S4 = 44.64 + 0.035T + 1.684S1 - 1.447C1 - 12.154S2 + 9.639C2 + \delta$$
$$(27.48)^{**} \quad (13.42)^{**} \quad (1.49) \quad (-1.28) \quad (-10.61)^{**} \quad (8.25)^{**}$$
$$R^2 = .70 \qquad \sigma = 10.20$$

$$S5 = 42.02 + 0.033T + 1.583S1 - 0.519C1 - 10.255S2 + 8.925C2 + \delta$$
$$(30.23)^{**} \quad (14.53)^{**} \quad (1.64) \quad (-0.54) \quad (-10.47)^{**} \quad (8.93)^{**}$$
$$R^2 = .72 \qquad \sigma = 8.71$$

$$S6 = 40.10 + 0.031T + 1.434S1 - 0.081C1 - 9.013S2 + 8.397C2 + \delta$$
$$(32.96)^{**} \quad (15.82)^{**} \quad (1.69)^{*} \quad (0.10) \quad (-10.51)^{**} \quad (9.60)^{**}$$
$$R^2 = .75 \qquad \sigma = 7.62$$

$$UT = 25.88 + 0.017T + 1.950S1 - 1.722C1 - 5.375S2 + 4.726C2 + \delta$$
$$(34.40)^{**} \quad (14.38)^{**} \quad (3.72)^{**} \quad (-3.30)^{**} \quad (10.13)^{**} \quad (8.73)^{**}$$
$$R^2 = .72 \qquad \sigma = 4.72$$

$$PR = 348.25 + 0.269T + 5.217S1 - 21.159C1 - 93.730S2 + 108.62C2 + \delta$$
$$(24.22)^{**} \quad (11.58)^{**} \quad (0.52) \quad (-2.12)^{**} \quad (-9.25)^{**} \quad (10.51)^{**}$$
$$R^2 = .68 \qquad \sigma = 90.10$$

$$RP = 33.39 + 0.152T + 1.510S1 - 0.222C1 - 8.616S2 + 7.42C2 + \delta$$
$$(30.22)^{**} \quad (8.49)^{**} \quad (1.96)^{*} \quad (-0.29) \quad (-11.06)^{**} \quad (9.34)^{**}$$
$$R^2 = .65 \qquad \sigma = 6.92$$

$$BL = 813.28 + 1.106T + 160.77S1 - 117.028C1 - 38.465S2 + 159.454C2 + \delta$$
$$(11.21)^{**} \quad (9.43)^{**} \quad (-3.18)^{**} \quad (-2.32)^{**} \quad (-0.75) \quad (3.06)^{**}$$
$$R^2 = .43 \qquad \sigma = 454.57$$

[a] t-values for each parameter are in parenthesis below parameter estimates.

* and ** imply significantly different from zero at the 90% and 95% level, respectively.

Where, σ = standard deviation, H4, H5, H6, S4, S5, and S6 = Heifer (H) and Steer (S) price per cwt. for 400-500(4), 500-600(5), and 500-600(5), and 600-700(6) pound calves, respectively; UT = price per cwt. for utility cows; PR = price per pair for cow-calf pairs; RP = price per cwt. for replacement heifers; BL = price per head for replacement herd sires; t = time trend (e.g., 1, 2, 3...); t = time trend (i.e., 1, 2, 3...); T = $2\pi t/L1$); S1 = SIN($2\pi t/L1$); C1 = COS($2\pi t/L1$); S2 = SIN($2\pi t/L2$); C2 = COS($2\pi t/L2$); L1 = cycle length of 12 months; L2 = cycle length of 120 months.

