Economic Evaluation of Chemical Mesquite Control Using 2,4,5-T

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Abstract

Honey mesquite *(Prosopis glandulosa* var. *glandulosa)* represents the most severe brush problem in the Texas Rolling Plains. Substantial research has been conducted on control methods, but economic analysis has been limited. The purpose of this study was to develop an evaluation model and evaluate the economic feasibility of 2,4,5-T (2,4,5-trichlorophenoxy acetic acid) for honey mesquite control in the Rolling Plains. The model is used to estimate the net present value of added grass production from treatment with 2,4,5-T over the life of the treatment; the central part of the model is the estimated herbage yield response function. The gross value of treatment with 2,4,5-T was estimated using different combinations of livestock price, top kill, canopy cover, and discount rate. Of the situations analyzed, gross value of mesquite control varied from a low of $22/ha to over $73/ha. These returns compare to current treatment costs of $22-25/ha.

Infestation with honey mesquite *(Prosopis glandulosa* var. *glandulosa)* constitutes the single most severe deterrent to range production in the Texas Rolling Plains. Almost 4.8 million hectares of the 5.6 million hectares of native rangeland in the Texas Rolling Plains are infested with mesquite (Whitson and Scifres 1980). Osborn and Witowski (1974) estimated that mesquite decreased economic activity in Texas by $429 million to $832 million in 1967 dollars; adjusting to 1981 dollars with the Gross National Product implicit price deflator, the cost becomes $1.05 billion to $2.04 billion.

The decision to invest in mesquite control, or any other form of brush control measure, is complex. A major factor contributing to this complexity is that results of a control measure extend over a period of time, the length of which may vary. Some factors may be unknown or not well understood, and others may be known or understood but beyond the decision maker's control. Another major factor is the uncertainty associated with important economic variables, such as livestock prices and production costs, through time.

A substantial amount of research has been conducted on both mechanical and chemical control of mesquite; however, economic research on the various methods has been limited. Several studies have evaluated costs with little or no emphasis on benefits. Boykin (1960) estimated the costs of root plowing and reseeding in the Rio Grande Plains. Wiedemann and Cross (1975) considered costs of grubbing small trees. Freeman et al. (1980) estimated costs of harvesting mesquite in the Texas Rolling Plains using mechanical methods. In a study evaluating costs and revenues, Freeman et al. (1978) studied the effects of cattle prices and levels of mesquite control on ranch organization and income in the Texas Rolling Plains. In the linear programming analysis, they assumed that forage production would increase by 31% in each year from year 2 through year 7 after treatment from spraying mesquite with 2,4,5-T (2,4,5-trichlorophenoxy acetic acid); lower response rates were also assumed to test for sensitivity. Workman et al. (1965) conducted a study of costs and returns from spraying in which they attempted to determine the longevity of chemical treatment in a survey by asking ranchers to estimate the life of treatment. Sharp and Boykin (1967) evaluated returns from mesquite control using a dynamic programming model in which they assumed a distribution of added forage production over a 10-year planning horizon. Whitson and Scifres (1981) conducted an extensive economic study of different methods of controlling mesquite in several regions of Texas. Their study provided recommendations for control on a regional basis; it was not addressed to specific situations or to the most efficient method of control in most instances. Among procedural problems they recognized was that long-term response data were lacking because of cost, personnel changes, and short-term research goals. Consequently, they assumed a 20-year production response for each region in their study.

The general objective of this study was to develop a procedure for evaluating the economic feasibility of honey mesquite control on rangeland with which decision makers can consider (1) variations in effectiveness of control in terms of longevity and (2) variations in economic variables affecting returns from the control technique through time. The specific objective was to evaluate the economic feasibility of 2,4,5-T for control of honey mesquite in the Texas Rolling Plains.

