Journal of Agricultural and Applied Economics, 33,3(December 2001):539–549

The Use of Biophysical and Expected Payoff Probability Simulation Modeling in The Economic Assessment of Brush Management Alternatives

Keith D. Schumann, J. Richard Conner, James W. Richardson, Jerry W. Stuth, Wayne T. Hamilton, and D. Lynn Drawe

ABSTRACT

Woody plant encroachment restricts forage production and capacity to produce grazing livestock. Biophysical plant growth simulation and economic simulation were used to evaluate a prescribed burning range management technique. Modeling systems incorporated management practices and costs, historical climate data, vegetation and soil inventories, livestock production data, and historical regional livestock prices. The process compared baseline non-treatment return estimates to expected change in livestock returns resulting from prescribed burning. Stochastic analyses of production and price variability produced estimates of greater net returns resulting from use of prescribed burning relative to the baseline.

Key Words: *biophysical simulation, prescribed burning, range management, simulation.*

Historically, the primary revenue source from native rangeland has been grazing domestic animals for production of consumer goods. It is generally accepted that invasions of woody plant species on a large percentage of native and improved pastureland are highly correlated to increased grazing intensity of domestic animals over time (Archer 1989, Box 1957). This relationship between grazing animals and plant composition on rangeland poses a problem for areas where continued grazing is desired. For sustainable grazing to provide equitable economic rents, a system of woody plant management must be effectively administered. Most brush management is costly to implement and maintain, and its effectiveness varies widely with changes in weather conditions.

Prescribed burning involves burning a specified area of land under desired weather conditions to maintain a controlled grass and

Schumann is extension associate in the Department of Agriculture Economics at Texas A&M University; Conner is professor in the Department of Agriculture Economics and Thomas M. O'Connor Professor in the Department of Rangeland Ecology and Management at Texas A&M University; Richardson is professor and TAES Faculty Fellow in the Department of Agricultural Economics at Texas A&M University; Stuth is professor and Grazingland Management Specialist in the Department of Rangeland Ecology and Management at Texas A&M University; Hamilton is director of the Center for Grazinglands and Ranch Management and senior lecturer in the Department of Rangeland Ecology and Management at Texas A&M University; and Drawe is director of the Rob and Bessie Welder Wildlife Foundation

This research was funded by the Rob and Bessie Welder Wildlife Foundation. The primary research was conducted on the Rob and Bessie Welder Wildlife Refuge with the gracious help and assistance of the directors, staff, and students.

brush fire. The goal is to use the available fine fuel loads, primarily plant litter and standing dead or arid plant material, to sustain a manageable fire to retard or remove woody plant growth (Scifres and Hamilton 1993). In addition to managing the amount of brush in a given area, a burn can increase the production of preferable post-burn species by stimulating sprouting of woody species and tillering of grasses (Scifres and Hamilton 1993). Timing of burning may drastically affect forb production (Hansmire 1983).

Relative to other brush management methods, such as mechanical or chemical, costs associated with a prescribed burn are generally low. Primary expenditures involved include land preparation and labor and resources necessary to contain a burn once it is initiated (Van Tassell and Conner 1986; Van Tassell, Conner and Richardson 1989). A major cost not always quantifiable is grazing deferment time required for building fuel loads for a successful burn. In areas of highly variable weather, this deferment period may take several years (Scifres and Hamilton 1993).

Several methods have been employed for dealing with estimating impacts of climatic variation on effectiveness and efficiency of brush management practices in this region (Van Tassell and Conner 1986; Van Tassell, Conner and Richardson 1989; Garoian, Conner and Scifres 1987). Stochastic simulation techniques have been used to attempt to forecast ranch management impacts and production given specified exogenous and endogenous expectations (De Souza Neto 1996). Probability distributions involving output potential and possible prices received have given producers a better idea of decisions to make regarding longevity of the operation (Richardson and Nixon 1981; Hardaker, Huirne, and Anderson 1997).

The purpose of this study was to evaluate net economic benefit of using prescribed burning as a range management tool in South Texas. The evaluation was conducted by assessing economic feasibility of prescribed burning on specified pastures of the ranch. A hydrological based range forage growth simulation model, PHYGROW (Stuth 1995), was used to simulate forage production using historical precipitation and temperature scenarios for each year in a planning period. Simulated annual forage production was then incorporated into a Monte Carlo simulation model that produced estimates of costs and benefits to compare expected net returns from the baseline management system (no prescribed burning) with those obtained when prescribed burning was used.

