

An economic assessment of risk and returns from prescribed burning on tallgrass prairie

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Abstract

A stochastic (Monte Carlo) simulation model was developed to evaluate the influence of prescribed burning on the expected value and variability of net returns from a representative stocker cattle enterprise. The model was applied to both shallow prairie and eroded prairie range sites in eastern Oklahoma. Prescribed burning is shown to be an economically feasible means of improving the productivity of eastern redcedar infested rangeland. Implementation of an annual burning program resulted in a \$69.00 and \$4.80 per hectare increase in the net present value of the 10-year return stream generated from stocker cattle production on shallow prairie and eroded prairie range sites, respectively. Prescribed burning does not increase the variability of annual income from stocker cattle production. However, when risk is measured in terms of relative variability (coefficient of variation) or the probability of annual returns below zero, prescribed burning is determined to be a risk-reducing practice.

Key Words: plant control, eastern redcedar *Juniperus virginiana*, range improvements, stochastic simulation model, profitability, risk, variability of returns

Maintenance and improvement of the productivity of Oklahoma's rangeland is critical to the long-run profitability of the state's beef cattle industry. Considerable concern has been expressed by decision makers and agriculturalists as to the declining condition and productivity of Oklahoma's range resource. Recent estimates indicate that forage production has been reduced below 50% of potential on 70% of Oklahoma's rangeland. Also, forage production on over 4 million of Oklahoma's 6.3 million hectares (65%) of rangeland could be increased by some form of brush control (Soil Conservation Service 1982).

Much of the decline in the condition of Oklahoma's rangeland may be attributed to the reduced profitability of cattle enterprises and its depressing effect on incentives to invest in range improvements. Implementation of most brush control practices requires substantial initial investment followed by increased annual benefits experienced several years into the future. Many producers'

financial position precludes them from incurring the negative influence of these investments on initial annual cash flows. Range improvement practices are needed that require low initial investment and provide immediate benefit in the form of improved animal performance or production.

Prescribed burning has been advocated as a profitable range improvement practice under the economic environment currently faced by livestock producers. The most appealing feature of late-spring burning is that it provides immediate benefits in the form of increased stocker cattle weight gains (Anderson et al. 1970, Owensby and Smith 1979). These short-term benefits result from improvements in the quality of forage available to grazing cattle (Allen et al. 1976). Data from Kansas (Anderson et al. 1970, Owensby and Smith 1979, and Woolfolk et al. 1975) and Oklahoma (McCollum 1987) indicate that summer gains of yearling cattle on tallgrass prairie increase 10 to 20% in response to prescribed burning. Burning also provides long-term range improvement by advancing grassland succession and favoring desirable grasses (Anderson et al. 1970, McMurphy and Anderson 1965, and Towne and Owensby 1984) and controlling undesirable weed and brush species, especially eastern redcedar (Anderson et al. 1970, Stritzke et al. 1975, and Stritzke and Rollins 1984). Thus, prescribed burning offers the producer an opportunity to meet the long-term goals of income stability, increased net worth, and improved range condition without incurring significant negative cash flows in the initial portion of the planning horizon. Of course, prescribed burning is not without its disadvantages. Reductions in soil moisture as a result of burning can decrease forage yield in dry years (Anderson et al. 1970). In addition, improper timing of prescribed burns and poor grazing practices on burned rangeland can have considerable detrimental effects (Towne and Owensby 1984, Anderson et al. 1970).

Economic analysis of range improvement investments has traditionally been conducted through application of net present value (NPV) criteria in a partial budgeting framework. Annual cash flows (income less costs) are estimated over the investment's life, discounted by an appropriate discount rate, then summed to determine the NPV of the investment. The NPV estimates may then be used to estimate the profitability of an investment or rank alternative investments. Previous applications of this approach

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Manuscript accepted 29 October 1987.

include Whitson and Scifres 1981, McBryde et al. 1984, Garoian et al. 1984, and Scifres 1985. Cotner (1963) and Jameson (1971) employed a variation of this discounting approach to determine optimum timing of range improvement controls.

The primary shortcoming of these analyses is that they are deterministic, ignoring the uncertainty inherent in livestock production and the effect of this uncertainty on the economic feasibility on the range investment. Production response is based upon expected forage and animal response to the range improvement practice. Also, product prices and factor costs are set at predetermined levels. When evaluating range investments, consideration must be given to the effect of adoption on risk (income variability) as well as expected income levels. Range improvement practices that increase risk along with expected income may not necessarily be production techniques preferred by the rancher. Thus, criteria based upon income variability as well as profitability measures should be employed to evaluate the efficacy of range investments (Cook and Stubbendieck 1986).