Two different starting points in the cattle cycle were assumed for the simulation as shown in Figure 4. Following the harmonic functions through time, the position for 1987 prices would be at the beginning of Path A. To follow closely with the COMGEM high deficit scenarios, in which average cattle prices decline slightly from 1987 through 1990, and because several conditions pointed to continued soft cattle prices (e.g., decreased demand for beef and dairy buyout program), Path B was also assumed. Subjective probabilities of 0.70 for Path B and 0.30 for Path A were given for determining which path was followed each iteration. Using a 0.725 transmission coefficient between inflation rates of costs of production and farm output prices (Tweeten 1980), and assuming a 6.0 percent general rate of inflation, average annual cattle prices were increased by an annual rate of 4.35 percent after the fourth year in each iteration.

While the random normal deviates used to simulate cattle prices were correlated between classes, they were not correlated between months. To maintain this correlation in the stochastic simulation, monthly prices from each equation were averaged into yearly prices and then seasonalized using seasonal indices developed from the historical cattle prices.

Results and Discussion

To obtain a representative sampling of the stochastic process inherent in the model, a 20-year planning horizon was simulated for 100 iterations. Nine scenarios, CN, CS, CB, DN, DS, DB, RN, RS, and RB, were designated for the CG (C), DG (D), and RG (R) grazing strategies, combined with no mesquite treatment (N), spray (S), and spray-burn (B), respectively.

The ranch's probability of success (the probability that the ranch would return at least an 8 percent after-tax net return to initial equity), and the probability of survival (the probability that the rancher would remain solvent over the 20-year planning horizon) under each scenario are contained in Table 5. Also presented are simple statistics for discounted net present values (NPV's), discounted ending net worths (ENW's), and average size of cow herd maintained.

Continuing Scenario CN, a rancher in the Rolling Plains would have a 24 percent chance of surviving during the 20-year planning period, and a 26 percent probability of success. Income from an average of 477 cows did not allow the rancher to maintain the necessary cash flow to remain in business past an average of 16 years. This scenario did, however, have

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[2] Slaughter bull prices were only available for the years 1972, 1973, and 1980 through 1985. Ordinary least square regressions showed that slaughter bull prices over that period were almost exactly 1.25 times utility cow prices (R^2 = 0.99). Slaughter bull prices were therefore determined by multiplying the predicted utility cow prices by 1.25.