Materials and Methods

Information used in this study comes from a ranch in South Texas owned by the Welder Wildlife Foundation. The ranch lies in a transitional zone between the Gulf Prairies and Marshes and South Texas Plains land resource areas (Box 1978). The land has historically been grazed. Early settlement and the cessation of prairie fires along with cattle grazing allowed native woody plants such as honey mesquite (*Prosopis glandulosa*) to invade the area (Archer 1989; Box 1957). Drought and extreme weather may also have helped perpetuate woody plant invasions (Box 1957 and 1959 and Box, Drawe, and Mann 1979).

The Welder Foundation experienced a brush management problem over the latter portion of the 20th century. Increasing woody plant density has reduced the potential for cattle production (Box 1959 and 1964). Prescribed burning has been used to manage brush in selected pastures. Frequent droughts and hurricanes from the Gulf of Mexico create significant weather variability and hinder burning effectiveness (Drawe 1988 and 1991).

Forage production, range condition score, and animal grazing responses can be estimated for specified management units on the Welder Foundation Ranch using annual herbaceous plant survey data, quinquennial brush survey data, historic grazing intensities (Drawe 1988 and 1991), plant production data, and historical weather data. Given parameters for those variables, the animal unit carrying capacity can be determined for a specified management objective over time (Scifres *et al.* 1985).

Historical trends show highly variable climate conditions in the study region, making it difficult to use expected values in management forecasting. Prescribed burns could not be predetermined at the beginning of the planning horizon, nor could an optimum response be expected from each burn. The risk derived from weather variability impaired a decision based on predefined deterministic criteria and compound analytical effectiveness in decision making.

Biophysical Simulation

Biophysical plant growth simulation was used to conduct comparative analyses. The PHYGROW model (Stuth 1995) is a hydrologic based, range plant growth simulation model. Simulation files were configured based on historical rainfall and temperature data, soil types, relative plant composition by species, plant productivity, species preferences by grazing animals, and grazing intensity of the Welder Foundation.

Two pasture units of the Welder Foundation Ranch were used in the PHYGROW simulations. The Mesquite-Clay Pasture represented a light brush mesquite community on a Victoria Clay soil. The Tule-Sand Pasture represented a sparse brush bunchgrass community on an Odem Fine Sandy Loam soil. These were chosen based on brush canopy cover and categorical representations of potential brush management alternatives.

PHYGROW allowed stocking rate changes based on management decision days, available forage, and animal forage preferences. Based on preference values for plant species present, initial cattle stocking rates were determined from the GLA nutrition balance analyzer (Ranching Systems Group 1994). Cattle stocking rates for modeling were based on historical ecologically safe stocking intensities used on the Welder Foundation Ranch (Drawe 1988 and 1991). Maximum forage available to grazers was also based on historical production values for grasses and forbs across pastures (Drawe 1988 and 1991) and individual species' grazing preference values.

Baseline scenarios (no prescribed burning) were compared to field data for 1997 to calibrate individual plant species parameters within each plant community. Once baseline scenarios were simulated, the plant community and productivity expected by management using prescribed burning were used to simulate production based on an alternative prescribed burn response. Management-elicited responses were necessary since no actual post-prescribed burning data were available. A one-year post treatment and an end horizon without a prescribed burn treatment scenario were simulated. All three scenarios for each pasture were simulated using the same historical weather and soils data. Differences in scenarios were in the yield values, standing crop values and stocking rate rules used. Stocking rate decisions were modified to allow for varying ranges of potential stocking rates given an essentially different plant community.

Monte Carlo Simulation

In an attempt to incorporate weather variability and potential dynamics into a brush management plan, an expected payoff simulation model was developed. This model used ranch data and results of biophysical simulations to ascertain probabilities of potential payoffs for implementing a prescribed burning brush management system. Variable plant production in both a baseline and alternative planning horizon results in variable annual animal stocking rates and calving crops. Because net change in these components between scenarios is the primary factor in determining economic feasibility, environmental risk becomes a significant force in the effectiveness of investment evaluation. Intuitively, abdicating this risk in a planning horizon leads to overestimating benefits resulting from brush management systems.

Several components of the PHYGROW simulation output were prerequisites for crafting a stochastic economic feasibility model. The model was derived from trends, values, and correlations produced from PHYGROW data. For multiple scenarios of 24-year simulations, total standing plant biomass, standing dead leaf, standing wood biomass, grazable standing crop, and cattle stocking rates generated by PHYGROW were used for further computation. Statistics from these data were used to formulate a simulation model to be used in forecasting potential payoffs based on changes in animal unit carrying capacity.