Analytical Framework

Purchasing mesquite control is fundamentally different from purchasing production inputs, such as supplemental feed, which are used in a single production period. Mesquite control by chemical or mechanical means constitutes a capital investment. The major expenditure occurs at a point in time and the effects of the control extend for some period of time into the future, usually several production periods. Since the treatment is expected to last for several years, there is more uncertainty and more production risk than with the one-period production input. Sources of risk are of two types: (1) biological variation, of which the impact of weather is an example, and (2) economic uncertainty, arising mostly from variations in product (livestock) prices.

The effectiveness of mesquite control treatments over time, in conjunction with certain economic variables, largely determines the feasibility of treatment. A treatment which reduces mesquite and its impact on rangeland and productivity for 10 years is more likely to be economically feasible than a treatment which diminishes the mesquite infestation for fewer years. Although the time pattern of control is an important element of economic feasibility (Whitson and Scifres 1980, Freeman et al. 1978), little empirical analysis exists on the longevity of treatments on control of mesquite; little data have existed with which to establish longevity.

The conceptual model developed for this analysis consists of

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several generalized relationships. The basic relationship on which the other relationships depend is a herbage yield response function which relates grass production resulting from treatment of mesquite with the herbicide to time and other variables.

$$MP_G = f(X_1, X_2, \ldots, t) \quad (1)$$

where MP_G = additional grass production per unit of land associated with the mesquite control treatment,
t = time, and
X_i = other explanatory variables.

It is expected that MP_G declines over time because mesquite reestablishes after the initial damage from treatment and consequently decreases the added grass production as reinfestation occurs.

Added grass production is not directly marketable, but it may be converted to a product which is marketed—livestock. This relationship can be expressed as:

$$MP_L = k(MP_G) = g(X_1, X_2, \ldots, t) \quad (2)$$

where MP_L = additional livestock production per unit of land associated with the mesquite control treatment, and

k = units of livestock produced per unit of grass; a conversion factor for converting grass to meat.

Equations (1) and (2) are biological relationships. No purely economic factors have been introduced. Equation (2) is transformed into an economic relationship as follows:

$$VMP = MP_l(P_L) = j(X_1, X_2, \ldots, t) \quad (3)$$

where VMP = value of the additional production per unit of land, and
P_L = price (net) of the livestock produced.

The ranch manager cannot affect the price of the livestock, thus price is determined outside his influence. However, price may not remain constant over time. The VMP is the additional revenue from the mesquite control treatment, and there is VMP each year during which the treatment has an impact on grass (and livestock) production. If it is assumed that all costs of treatment occur at the time of treatment, the stream of additional returns must be discounted in order to place them on an equivalent basis with the costs (Whitson and Scifres 1980). Thus,

$$PV_{VMP} = \Sigma[VMP_t/(1 + r)^t] \quad (4)$$

where PV_{VMP} = present value of the added revenue from mesquite control treatment,
VMP_t = added revenue from treatment in year t, and
r = discount rate, i.e, the price of the capital used for the treatment.

Equation (4) shows that the longer the life of the treatment (t) and the lower the discount rate (r), the greater the present value of the revenue generated from mesquite control.

For the manager, the decision criterion is: If PV_{VMP} is greater than or equal to the cost of treatment, the treatment is economically feasible. Otherwise, the added costs exceed the added revenues. This is a modification of the marginal analysis principle explained by Whitson and Kay (1978) and numerous other authors. To make reliable estimates of the appropriate costs and returns, several things must be known: (1) the nature of the MP_G and/or the MP_L relationship, (2) the price of livestock, and (3) the cost of mesquite control treatment. Item (3) is relatively easy to determine with a small margin of error. Item (2) is extremely difficult to forecast, especially with a high degree of precision and over a long period. There are, however, ways to use alternate assumptions regarding livestock prices to facilitate analysis and decisions. Item (1) requires identification of factors which affect productivity of the treatment and quantification of impacts of those factors.

Methods and Procedures

The source of data for this analysis was a 6-year plot study at 7 locations in the Rolling Plains treated with 0.55 kg 2,4,5-T/ha. The sites were located in Kent, Lynn, and Tom Green counties. Details of treatments are reported in Dahl et al. (1978) and grass response data were from those experiments.