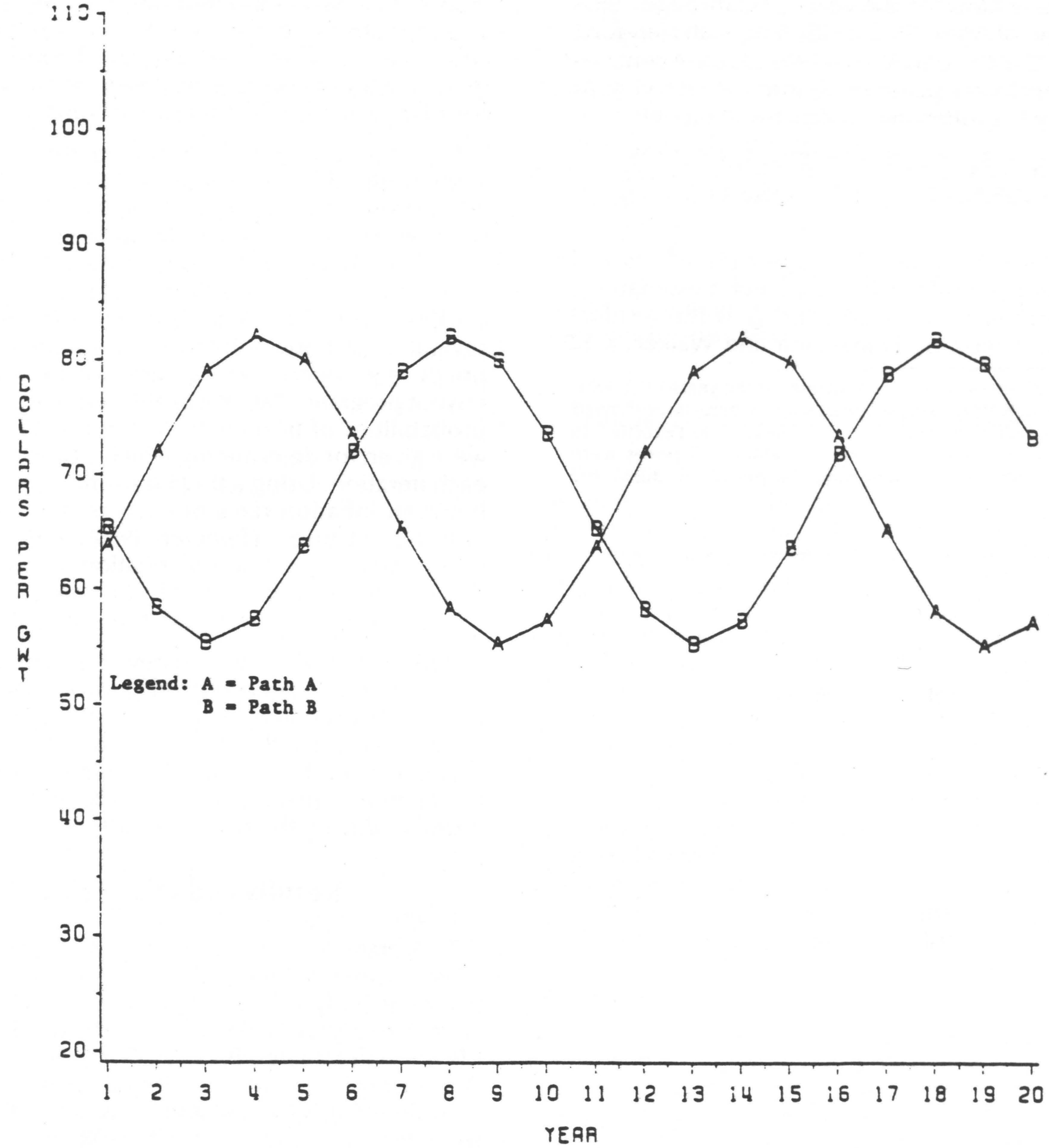

Figure 4. Starting points and associated cycles for the simulated prices for 500-600 pound steers.

the greatest probability of success and survival of all the no mesquite treatment scenarios. NPV averaged -$138,660 and ENW diminished to $80,750, down from the original $538,356 under Scenario CN.

Controlling mesquite, the probabilities of success and survival were increased to 93 percent and 92 percent, respectively, for Scenario CB, and 90 percent under the Scenario CS. These probabilities were the highest obtained of the nine scenarios examined. Scenarios CS and CB had equal probabilities of survival until the twelfth year when the relatively inexpensive second burn of Scenario CB began to pay off. Scenarios CS and CB also had the highest average NPV of all scenarios ($976,550 and $909,670, respectively), and the highest average ENW ($876,190 and $843,360, respectively). Scenario CB obtained the lowest and Scenario CS the second lowest positive relative variance of NPV and ENW, as measured by their coefficients of variation.

The number of mother cows operated by Scenarios CS and CB averaged 185 head more than under the CN strategy. Average number of sections treated for mesquite infestations were the highest of all Scenarios, with a yearly average of 0.75 sections first sprayed, and 0.84 sections resprayed under Scenario CS; and a yearly average of 0.64 sections first burned, and 0.29 second burned under Scenario CB.

A rancher using Scenario DN under the stated assumptions would have had a zero probability of success and survival, while remaining in business an average of 9.6 years. This strategy operated the smallest average size cow herd (420 head), but had the lowest variation in the number of cows maintained. Scenario DN had the lowest average NPV (-$327,820), with ENW decreasing $500,000 from the initial $538,351. While each scenario started with the same net worth, Scenario DN was not able to produce enough calves to maintain its equity position.