For the baseline simulation scenario, PHYGROW simulation data were used for values in a payoff simulation equation. For each management unit, data sets from the three PHYGROW simulation scenarios were used to represent different stages in plant communities. These scenarios were used to develop an estimation of variable production over a planning horizon. Since animal carrying capacities are not predetermined before simulation, carrying capacities were necessarily based on plant production values simulated periodically. The basic method for simulating plant production components is outlined in the following simulation formula:

$$(1) \quad \tilde{x}_Q = \hat{x}_{Q-1} \times (GF_Q + \widetilde{SDF}_Q)$$

where

$$(2) \quad GF_Q = \left[1 + \left(\frac{\bar{x}_{Q_{PC_2}} - \bar{x}_{Q_{PC_1}}}{\bar{x}_{Q_{PC_1}}}\right)\right]^{1/(4t)} \quad \text{and}$$

$$(3) \quad \widetilde{SDF}_Q = \left(\frac{\bar{x}_Q - \bar{x}_{Q-1}}{\bar{x}_{Q-1}}\right)\Bigg|\tilde{R}$$

In previous equations, x is the weight (lbs./ac) of total standing biomass, dead leaf, wood biomass, or grazable standing crop. The variable Q is a seasonal quarter, i.e. December to February, March to May, etc. The stochastic value of x in the current quarter is $\tilde{x}_Q$. The value of x in the prior quarter is $\hat{x}_{Q-1}$. The growth factor in quarter Q is GF_Q. The variable $\bar{x}_{Q_{PC_1}}$ is the average quarterly value of x in a baseline plant community (PC_1). The variable $\bar{x}_{Q_{PC_2}}$ is the average quarterly value of x in an anticipated plant community (PC_2). Expected number of years to reach $\bar{x}_{Q_{PC_2}}$ from $\bar{x}_{Q_{PC_1}}$ is t. The seasonal growth factor in quarter Q, $\widetilde{SDF}_Q$, is subject to $\tilde{R}$, a random number between 1 and 100. The historical quarterly monthly average value of x is $\bar{x}_Q$. The historical quarterly monthly average of x prior to $\bar{x}_Q$ is $\bar{x}_{Q-1}$.

Simulation equation 1 employs both an expected growth factor and a seasonal deviation factor to estimate future values for stochastic values. The growth factor term represents the expected quarter-to-quarter growth from the baseline value to the anticipated future value. The expected number of years to actualize this change is multiplied by four to arrive at quarterly changes. For this analysis, it was estimated that a 15-year period was necessary to achieve the full change.

The seasonal deviation factor is used to simulate cyclical and environmental fluctuations in plant production. This process used historical monthly average simulation values constructed by PHYGROW. Percent change from quarter to quarter was calculated monthly from 1974 to 1997. This produced deviations showing positive or negative growth between approximate 91-day quarters. These deviations reflected change in plant production as a result of historical weather trends over several years and seasons.

A bootstrap method is used to sample from the deviates of the biophysical simulation results. The effect gave simulated production years the same quarter-to-quarter deviations as was experienced in the previous twenty-four, but simulation periods were sampled from those years at different starting intervals. All simulated production values were sampled using the same bootstrap selection method. Despite individual deviations being different for each value, historical correlation between values was forced to remain intact. The random values moved in tandem, replicating historical trends.

The combination of growth factor and cyclical deviation factor, or total quarterly deviation, produces a multiplier that adjusted quarterly production values according to expected growth, cyclical patterns in weather, and uncertainty associated with extreme weather events, such as annual droughts. For the baseline scenario of the simulation, baseline PHYGROW data were used as the initial plant community (PC_1), and the end horizon resulting from no-prescribed-burning scenario was used as an anticipated plant community (PC_2). Seasonal deviation was taken from the baseline for the initial ten years, and then afterwards it was assumed that the simulated community experienced deviation attributed to the anticipated community.

This simulation formula was useful in representing a plant community where range management does not influence production significantly, but management systems designed to restrict or reduce brush encroachment can drastically change composition and production. Prescribed burning can change average quarterly production values, the growth factor and vegetative response to cyclical and significant weather fluctuations. In addition, prescribed burning can vary in effectiveness and application time depending on specific weather conditions.