The first question relating to equation (1) in the previous section was: What are the variables which affect the grass response from treatment with 2,4,5-T (i.e., what are the X_i's which impact on MP_G?). The experimental results clearly indicated that initial mesquite infestation (measured as canopy cover or number of trees /ha) and top kill (the percentage of trees unsprouted at the end of the first year) were explanatory variables. The study also implied that soil type might be an explanatory variable. It was hypothesized that climatic factors (rainfall and temperature) also affect additional grass production and that location may also have an impact. It was further assumed that the relationship between MP_G and each of the independent variables except time was linear and relationship to time was hypothesized to be in semi-log form. The mathematical model formulated was:

$$MP_G = B_o + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4 + B_5X_5 + B_6\ln t + B_7D_1 + B_8D_2 + B_9D_3 + B_{10}D_4 \quad (5)$$

where MP_G = added grass production from treatment (kg/ha),
X_1 = mesquite canopy cover prior to treatment (%),
X_2 = top kill measured as percent of trees unsprouted at the end of the first year,
X_3 = rainfall during the Sept.-Mar. period prior to the growing season (cm),
X_4 = rainfall during the April-Aug. growing season (cm),
X_5 = number of days during the year with the high temperature >37.8°C,
$\ln t$ = natural logarithm of year following treatment (1 = year of treatment),
D_1 = location dummy variable; D_1 = 1 if site in Tom Green County, O otherwise,
D_2 = location dummy variable; D_2 = 1 if site in Lynn County, O otherwise,
(If D_1 and D_2 are both O, site is in Kent County.)
D_3 = soil type dummy variable; D_3 = 1 for Redland, O otherwise, and
D_4 = soil type dummy variable; D_4 = 1 for valley soil, O otherwise.
(If D_3 and D_4 are both O, soil is hardland.)

Data on rainfall and temperature were obtained from secondary sources (U.S. Dep. Commerce). For the Kent County site, climatological data for Jayton was used. For the Lynn County site, averages of observations for Post and Tahoka were used and for the Tom Green County site, averages of Water Valley and San Angelo Airport observations were used. Ordinary least squares was used to estimate parameters of equation (5).

Once the MP_G relationship was established, conversion to MP_L was accomplished as follows. It was estimated that for the Rolling Plains areas in the study 9,525.5 kg of grass were required annually to support one animal unit (AU); this allowed for trampling and restoring vigor. It was assumed that the livestock enterprise would consist of a cow-calf operation and that one animal unit consists of a 453.6-kg cow, one 181.4-kg calf, a 5% of a 725.8-kg bull, and 14% of a 294.8-kg replacement heifer (Kennedy 1970). A calving rate of 90% and marketing of calves at 181.4 kg was assumed. Thus, under these conditions, one AU produced 137.9 kg; .76 = .90 calving rate minus .14 heifer replacement.

Therefore,

9525.5 kg grass = 137.9 kg calf and
1 kg grass = .0145 kg calf.

The value of the calves (P_L) was determined in terms of net value rather than gross value; i.e., if additional animal units are placed on the land, there are additional costs associated with grazing those livestock. The value of livestock marketed was calculated as:

$$P_L = P_c - VC_c \quad (6)$$

where P_c = market price of 181.4 kg calves in dollars/kg, and
VC_c = variable cost of producing 181.4 kg calves in dollars/kg

Variable costs consist of supplemental feed and minerals, veterinarian costs, fuel, lubrication, and repair costs on equipment, marketing cost, depreciation, taxes, and insurance on livestock, interest on operating capital, and interest on investment in the cows, bulls, and replacement heifers. Variable costs in this case excluded land costs and overhead costs and the value of cull cows, a function of cow prices, was subtracted to make calf costs a net cost estimate. Cost estimates were derived from enterprise budgets by the Texas Agricultural Extension Service (1982). The VC_c was estimated to be \$.55/kg. The market price for calves, P_c, was obtained from Texas Department of Agriculture (1982).