Utilizing mesquite control methods, the probabilities of survival and success were improved from zero under Scenario DN to 38 percent and 43 percent each under Scenarios DS and DB, respectively. While the NPV and ENW positions were better than any no mesquite treatment scenario, they were the lowest of all mesquite treatment scenarios. The number of cows operated under these two scenarios were increased by approximately 80 head over the number maintained by Scenario DN, with the variation in average number of head run increasing because of brush control. Insufficient cash flow and the low number of years in operation left Scenarios DS and DB with the fewest number of sections treated for mesquite of the treatment scenarios.

The probability of success and survival for Scenario RN (5 percent) was slightly above Scenario DN, but below that of Scenario CN. This scenario maintained the fifth highest average number of cows at 593, but remained in business 14.7 years, the second lowest of all scenarios. Average NPV (-$230,300) was second lowest, and ENW ($14,580) was the lowest of the all scenarios considered. The poor financial showing of Scenario RN was attributed to the initial investment needed to establish the grazing system and the outflow of cash needed for maintenance.

Mesquite control enhanced the survivability and success of the RG strategy, with Scenario RS exhibiting an 81 percent probability of success and survival and Scenario RB a 76 percent probability of each. Average NPV's and ENW's for Scenario RS ($626,370 and $634,640) and Scenario RB ($488,810 and $539,400) were the third and fourth highest, respectively, of all scenarios. Scenarios RS and RB were more subject to increased variation in NPV and ENW than Scenarios CS and CB, because of the high number (790) and extreme variation of herd size, plus the large debt load maintained. Scenario RS also provided the lowest single iteration NPV of any scenario examined (-$516,700). While Scenarios RS and RB first sprayed approximately the same number of sections per year as their counterpart CG strategies, fewer sections were resprayed or burnt, presumably because of the decreased equity position and fewer number of years in operation.

The pre- and post-burn deferment proved to be a detrimental factor in the economic success of the spray-burn scenarios. Because of the smaller herd size operated (i.e., lower deferment bill) under the DG strategy, Scenario DB was more profitable than Scenario DS. As the number of cows operated increased, i.e., under the CG and RG strategies, the economic advantages shifted toward the spray scenarios with the difference in NPV's between the spray and spray-burn alternatives increasing with the number of cows operated.

Evaluation Using Stochastic Dominance

Cumulative probability distributions of ending NPV's for each scenario (Table 5) were compared using stochastic dominance with respect to a function. Absolute risk aversion intervals of -.00001 to 0, 0 to .00001, and -.00001 to .00001 were used to distinguish producers who are risk loving, risk averse, and risk neutral, respectively.

Cumulative probability distributions of ending NPV for all nine scenarios are plotted in Figure 5. The distributions for Scenarios CS and CB clearly dominated (i.e., were always preferred by all risk aversion groups) all other distributions because they were always below and to the right. Scenarios RS and RB always dominated the scenarios associated with no brush treatment and those associated with the DG grazing strategy. The distribution for Scenario DN was dominated by all other scenarios. While NPV distributions for Scenarios DN, DS, DB, CN, and RN followed each other closely up to the 0.5 probability level, a distinct branching was obtained afterwards. After separating, these five scenarios were ordered roughly based on the number of cows they operated, except for Scenario RN, which had the highest fixed grazing system costs. The ordering of all distributions from right to left at the 1.0 probability level, was identical to ordering the scenarios by their average NPV.

The preference ordering of the nine scenarios for each risk aversion group is summarized in Table 6. For a risk loving rancher, the strategies could be ordered by second degree stochastic dominance because a clear preference was indicated by all risk lovers. This ordering was the same as would have occurred from ranking the scenarios by their average NPV's.

The ordering of scenarios was identical for risk neutral and risk loving ranchers. Their most efficient sets were basically the same as the risk loving producer's, except that Scenario CS and Scenario CB were both included in their most efficient set. Both these CG strategies engaged in mesquite control, and while Scenario CS had the higher average NPV, it also had a higher probability of lower returns and thus did not dominate Scenario CB.