A second shortcoming of range investment analyses conducted using a partial budgeting framework is their failure to fully represent the economic consequences associated with a range improvement program. The influence of a negative annual cash flow not only affects the NPV of income in the current year, but also reduces income in future years if additional debt is incurred to cover operating losses. A whole-ranch approach must be employed to accurately measure the economic ramifications of a particular range improvement investment.

The objective of this study is to evaluate the influence of prescribed burning on both the expected value and variability of net returns from a representative stocker enterprise. Economic evaluations of a burning program on shallow prairie and eroded prairie range sites are reported.

Methods and Procedures

Model Description

To represent the effect of prescribed burning in an uncertain production and economic environment, a stochastic (Monte Carlo) simulation model was employed. Monte Carlo models have been advocated as a useful means of exploring alternative investment strategies and their uncertain consequences (Anderson et al. 1980). Monte Carlo simulation involves the mathematical representation of a system, wherein critical stochastic variables are represented using specified probability distributions. In economic applications, important product prices, costs, and yield are typically specified as stochastic variables. Random variables drawn from these distributions are used in the model to simulate the firm's performance. By repeating this procedure many times, probability distributions of important economic performance measures can be derived.

The simulation model used in this study was developed to represent the production, marketing, and financial aspects of a representative ranch over a 1-year planning horizon. The model includes several stochastic factor cost, output price, and livestock response variable to represent the uncertainty inherent in stocker cattle enterprises. Through repeated iterations of the simulation model, the effect of various range improvement practices (e.g., prescribed burning) on both the expected value and variability of ranch income may be obtained.

To simulate the representative ranch operation, the model is initialized using a predetermined ranch situation, then run for a 10-year planning horizon following a specified management plan. The initial ranch situation dictates the beginning financial position, range condition, and resource endowments of the representative ranch. At the beginning of each year, steer prices, calf prices, feed prices, and livestock production performance variables are drawn from a multivariate probability distribution. These values are then entered into the model to estimate annual ranch income derived from the specified seasonal management plan. The user-

specified management plan stipulates the complete set of production and marketing decisions made by the producer (the number of calves purchased, feed rations, range improvement practices, marketing dates, etc.). The ranch operation is simulated recursively, using the ending financial and resource situation for 1 year as the beginning position for the next.

Alternative range improvement practices may be evaluated using the ranch simulation model by programming the particular practice into the specified production plan. For example, in evaluating the adoption of a prescribed burning program, probability distributions and relationships defining animal performance and range productivity in response to late-spring burning are specified. Also, additional costs of burning are included in the simulation model. The model is run for several iterations to derive distributions of relevant economic variables to be used in evaluating the range improvement investment. The economic consequences associated with prescribed burning may then be determined by comparing these results with those derived under baseline conditions (without prescribed burning). The model may also be under deterministic (no-risk) conditions by fixing each stochastic variable at its expected value. Comparison of the results derived using the stochastic and deterministic specifications indicate the effect of incorporating risk in the range investment analysis.

Production Response

Production data included in this analysis were restricted to those specific yield changes that affect the quantity of marketable product (beef). These include long-run changes in stocking rate associated with adopting (or failing to adopt) a burning program, as well as changes in forage quality that alter the expected value and variability of annual weight gains.

Herbage availability was estimated from Soil Conservation Service Technical Guide¹ herbage yield data for tallgrass rangeland of the Central Rolling Red Prairies Land Resource Area, Payne County, Oklahoma. These data were supported by forage standing crop data for the same area (Powell et al. 1982, Rollins et al. 1985, Brummer 1986, and Engle et al. 1987). In the absence of eastern redcedar trees, peak standing crop (i.e., late July to early August standing crop) was set at 3,360 kg/ha (3,000 lb/ac) on shallow prairie and 2,800 kg/ha (2,500 lb/ac) on eroded prairie, the approximate long-term averages as suggested by these clipping data. Initial herbage availability of 2,800 and 2,240 kg/ha (2,500 and 2,000 lb/ac) for shallow prairie and eroded prairie, respectively, reflects reduced herbage standing crop associated with infestations of 198, 2 to 6m (6 to 20 ft), eastern redcedar trees per hectare, which was adapted from the standing crop data provided by Engle et al. (1987).