To remedy this situation and more suitably simulate an alternative plant community including brush management planning, a decision factor was added to allow the alternative simulation model to decide when to apply prescribed burning brush treatments. Typically, 2500 to 3000 pounds per acre of dead leaf and litter fuel are necessary to carry a prescribed burn (Scifres et. al. 1985). More fuel may be necessary to effectively retard brush growth in heavy brush areas.

As a condition in the alternative simulation model, minimum fuel load required for a prescribed burn was specified according to plant community and management preferences. The model compared the dead leaf amount in the fall quarter to the minimum required load. If the amount exceeded the minimum, a prescribed burn was conducted in winter. This aspect makes the model an endogenous control process because it replicates expected periodic decisions made by management.

Another stipulation within the alternative simulation model was that brush treatments could not occur in consecutive years. Managing a pasture to reduce brush in successive years would impose excessive grazing deferment and produce treatment costs with little direct benefit. The model required at least a one-year lag between brush treatments.

Once the model decided when a treatment was to be applied, post-treatment production changed accordingly. If a prescribed burn was conducted in winter, then treatment response was assumed to fully show up the following spring. Once a treatment was discerned, the model substituted the response quarter with the following equation:

$$(4) \qquad \tilde{x}_Q = \bar{x}_{Q_{PC_1}} \times (GF_Q + \widetilde{SDF}_Q)$$

In this alternative formulation, $\bar{x}_{Q_{PC_1}}$ is the average for the simulated post treatment production value. This term replaces the lagged quarterly value used in the baseline. The average also denotes that plant communities were redefined for the total quarterly deviation term. In the simulation the initial plant community (PC_1) became the post-treatment scenario, and the baseline scenario became the anticipated value (PC_2). This reassignment of values denoted that a plant community with different compositions and values was produced from the treatment. The baseline value was then viewed as the expected plant community after a number of years without treatment.

In this simulation model, specifications allowed for a varying number of prescribed burns to occur over the planning horizon given a sample production variation. Zero to eight treatments could occur in the 15-year planning horizon. If a given sample produced no treatments over the planning horizon, the resulting production would equal baseline production. The baseline and alternative models were simulated simultaneously. The purpose of this was to use the same climate induced randomization to sample production variation for all scenarios. Despite the difference in relative production values of the scenarios, variations must be highly correlated to replicate similar weather patterns.

The primary variable that was dependent on changes in production was yearly stocking rates. In a multiple pasture system, part or all of a herd can be rotated between pastures to adjust for within-year stocking rate changes caused by plant production changes. This is also useful when deferment is necessary to build fine fuel loads for prescribed burning treatments. Cattle do not need to be sold to defer a pasture, but deferment costs are still incurred because the sum total of grazing capacity cannot be utilized during deferment periods (Scifres and Hamilton 1993). This is an example of opportunity costs associated with brush management.

The model used historical stocking rate trends produced by PHYGROW to determine stocking rates for a given planning quarter. The range of historical stocking rates bounded potential stocking rates for the planning horizon. The model compared simulated production of total forage available in a quarter to a historical value for total forage produced by PHYGROW. The closest value was matched and then the associated stocking rate was selected. This method was used in both baseline and alternative scenarios. Stocking rate selections came from the most comparable historical simulation scenario. This is another aspect of endogenous control for a management decision within the model.

It was assumed for this analysis that ranch management only makes net stocking decisions once a year, and the decision was based on the average of stocking rate values for the previous four quarters. If current year's production prescribed that stocking rates must be changed, then cattle were sold or bought relative to number stocked the previous year. Calves produced in a given year were based on the average number of cattle stocked multiplied by calving percentage. All calves were assumed to be the specified weaning weight at the time they were sold.

Cattle prices were randomized by the same method used to simulate production. USDA historical selling prices for heifers and steers in Texas were gathered (USDA, National Agricultural Statistics Service 1998). Since this ranch typically sells cattle in August, September, or October, these three average monthly selling prices were selected from 1975 to 1997. Values were converted to 1998 dollars using the Consumer Price Index. Real dollar values for each month across years were averaged, and annual deviation from average was calculated for each month. This produced values that corresponded to the historical simulated production values for the ranch. The array of values was sampled using the same bootstrap technique.