Scenarios CN, DS, and DB were also equally preferred under the risk averse and risk neutral ranges given. These scenarios were able to be ordered by the risk loving rancher because of the higher

Table 5. Selected statistics for the Conventional (CG), Deferred (DG), and Rotational (RG) Grazing Systems under the nine scenarios examined.[a]

	Scenario								
	CN	CS	CB	DN	DS	DB	RN	RS	RB
Probability of Survival	24.0	90.0	93.0	0.0	38.0	43.0	5.0	81.0	76.0
Probability of Success	26.0	90.0	92.0	0.0	38.0	43.0	5.0	81.0	76.0
Net Present Value ($1000)									
Mean	-138.66	976.55	909.67	-327.82	-64.14	-21.06	-230.30	626.37	488.81
Std. Dev.	192.86	512.26	461.06	65.14	324.39	382.16	133.77	533.46	522.46
Coef. Var.[b]	-139.09	52.46	50.68	-19.87	-505.73	-1,814.95	-58.09	85.17	106.88
Minimum	-432.53	-387.25	-332.51	-498.58	-432.92	-509.09	-433.70	-516.70	-500.24
Maximum	350.85	1,857.94	1,577.90	-96.56	751.66	983.94	218.69	1,439.33	1,433.94
P.V. of Ending Net Worth ($1000)									
Mean	80.75	876.19	843.36	40.72	159.72	201.46	14.58	634.64	539.40
Std. Dev.	119.25	355.92	325.39	67.42	217.52	253.10	89.53	394.89	383.79
Coef. Var.	147.68	40.62	38.58	165.56	136.19	125.64	614.15	62.22	71.15
Minimum	-114.72	-80.16	-68.42	-141.62	-118.31	-149.95	-145.27	-203.76	-213.75
Maximum	405.80	1,553.68	1,325.93	163.90	731.97	913.65	286.09	1,218.77	1,223.99
Number of Cows									
Mean	477.0	662.0	663.0	420.0	500.0	513.0	593.0	790.0	790.0
Std. Dev.	55.8	111.6	108.3	17.6	74.7	86.8	63.0	156.9	160.4
Coef. Var.	11.7	16.9	16.3	4.2	14.9	16.9	11.4	19.9	20.3
Minimum	354.0	388.0	396.0	369.0	379.0	375.0	393.0	450.0	427.0
Maximum	633.0	1,004.0	983.0	450.0	707.0	734.0	719.0	1,281.0	1,281.0

[a] CN=CG system with no brush control, CS=CG system with spraying, CB=CG system with spray-burn.
DN=DG system with no brush control, DS=DG system with spraying, DB=DG system with spray-burn.
RN=RG system with no brush control, RS=RG system with spraying, RB=RG system with spray-burn.

[b] Coefficient of variation is expressed as a percentage.

probability of receiving a big payoff, regardless of the increased variation.

Summary

Uncertain forage production created by variation in climatic conditions and encroachment of undesirable brush species provide much of the business risk facing range livestock producers. This study focused on the evaluation of range improvement techniques which may decrease economic losses occurring from operating in this complex and uncertain environment. The investment alternatives in question were implementation of grazing systems and control of mesquite infestations.

For the representative ranch, results showed that it was economically prudent to control mesquite infestations. All three grazing systems studied obtained negative average net present values under the no brush control options. The increased productive capacity obtained from mesquite control increased both the NPV and ENW for each grazing strategy, while decreasing the relative variance of both economic measures. Probabilities of success and survival were also increased when mesquite control was undertaken.

Spraying mesquite-infested land returned the highest NPV's for the CG and RG strategies. The deferment seemed to be a detrimental factor for the burn options, especially for the grazing strategies with high stocking rates.