Forage release, a result of eastern redcedar control with annual spring burning, is estimated to be maximized in 3 years. The greatest proportion of herbage availability increase is assumed to occur with the first annual burn. With no spring burning, herbage availability would linearly decline to about 1,792 and 1,680 kg/ha (1,600 and 1,500 lb/ac) on shallow prairie and eroded prairie sites, respectively, as a result of additional eastern redcedar encroachment. Thus, over the 10-year planning horizon, eastern redcedar population is assumed to increase from about 198 trees/hectare (80 trees/ac) to 568 trees/hectare (230 trees/ac) on the shallow prairie and from 198 to 420 trees/hectare (80 to 170 trees/ac) on the eroded prairie range sites.² Estimated herbage availability over the 10-year time horizon is depicted graphically for both shallow and eroded prairies in Figures 1a. and 2a., respectively.

Stocking rate was set by allowing 12.0 kilograms (26.5 pounds) herbage/steer/day for herbage disappearance, the herbage disappearance associated with stocker cattle grazing tallgrass prairie

¹U.S.D.A. Soil Conservation Service, Field Office, Stillwater, Oklahoma.

²Based upon an average herbage reduction of 13.23 kg (6.0 lbs.) per tree (Engle et al. 1987).

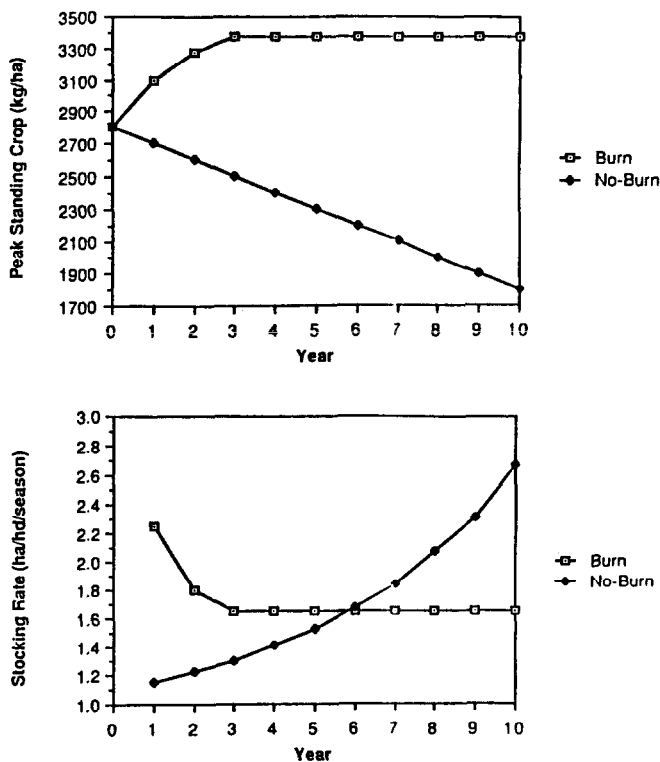


Fig. 1. Peak standing crop and associated stocking rates for the 10-year time horizon, shallow prairie range site.

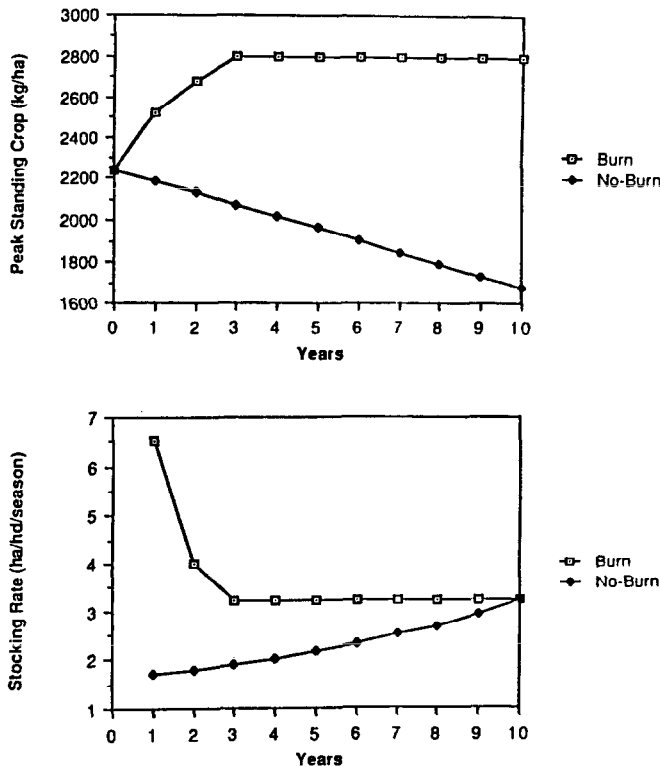


Fig. 2. Peak standing crop and associated stocking rates for the 10-year time horizon, eroded prairie range site.