In addition to prices received, variable costs per animal unit were also randomized. Budgeting values indicated that variable costs per head were composed of replacement costs, supplemental feed, veterinarian and medical costs, and marketing costs. Price indexes for these values for 1990 to 1997 were used to correlate costs to the selling price (USDA, National Agricultural Statistics Service 1998). Historical correlation coefficients were used to produce correlated random numbers for each component given the original price distribution. For each value, an array of pseudo random numbers, ranging from zero to one, was used to correlate component values to the original price distribution. All cost components used the base price distribution for sampling, and correlation and pseudo random number adjustments produced individual variations for each component.

The price randomization method was applied to calf selling price, variable costs per animal unit, and stocker cow buying and selling prices. The model applied annual deviations from mean to values given in the input specifications. After 100 iterations, the simulation model reproduced average values with no statistically significant difference. Instead of expected mean cattle prices across all years, the model produced variations about the mean that might be expected given sample values for production.

Net present value of each scenario was calculated using partial budgeting to estimate annual net cash income for a sample. The net difference in annual average stocking rate was sold or bought in each year. All calves produced within a year were also sold. Prescribed burning costs were applied in the years they occurred, and cattle variable costs were incurred on an animal unit basis. Streams of annual net cash income were discounted using a fixed discount rate, and salvage value was the market value of net gain in final cows stocked above initial stocking rate. Probabilistic net present values of baseline and alternative scenarios were calculated separately. Net difference between averages of the two simulation scenarios represented expected value of using brush management systems.

Table 1. Mesquite-Clay Pasture Stochastic Simulation Results for the Mean, Standard Deviation, and Coefficient of Variation for Relevant Values Under the Given Specifications

Production Variable		Baseline	Alternative	Descision Variable		Baseline	Alternative
Total Standing	Mean	9,717	7,323	Grazable	Mean	2,196	2,700
Biomass	S.D.	1,706	1,146	Standing Crop	S.D.	755	978
(lbs./ac)	C.V.	18	16	(lbs./ac)	C.V.	34	36
Standing Wood	Mean	6,579	4,180		Mean	0.11	0.14
Biomass	S.D.	1,398	1,674	Stocking Rate	S.D.	0.02	0.02
(lbs./ac)	C.V.	21	40	(au/ac)	C.V.	18	16
	Mean	1,865	2,176		Mean	$250.54	$271.41
Total Dead	S.D.	602	737	Net Present	S.D.	36.33	39.22
Leaf (lbs./ac)	C.V.	32	34	Value/Acre	C.V.	15	14

Cost Factors	Calf Price ($/lb.)	Variable Costs ($/au)	Stocker Cow Price ($/au)	Analysis of Brush Management System	Number of Treatments	Net Present Value/Acre
Mean	$0.81	$123.80	$624.28	Mean	3.93	$20.87
S.D.	0.17	1.01	132.60	S.D.	2.61	17.26
C.V.	21	1	21	C.V.	66	83

Specifications			
Initial Cattle Stocking Rate (au/ac)	0.11	Discount rate for calculating NPV	0.08
Average Calving Percentage	0.88	Prescribed Burning Costs ($/ac)	$4.00
Average Calf Selling Weight (lbs./head)	493	Expected Calf Selling Price ($/lb.)	$0.81
		Expected Variable Costs ($/au)	$123.37
Minimum Fuel Load for Burning (lbs./ac)	2,650	Stocker Cow Buying/Selling Price ($/head)	$625.00

Results

To compare suitability of simulation results, a rationalistic decision and inventory process was used as a basis. The expectation would be that an analysis deficient in assessing environmental and exogenous risks would yield more favorable yet unreliable results. The purpose of stochastic simulations was an attempt to relax some of the normality assumptions typically made in this type of decision analysis.

Table 1 summarizes the simulation output for the Mesquite-Clay Pasture management unit. Results show that, on average, utilizing prescribed burning generates a higher mean net present value ($271.42/ acre) than using no brush management ($250.54/ acre) over the planning horizon. Mean woody plant biomass is reduced and grazable standing crop is increased. The result is a general increase in stocking rates over the planning horizon that produces higher revenues. Costs of the prescribed burns do not outweigh the benefit of increasing grazing capacity.

Figures 1 and 2 show cumulative probability functions for net present values of baseline non-treatment and alternative prescribed burning treatment. Y-axis values are probabilities of occurrence of x-axis values. A value associated with .70 means there is a 70-percent chance of actualizing that value or less. Conversely, there would be a 30-percent chance of experiencing that value or higher. Figure 1 shows that prescribed burning is always preferred over no brush management with the given expectations. At any given probability, using prescribed burning will always produce a higher net present value with the given expectations.