Holding brush control practices constant, it was not profitable to alter cattle production by deviating from the CG strategy. When the representative ranch was changed to a DG grazing strategy, it suffered disastrous financial results and obtained the lowest average NPV of all scenarios. The increased performance per animal unit could not compensate financially for the decrease in total numbers. Combining brush control practices with the DG strategy increased the average NPV and ending net worth above those obtained by Scenario CN, but these

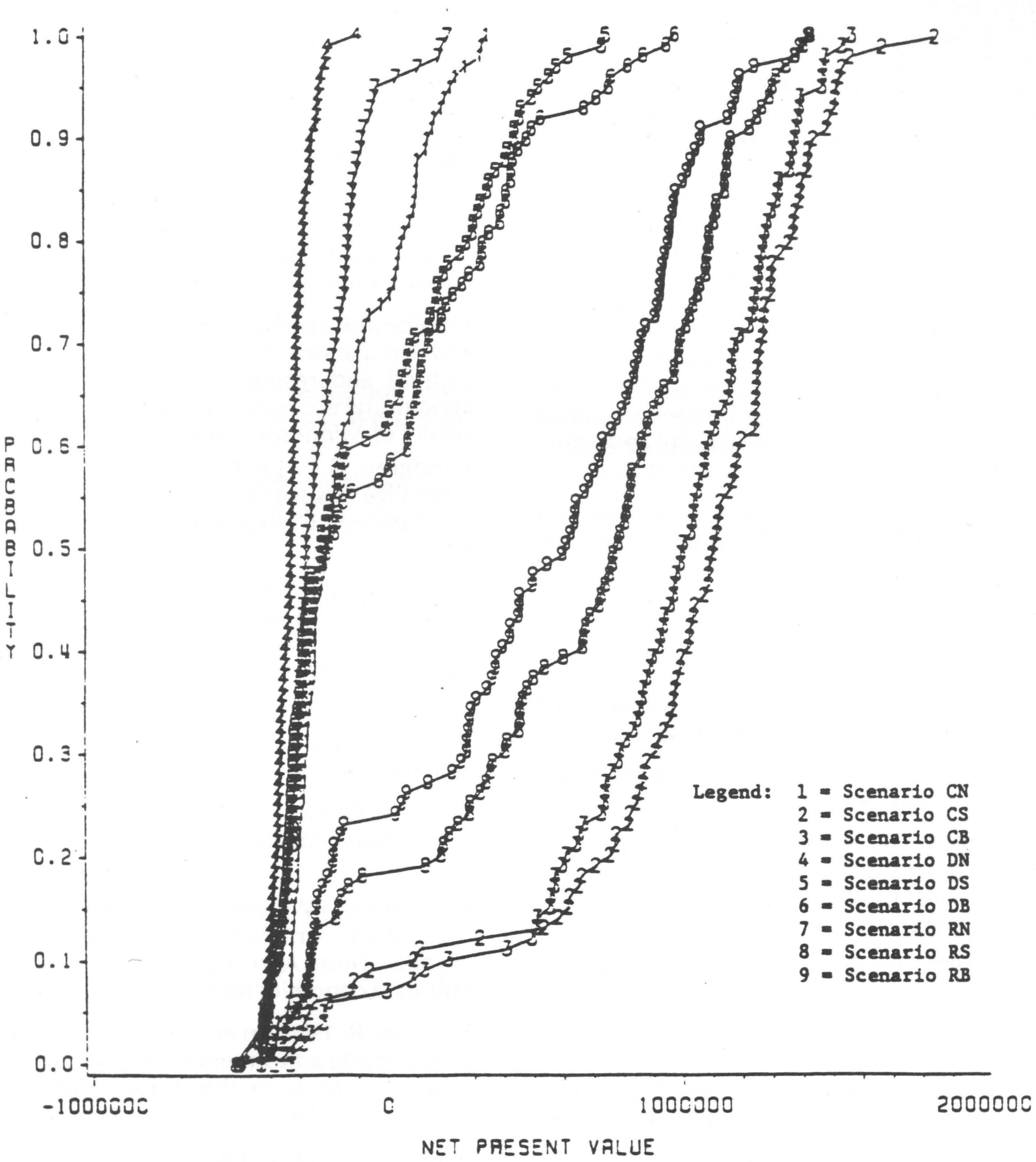

Figure 5. Cumulative probability distributions for net present values for the nine range improvement scenarios.

scenarios were still unable to obtain an average NPV or build on beginning net worth.