(Brummer 1986). Stockers are grazed from late-April to late-September, a period of approximately 150 days. Herbage allocation on burned pastures was limited to herbage in excess of 2,240

kg/ha (2,000 lb/ac) residue, the fine fuel threshold requirement for late spring burning for eastern redcedar control (Launchbaugh and Owensby 1978, Rollins 1985). On unburned pastures, herbage in excess of 1,120 kg/ha (1,000 lb/ac) was allocated for stocker use. Stocking rates approximate those calculated by Kothmann's (1984) method and the SCS Technical Guide recommended stocking rates, except that stocking rate was set lower on burned pasture to conserve fuel for burning. Our calculated stocking rates on unburned pastures were heavier than Kothmann's in the first portion of the 10-year period to approximate conventional stocking in the region. The derived stocking rates under burn and no-burn conditions for summer stocker production on shallow prairie and eroded prairie range sites are shown in Figures 1b. and 2b.

To represent the short-term effect of prescribed burning, triangular probability distributions of annual steer performance (seasonal weight gain) were derived using late-spring burning from the Kansas Flint Hills and data from Oklahoma State University (Launchbaugh and Owensby 1978, Owensby and Smith 1979, and McCollum 1987). These distributions reflect the expected value and variability of steer performance resulting from differences in forage quality among years. Prescribed burning is estimated to improve summer gains of yearling cattle an average of 12% on tallgrass prairie in Oklahoma (McCollum). Results reported from several studies investigating the effects of late-spring burning suggest similar improvement in gain from burning (Anderson et al. 1970, Smith and Owensby 1972, Woolfolk et al. 1975, and Owensby and Smith 1979). Mean annual weight gains of 113.4 and 102.1 kilograms (250 and 225 pounds) per steer were specified in the burn and no-burn distributions, respectively. To obtain an estimate of the degree of variability in annual steer gains, a 10-year data set was employed. Since statistical tests indicate no serial correlation, the data were used to estimate the distribution of annual steer weight gains with and without prescribed burning. For reasons cited in Young (1983), 10 and 90 percentiles were substituted for exact endpoints in deriving distribution parameters from the data series. The derived triangular distributions are shown in Figure 3.

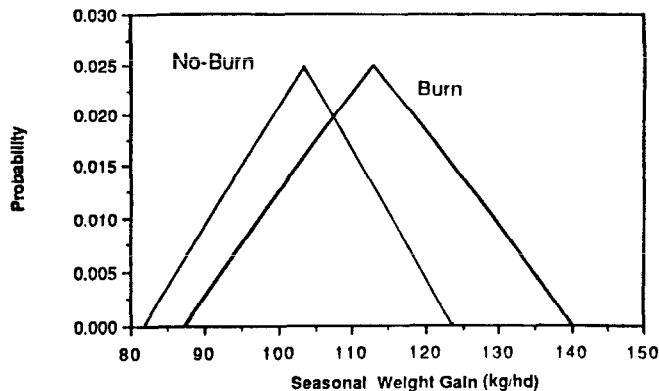


Fig. 3. Triangular probability distributions of seasonal weight gain on a 216 kg (475 lb) steer, with and without prescribed burning.

Livestock Receipts and Production Costs

Net returns were determined by combining values derived from the production response models with stochastically derived product price and factor cost estimates. Steer prices, supplemental feed costs (prairie hay and protein supplement), and calf prices were represented using a multivariate normal distribution based upon a historical series of normalized price data. Mean values of distribution variables were determined exogenously from price models that reflect the level of expected values of each price over the time horizon.

Gross livestock receipts were estimated as the product of 3 variables: (1) the number of steers grazed (as dictated by the current

stocking rate), (2) the average steer weight (derived from the production model), and (3) the stochastic steer price. Revenues were adjusted to reflect a 2% death loss. Average steer and calf prices were determined from price prediction models specified to represent seasonal and cyclical movements of cattle prices over time.