Simulation results for the Tule-Sand Pasture are summarized in Table 2. This pasture was not heavily infested with invasive woody

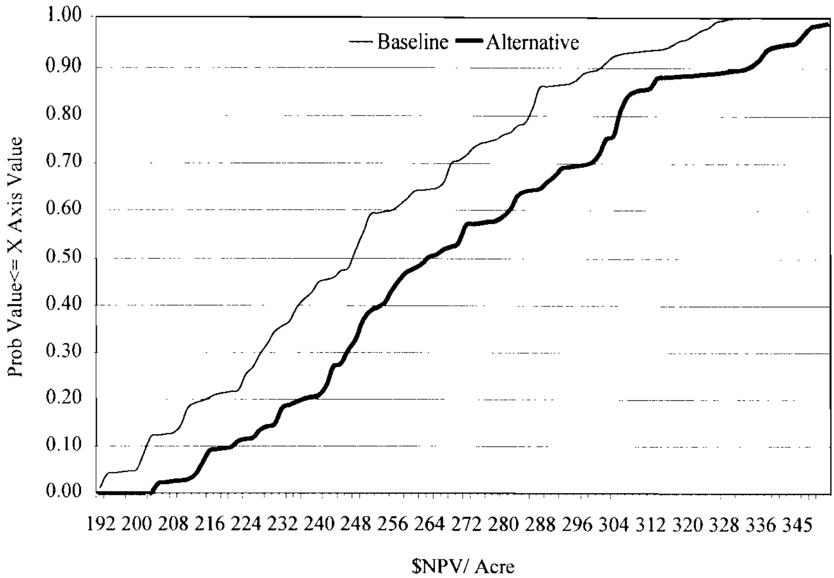

Figure 1. Mesquite-Clay Pasture NPV cumulative probability density functions

species. Prescribed burning retards further expansion of brush and can increase forage quality in the burn area (Scifres and Hamilton 1993). Simulation results show that with prescribed burning grazable standing crop increases on average, and cattle stocking rate increases 14 percent on average. Variability of the stocking rate expands as the coefficient of variation increases from 18 percent to 26 percent. Net present value increases approximately 5 percent on average, and relative variability also rises about 1 percentage point.

The cumulative probability functions in Figure 2 show that using prescribed burning is not clearly preferred over the nonuse of brush management for this pasture. Despite the fact that use of prescribed burning is not preferred at all levels, use of prescribed burn-

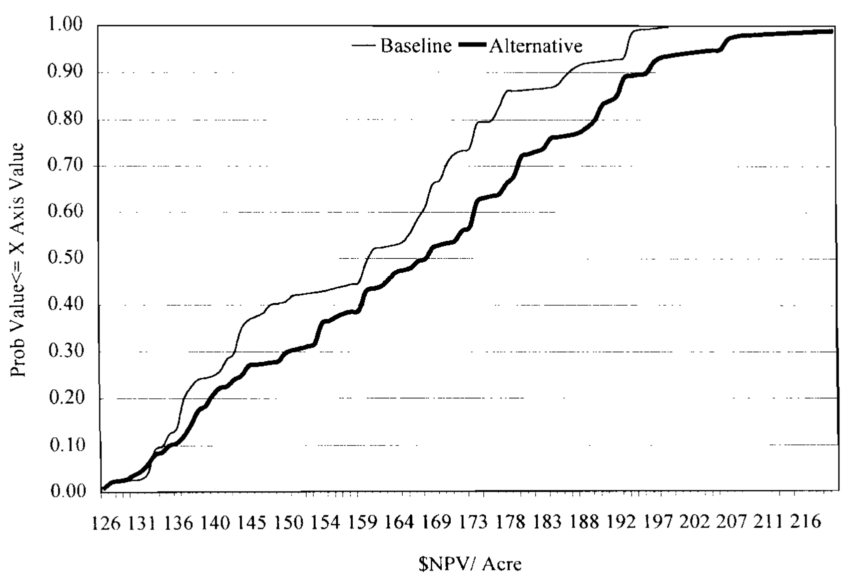

Figure 2. Tule-Sand Pasture NPV cumulative probability density functions

Table 2. Tule-Sand Pasture Stochastic Simulation Results for the Mean, Standard Deviation and Coefficient of Variation for Relevant Values Under the Given Specifications