Increasing stocking rates by investing in a RG system was more economically viable than divesting in cows for a DG strategy, but was not as profitable as maintaining the CG system under similar brush control techniques. The increased number of cows did not compensate for the increased debt or decreased performance per animal unit. Because of the increased available debt incurred from establishing the RG system, less capital remained available to invest in brush control.

As with most comparative analysis of range improvement methods, results are applicable only to the area

Table 6. Preference ordering by risk aversion intervals for the nine range improvement scenarios examined[a]

Rank	Risk Averse[b]	Risk Neutral	Risk Loving
1st Most Preferred	CS, CB	CS, CB	CS
2nd Most Preferred	RS	RS	CB
3rd Most Preferred	RB	RB	RS
4th Most Preferred	CN, DS, DB	CN, DS, DB	RB
5th Most Preferred	RN	RN	DB
6th Most Preferred	DN	DN	DS
7th Most Preferred			CN
8th Most Preferred			RN
9th Most Preferred			DN

[a] Scenarios are the same as defined in Table 3.

[b] Risk aversion coefficients were: -0.00001 to 0.0 for risk loving, 0.0 to 0.00001 for risk averse, and -0.00001 to 0.00001 for risk neutral.

under study because of the differences in climate, soil, and vegetation. Caution should also be taken when interpolating the results of this study to individual ranch situations. While conditions representative of the Eastern Rolling Plains area were utilized for this study, they individually and collectively are not identical to any of the actual ranches in the area. The assumptions made for obtaining the production responses of the individual grazing systems and mesquite control practices will vary immensely as the designated climate, soil, and vegetation differ. The results are also sensitive to the assumed economic conditions which may occur during the life of these investments. While the results may not be applicable to all situations, the methodology used to quantify the risks inherent in range livestock production should prove helpful and transferable to similar studies.

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Appendix 1

Annual interest rates, inflation rates, and self-employment tax rates for 1987-2006.

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Annual Interest Rates (fractions)										
Long-term Loans	0.131	0.141	0.156	0.172	0.172	0.172	0.172	0.172	0.172	0.172
Intermediate-term Loans	0.127	0.134	0.139	0.154	0.154	0.154	0.154	0.154	0.154	0.154
Received for Cash Reserves	0.087	0.094	0.099	0.114	0.114	0.114	0.114	0.114	0.114	0.114
Annual Fractional Change in Prices (fractions)										
New Farm Machinery	0.033	0.040	0.053	0.065	0.065	0.065	0.065	0.065	0.065	0.065
Used Farm Machinery	-0.040	-0.040	-0.040	-0.040	-0.040	-0.040	-0.040	-0.040	-0.040	-0.040
Fixed Costs, Insurance	0.043	0.049	0.055	0.060	0.060	0.060	0.060	0.060	0.060	0.060
Chemicals	0.112	0.015	0.034	0.069	0.069	0.069	0.069	0.069	0.069	0.069
Fuel & Lube Costs	0.040	0.045	0.055	0.069	0.069	0.069	0.069	0.069	0.069	0.069
Repairs on Machinery	0.043	0.049	0.055	0.060	0.060	0.060	0.060	0.060	0.060	0.060
Other Production Cost	0.043	0.049	0.055	0.060	0.060	0.060	0.060	0.060	0.060	0.060
Labor Costs	0.054	0.069	0.086	0.108	0.108	0.108	0.108	0.108	0.108	0.108
Purchase Livestock Inputs	-0.024	0.016	0.047	0.076	0.076	0.076	0.076	0.076	0.076	0.076
Farmland Values	0.027	0.026	0.030	0.036	0.036	0.036	0.036	0.036	0.036	0.036
Consumer Price Index and Self-Employment Tax Rates										
Consumer Price Index	312.9	328.2	346.3	367.1	389.1	412.5	437.2	463.5	491.3	520.7
Self-Employment Tax Rate	.1302	.1302	.1530	.1530	.1530	.1530	.1530	.1530	.1530	.1530
Maximum Income Subject to Self Employment Tax ($)	43218.0	44016.0	46441.0	49274.0	52231.0	55364.0	58686.0	62208.0	65940.0	69896.0