Annual costs allocated to the stocker enterprise included livestock and non-livestock costs associated with ownership and maintenance of the representative ranch. An itemized list of annual livestock expenses (with stochastic prices set at expected values) is presented in Table 1. Estimated annual costs of pasture burning

Table 1. Per head operating cost for stocker steers on eroded prairie and shallow prairie range sites.

Input	Units	Price	Quantity	Value
Steer Calves*	kg	1.59	204	\$324.00
Supplemental Feed*	kg	.22	35	7.70
Salt and Minerals	kg	0.77	5.45	4.20
Vet. & Medical Expenses	hd	9.08	1.00	9.08
Mach. Fuel, Lube, & Repairs	hd	5.91	1.00	5.91
Equip. Fuel, Lube, & Repairs	hd	.85	1.00	.85
Hauling Charges*	kg	0.008	544	4.20
Marketing Charges*	kg	0.038	329	12.47
Annual Operating Capital*	dol			26.36
Total Operating Costs				\$394.77

*The actual cost of this input is dependent upon stochastic prices or stochastic weight gain values. Costs reported are expected values.

were estimated to be \$5.73 per hectare (\$2.32 per acre). Non-livestock expenses included interest and principal payments on short-, and intermediate-term debt, land rental and ownership expenses, property taxes, pasture maintenance and improvement costs, and various ranch overhead expense items. Additional debt may be accumulated over the planning horizon through financing of operating losses.

Results and Discussion

The simulation model was applied to investigate the profitability of implementing a prescribed burning program on both shallow prairie and eroded prairie range sites to control eastern redcedar. The profitability of the burning program was estimated by comparing simulation results derived from an enterprise employing late-spring burning each year with baseline results (without prescribed burning).

The current stocker enterprise was assumed to consist of 300 head of stocker steers grazed on 607 hectares (1,500 acres) of tallgrass prairie range. Stocker calves weighing 215.5 kilograms (475 pounds) are purchased in early-April, placed in a 28-day receiving program, and then grazed until late-September (approximately 150 days). Steers are supplemented with 0.45 kilograms (1 pound) of soybean meal per day over the last 77 days of the summer grazing season.

Shallow Prairie Range Site

Expected annual cash flows (receipts less operating costs) from stocker production on a shallow prairie range site were estimated for both burn and no-burn scenarios under stochastic (risk) and deterministic (no-risk) conditions. Annual cash flows from each year of the 10-year planning horizon, accumulated cash flow and the net present value of the cash flows are given for each scenario in Table 2. A real discount rate of 4% was used to estimate the net present value of the 10-year return stream.³ The risk results represent the expected values of the annual cash flows from 200 iterations of the simulation model. In the deterministic analysis, expected

cash flows were estimated using expected values of annual steer performance (weight gain), input cost, and steer price variables.

Results indicated that prescribed burning is an economically feasible range improvement practice for stocker producers operating on shallow prairie range sites. Under stochastic conditions, the net present value (NPV) of the return stream generated using prescribed burning exceeds the no-burn NPV by \$41,905 or \$69.04 per hectare (\$27.94 per acre). Expected returns derived when burning is used exceed no-burn returns for all but the first year of the planning horizon, despite the higher no-burn stocking rate for years 1 through 5 (see Fig. 1b). In years 2 through 5, additional returns derived from improved animal performance on burned pastures exceed returns lost from the lower stocking rate. Returns from prescribed burning increased over the first 3 years of the planning horizon and then appeared to level off. Conversely, returns from no burn scenarios decrease monotonically over time as a result of the declining stocking rate.

Comparison of results derived under risk and no-risk assumptions indicates a decrease in the estimated profitability of stocker production as a result of incorporating stochastic economic and production influences. The NPV of returns derived from deterministic application of the model exceed stochastic estimates for the burn and no-burn scenarios (Table 2). Also, mean annual cash flows from the deterministic analysis exceed annual cash flows for each year of the stochastic analysis. This result primarily reflects 2 conditions. First, because output and factor price variables are not independent, the expected value of net returns under stochastic conditions is not necessarily equivalent to the net return generated using expected price and production values. Also, under stochastic conditions, negative annual cash flows may result from poor animal performance, low steer prices, and/or high factor costs. Financing these operating losses results in an increase in annual operating expenditures relative to those estimated under deterministic assumptions.