Production Variable		Baseline	Alternative	Descision Variable		Baseline	Alternative
Total Standing	Mean	4,066	3,884	Grazable	Mean	1,184	1,382
Biomass	S.D.	1,887	1,301	Standing Crop	S.D.	1,144	857
(lbs./ac)	C.V.	46	34	(lbs./ac)	C.V.	97	62
Standing Wood	Mean	615	281		Mean	0.07	0.08
Biomass	S.D.	328	221	Stocking Rate	S.D.	0.01	0.02
(lbs./ac)	C.V.	53	79	(au/ac)	C.V.	18	26
	Mean	2,311	2,603		Mean	$158.99	$166.35
Total Dead	S.D.	1,080	941	Net Present	S.D.	19.91	23.56
Leaf (lbs./ac)	C.V.	47	36	Value/Acre	C.V.	13	14

Cost Factors	Calf Price ($/lb.)	Variable Costs ($/au)	Stocker Cow Price ($/au)	Analysis of Brush Management System	Number of Treatments	Net Present Value/Acre
Mean	$0.81	$123.80	$624.28	Mean	3.93	$7.36
S.D.	0.17	1.01	132.60	S.D.	2.56	8.27
C.V.	21	1	21	C.V.	65	112

Specifications			
Initial Cattle Stocking Rate (au/ac)	0.08	Discount rate for calculating NPV	0.08
Average Calving Percentage	0.88	Prescribed Burning Costs ($/ac)	$4.00
Average Calf Selling Weight (lbs./head)	493	Expected Calf Selling Price ($/lb.)	$0.81
		Expected Variable Costs ($/au)	$123.37
Minimum Fuel Load for Burning (lbs./ac)	2950	Stocker Cow Buying/Selling Price ($/head)	$625.00

ing is still preferred based on an analysis of stochastic dominance with respect to a function. Based on a feasible range of risk-aversion levels, use of prescribed burning exhibits third-degree stochastic dominance over no management (Hardaker, Huirne, and Anderson 1997). This means that prescribed burning is still a more preferable alternative to no brush management for risk-averse decision makers.

Summary

The Welder Wildlife Foundation Ranch was used as a case study in utilizing stochastic simulations to examine the impacts of risk in a brush management investment analysis. Information from selected management units was used to develop technically and economically feasible brush management alternatives. Simulation results on two management units indicate that prescribed burning is a viable investment option in general. Costs associated with prescribed burning were not varied because of the level of control the ranch has over its own costs. Cattle prices were simulated using the historical distribution of real prices received for steers and heifers. Prices were sampled in the same way as production, so simulated prices corresponded to historical levels of production. The purpose of this was an attempt to recreate the historical correlation of prices and production. Based on simulation results, implementation of prescribed burning on these units was still more favorable than using no brush management treatments across the range of possible outcomes.

The hypothesis given in this project was that prescribed burning is a cost-effective method for managing woody plant species on specific grazed pastures in South Texas. Based on biophysical and cost simulations, costs and use of prescribed burning resulted in increases in ecologically safe stocking rates and associated net income. Benefits of using prescribed burning usually offset treatment costs in these study areas. The purpose of the analysis was to aid decision-makers in implementing management based on reasonable expectations.

The analysis reinforced the hypothesis that prescribed burning is generally a cost-effective method for managing brush. Methodology of incorporating biophysical simulation into Monte Carlo simulation for the purpose of a brush management analysis was effective for the Welder Wildlife Ranch.

The methodology can be applied to brush management feasibility studies on several types of rangeland where revenue is positively or negatively related to prevalence of woody plant species. Necessary data for the PHYGROW modeling process would include soil and plant characteristics and historical weather data. For grazing animal production, historical grazing animal stocking rates would be necessary. Baseline and alternative simulations should be conducted in the PHYGROW modeling process. Alternatives should include the impact brush management and the resulting revenue source (e.g. increased stocking rates) have on plant and soil characteristics. Simulation data from the PHYGROW simulation can then be used in formulas for the Monte Carlo simulation to determine probability-based payoffs of potential brush management methods.

Methodology used in this analysis can be improved if primary data are richer and historical data are more readily available and applicable. The PHYGROW model uses several biophysical sub-models and thus has a great deal of information that can be incorporated into the Monte Carlo process to improve the feasibility study. Formulas in the Monte Carlo simulation can be adjusted for shorter periods, expectations in the planning horizon, and number of endogenous and exogenous decision variables. This methodology can also be used as a feedback mechanism when a brush management system is implemented. Data gathered from the brush management system can be fed back into the PHYGROW model and Monte Carlo simulation to verify cost-effectiveness of the system and reduce uncertainty in the process by fine-tuning periodic decisions involved in the investment process.