Appendix 2

To illustrate the method used, assume quarterly precipitation data is to be stochastically generated and then aggregated into various production periods beginning with Quarter 3 in the previous year and going through the first three quarters in the current year (e.g., $Q^L_3 + Q^L_4 + Q_1 + Q_2 + Q_3$, with L signifying precipation lagged 1 year). The 6x6 upper triangular correlation matrix of $Q_1, Q_2, Q_3, Q_4, Q^L_3, Q^L_4$ would normally be factored into a unique upper right triangular matrix via the "square root method" and multiplied by a vector of random normal deviates "d" to obtain the vector of correlated random normal deviates "c" as:

$$(1)\quad \begin{bmatrix} c_{1t} \\ c_{2t} \\ c_{3t} \\ c_{4t} \\ c_{5t} \\ c_{6t} \end{bmatrix} = \begin{bmatrix} r_{11} & r_{12} & r_{13} & r_{14} & r_{15} & r_{16} \\ & r_{22} & r_{23} & r_{24} & r_{25} & r_{26} \\ & & r_{33} & r_{34} & r_{35} & r_{36} \\ & & & r_{44} & r_{45} & r46 \\ & & & & r_{55} & r_{56} \\ & & & & & r_{66} \end{bmatrix} * \begin{bmatrix} d_{1t} \\ d_{2t} \\ d_{3t} \\ d_{4t} \\ d_{5t} \\ d_{6t} \end{bmatrix}$$

where t = the current year.

The correlated random normal deviate used to determine Q_{4t}, with t=1, would be calculated as

$$(2)\quad c_{41} = \sum_{j=1}^{6} r_{4j} * d_{j1}.$$

In year two, Q^L_{42} would be determined by c_{62} as

$$(3)\quad c_{62} = \sum_{j=1}^{6} r_{6j} * d_{j2}.$$

Because $Q^L_{42} = Q_{41}$, it follows that $c_{62} = c_{41}$. Therefore, sustituting c_{41} for c_{62} gives

$$(4)\quad c_{41} = \sum_{j=1}^{6} r_{6j} * d_{j2}$$

$$= r_{66} * d_{62},$$

with

$$(5)\quad d_{62} = c_{41}/r_{66}.$$

Thus the random normal deviate d_{62} needed to assure that c_{62} is defined so that $Q_{41} = Q^L_{42}$ can be determined by using c_{41}.

Using the same logic, $Q_{31} = Q^L_{32}$ implies $c_{31} = c_{52}$. Solving for d_{52} we get:

$$(6)\quad c_{31} = \sum_{j=1}^{6} r_{5j} * d_{j2}.$$

$$= r_{55} * d_{52} + r_{56} * d_{62}$$

with

$$(7)\quad d_{52} = c_{31} - r_{56} * d_{62}/r_{55}.$$

Therefore, instead of all normal deviates being randomly drawn, d_{5t} and d_{6t} are calculated conditional upon the correlated deviates obtained for c_{3t-1} and c_{4t-1} to have $Q^L_{42} = Q_{41}$ and $Q^L_{32} = Q_{31}$. At the beginning of each iteration (year 1), initial values are given to d_{62} and d_{52} to start each iteration at the same point.

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