Results from the stochastic analysis also indicate the influence of annual prescribed burning on the variability of annual cash flows. Table 2 reports the mean, standard deviation, and coefficient of variation of annual returns for the burn and no-burn scenarios. The standard deviation of annual cash flows increases for 6 of the 10 years of the planning horizon as a result of adopting a prescribed burning program. However, when variability in returns is measured using the coefficient of variation, the variability of returns derived from the no-burn scenario exceeds the variability resulting from using the burning program in 9 of the 10 years. Furthermore, the magnitude of this difference increases over time.

It may be argued that return variability does not accurately reflect the risk inherent in a particular livestock enterprise since both deviations above and below the mean contribute to the estimated level of risk. Several researchers have proposed a "safety-first" risk measure where the degree of risk inherent in an enterprise is measured by the probability of returns falling below some critical level (Walker et al. 1986, Robinson et al. 1984). To illustrate this concept, the probability of annual cash flows falling below zero during each year of the time horizon is given in Figure 4. When a critical return level of zero is assumed, the level of risk in stocker production is reduced in every year as a result of implementing a burning program. The probability of negative annual cash flows is reduced from 5% in year 1 to as much as 26% in year 10.

Eroded Prairie Range Site

Expected annual cash flows for stocker enterprises on eroded prairie range sites are given in Table 3. Under both stochastic and deterministic assumptions, the NPV of returns from the burning scenario exceed those derived from the no-burn scenario. This result occurs despite the fact that annual cash flows from stocker production without prescribed burning exceed cash flows from the prescribed burning scenario for the first 3 years of the planning horizon. Higher productivity of burned range sites (and lower productivity of unburned sites) results in increased stocking rates

³All prices and costs employed in the model are expressed in real (non-inflated) terms. Thus, a real discount rate (4%) is employed to represent the opportunity cost associated with investing money in the enterprise (Workman 1986).

Table 2. Annual cash flow parameters for a stocker cattle enterprise on a shallow prairie range site.

Year	With prescribed burning				Without prescribed burning			
	Risk			No-Risk	Risk			No-Risk
	Mean	S.D.	C.V.	Mean	Mean	S.D.	C.V.	Mean
1	4224	10018	2.37	4426	5970	17313	2.90	7369
2	6565	11816	1.80	6879	5639	16662	2.95	6634
3	7914	13670	1.72	8627	4838	16594	3.43	5974
4	8543	13440	1.57	8923	3673	13828	3.76	5372
5	8609	13741	1.60	9190	4454	13732	3.08	4787
6	9362	13589	1.45	9371	3708	12215	3.29	4111
7	9568	13832	1.44	9583	3090	1955	3.54	3513
8	9578	13964	1.46	9830	1662	11284	6.78	2924
9	10958	13121	1.20	11118	1014	9263	9.13	2448
10	12036	13822	1.15	12450	-134	4175	31.15	1890
ACF ¹	87,357			90,397	33,914			45,022
NPV ²	71,075			71,559	29,170			38,108

¹Accumulated cash flow

²Net present value (4% discount rate)

Table 3. Annual cash flow parameters for a stocker cattle enterprise on an eroded prairie range site.

Year	With prescribed burning				Without prescribed burning			
	Risk			No-Risk	Risk			No-Risk
	Mean	S.D.	C.V.	Mean	Mean	S.D.	C.V.	Mean
1	-2784	3414	1.23	-2769	2273	12320	5.42	2754
2	-665	4875	7.33	-464	1835	10684	5.82	2489
3	985	6948	7.05	1340	704	9657	13.72	1664
4	1100	6995	6.35	1691	825	9700	11.76	1515
5	1172	6837	5.83	2016	899	9846	10.95	1324
6	666	7369	11.06	2256	-210	9648	45.94	1100
7	711	6831	9.61	2529	-196	8469	43.21	1003
8	1392	6339	4.55	2840	-1840	9428	5.12	-391
9	481	7514	15.62	3193	-3168	8226	2.60	-1836
10	685	7128	10.40	3592	-3873	8221	2.12	-2801
ACF ¹	3,743			16,224	-2,751			6,821
NPV ²	2,372			11,652	-549			6,975

¹Accumulated cash flow

²Net present value (4% discount rate)

and higher annual returns on burned ranges in the final 7 years of the planning horizon. Accumulated cash flows under prescribed burning greatly exceed no-burn cash flows in both the stochastic and deterministic analyses. However, because the primary income generating potential of burned range sites occurs in later years, a majority of these cash flows are heavily discounted. Therefore, the profitability of prescribed burning, as measured by the difference in burn and no-burn returns, is reduced. The difference between the NPVs derived with and without prescribed burning is \$2,921 and \$4,677 under risk and no-risk conditions, respectively.