References

Archer, Steve. "Have South Texas Savannas Been Converted to Woodlands in Recent History?" *The American Naturalist* 134, No. 4 (October 1989): 545–561.

Box, Thadis W. "Changes in Wildlife Habitat Composition Following Brush Control Practices in South Texas." Reprinted from *Transactions of the 29th North American Wildlife and Natural Resource Conference, March 9–11, 1964.* Wildlife Management Institute, Washington D.C., 1964.

Box, Thadis W. *Plant Communities of the Welder Wildlife Refuge.* Contribution No. 5, Series B, Revised. Welder Wildlife Foundation, Sinton, TX, 1978.

Box, Thadis W. *Relationships Between Soils and Vegetation on Four Range Plant Communities on the Welder Wildlife Refuge in South Texas.* Ph.D. Dissertation, Texas A&M University, 1959.

Box, Thadis W. *Vegetational Analysis and the Determination of Range Condition Classes on Selected Areas of the Welder Wildlife Refuge.* M.S. Thesis, Texas A&M University, 1957.

Box, Thadis W., D. Lynn Drawe, and David K. Mann. "Vegetation Change in South Texas—The Welder Wildlife Refuge Case." *Proceedings of the First Welder Wildlife Foundation Symposium.* Welder Wildlife Foundation Contribution B-7, 1979: 5–14.

De Souza Neto, Jose. *Integrating ecological and economic models for assessing institutional, environmental and technological change on rangeland.* Ph.D. Dissertation, Texas A&M University, 1996.

Drawe, D. Lynn. *Effects of Three Grazing Treatments on Vegetation, Cattle Production, and Wildlife on the Welder Wildlife Foundation Refuge, 1974–1982.* Welder Wildlife Foundation Contribution B-8, 1988.

Drawe, D. Lynn. *Influence of Grazing on Vegetation and Cattle on the Welder Wildlife Foundation Refuge, 1983–1987.* Welder Wildlife Foundation Contribution B-11, 1991.

Garoian, L., J.R. Conner, and C.J. Scifres. "A Discrete Stochastic Programming Model to Estimate Optimal Burning Schedules on Rangeland." *Southern Journal of Agricultural Economics* 19(2) (December 1987): 53–60.

Hansmire, Julie A. *Effects of Fire on Forbs and Grasses in the Texas Coastal Prairies.* M.S. Thesis, Texas Technical University, 1983.

Hardaker, J.B., R.B.M. Huirne and J.R. Anderson. *Coping with Risk in Agriculture.* CAB International, New York, 1997.

Ranching Systems Group. *Grazing Land Applications Information Technology for Improved Resource Management User's Guide.* Texas Agricultural Experiment Station, Texas A&M University, 1994.

Richardson, James W. and C.J. Nixon. *The Farm Level Income and Policy Simulation Model: FLIPSIM.* Texas Agricultural Experiment Station, Department of Agricultural Economics Technical Report No. 81–2, 1981.

Scifres, C.J. and W.T. Hamilton. *Prescribed Burning for Brushland Management—The South Texas Example.* Texas A&M University Press, College Station, TX, 1993.

Scifres, C.J., W. T. Hamilton, J.R. Conner, J. M. Inglis, G. A. Rasmussen, R. P. Smith, J.W. Stuth, and T. G. Welch. *Integrated Brush Management Systems for South Texas: Development and Implementation.* Texas Agricultural Experiment Station B-1493, 1985.

Stuth, Jerry W., Wayne Hamilton, and J. Richard Conner. *PHYGROW (Phytomas Growth Simulator) Version 2.0 Model Documentation.* Ranching Systems Group, Department of Rangeland Ecology & Management, Texas A&M University, 1995.

USDA, National Agricultural Statistics Service. *USDA Agricultural Prices, 1997 Summary.* USDA NASS ERS Pr 1–3 (98), Washington D.C., July 1998.

Van Tassell, L.W. and J.R. Conner. An Economic Analysis of Brush Control Practices and Grazing Systems in the Rolling Plains of Texas. Texas Agricultural Experiment Station MP-1619, 1986.

Van Tassell, L.W., J. Richard Conner, and James W. Richardson. *The Impacts of Range Improvement on the Economic Success and Survivability of Ranches in the Eastern Rolling Plains of Texas.* Texas Agricultural Exp. Sta. B-1618, 1989.