Despite the short- and long-term benefits of prescribed burning, the accumulated cash flow from stocker production on eroded prairie is quite low under the economic assumptions of the analysis. Under stochastic conditions, the stocker enterprise nets less than \$375 per annum when used in conjunction with prescribed burning and \$275 per year without a burning program. Similarly, average annual cash flows from the deterministic analysis range from only \$682 to \$1,622.

As on shallow prairie range sites, the adoption of prescribed burning decreases the risk inherent in the summer stocker enterprise. When measured by the variance and coefficient of variation of annual cash flows, the variability of annual returns is greater under no-burn conditions. Also, the probability of negative annual cash flows from the no-burn scenario exceeds that derived from the prescribed burning scenario in all but the first 2 years of the 10-year planning horizon (Fig. 5).

Summary and Conclusions

Stochastic simulation and deterministic results indicate that prescribed burning is an economically feasible range improvement practice for eastern redcedar control on both shallow prairie and eroded prairie range sites. Under deterministic conditions, the NPV of returns from the burning scenario exceed those from the no-burn scenario by \$33,451 on shallow prairie range sites and \$4,667 on eroded prairie range sites. When the effects of stochastic production response, factor costs, and product prices are incorpo-

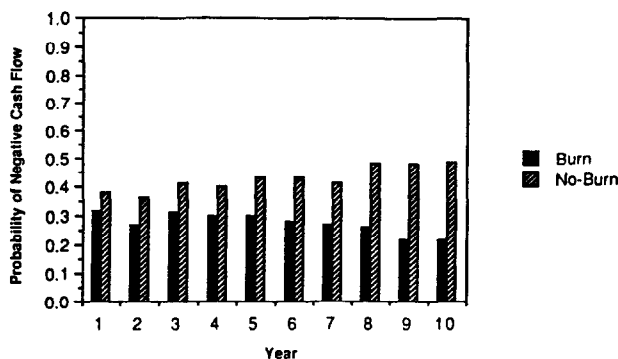


Fig. 4. Probability of negative annual cash-flows over the 10-year time horizon, shallow prairie range site.

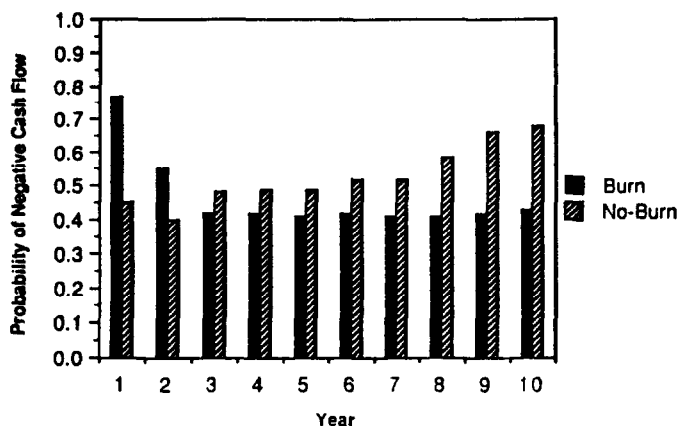


Fig. 5. Probability of negative annual cash-flows over the 10-year time horizon, eroded prairie range site.

rated, the profitability of prescribed burning is reduced below estimates derived under deterministic conditions. Nonetheless, NPV estimates derived from the burning scenario still exceed those estimated without burning on both range sites.

A prescribed burning program does increase the variability of annual income derived from stocker production. However, much of this increase in dispersion may be attributed to an increase in the probability and magnitude of deviations above the mean value. When risk is measured in terms of relative dispersion (coefficient of variation) and the probability of negative annual cash flows, prescribed burning is shown to reduce the risk associated with stocker production.

The results presented here should be interpreted in light of the assumptions used in the analysis. A number of factors may influence the relative profitability of range improvement investments, including weather, treatment cost, range site potential, initial range condition, and projected product and input costs. In addition, the derived results are specific to the financial, production, and resource conditions that characterize the representative ranch. Application of the model to alternative economic and environmental conditions, as well as other range improvement practices, requires respecification of the production and economic data used in the analysis.

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