Results and Interpretation

Estimation of equation (5) yielded the following relationship:

$$\underset{}{MP_G} = 11.48 + \underset{(.01)}{19.15 X_1} + \underset{(.00)}{23.72 X_2} - \underset{(.05)}{15.56 X_3} - \underset{(.12)}{13.50 X_4} - \underset{(.12)}{31.14 X_5} - \underset{(.04)}{625.6 \ln t} \quad (7)$$

Numbers in parentheses below the estimated regression parameters represent the probability of an equal or greater *t*-value associated with the parameter (the significance level). The *F*-statistic for the model was 4.89 and R^2 was .607. The location and soil type dummy variables were insignificant; i.e., with the data used, location, and soil type had no significant effect on the added grass production from treatment of mesquite with 2,4,5-T. Canopy cover, top kill, pre-season rainfall, and time were highly significant explanatory variables; growing season rainfall and temperature were less significant. Negative signs for coefficients at X_3 and X_4 indicate that treatment of mesquite with 2,4,5-T adds less to grass production in high rainfall years than in low rainfall years, as expected. When there is sufficient soil moisture for both the mesquite and the grass, damaging the mesquite does not benefit the grass to the same extent as when mesquite and grass are more competitive for soil moisture.

To facilitate interpretation, several variables in equation (7) were fixed at some value(s) to produce a grass yield function with added grass yield as a function of time. If all independent variables

Table 1. Descriptive statistics for variables in the MP_G relationship.

	Variable	Mean	Standard deviation
MP_G	(added grass produced); kg/ha	358.40	376.1
X_1	(initial % canopy cover)	25.85	14.98
X_2	(% top kill)	74.88	14.33
X_3	(pre-season rainfall); cm	25.10	12.28
X_4	(growing season rainfall); cm	34.29	13.68
X_5	(number of days with high temperature >37.8°C)	9.08	3.57
ln t	(logarithm of year)	1.103	.39

except time are held constant at their mean values (Table 1), then equation (6) becomes

$$MP_G = 1048.6 - 625.6 \ln t \quad (8)$$

shown graphically (Fig. 1). This relationship indicates that with normal (average) temperature and rainfall conditions, a 26% initial canopy cover, and a 75% top kill, treatment with 2,4,5-T would produce 1,049 kg more grass per hectare the first year after treatment, 615 kg the second year, 361 kg the third, 181 kg the fourth, and 42 kg the fifth year. After year five, the effect of the treatment is negligible.

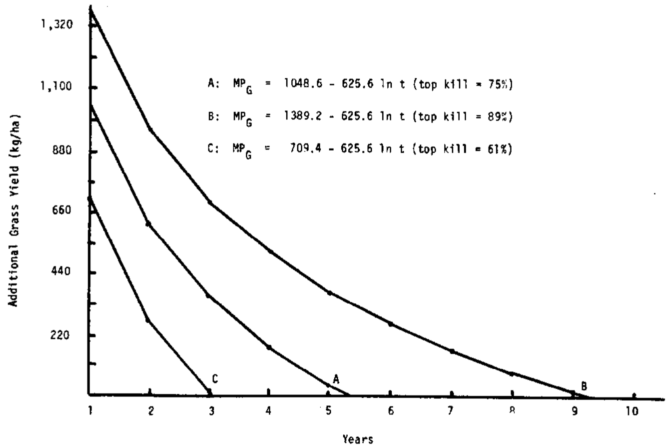

Fig. 2. *Estimated grass yield functions with independent variables at mean values and top kill varying one standard deviation.*

As climate, initial infestation, or top kill change, the MP_G relationship changes. For example, with normal weather patterns and average top kill but a more dense (sparse) infestation of mesquite, the MP_G relationship increases (decreases). With all conditions the same except the initial canopy cover increased one standard deviation from the mean, from 25.85% to 40.83%, the grass production relationship became

$$MP_G = 1336.9 - 625.6 \ln t \quad (9)$$

also shown (Fig. 1). If the initial canopy cover is one standard deviation below the mean, the MP_G relation is the lowest curve (Fig. 1). The heavier the infestation of mesquite when treated with 2,4,5-T, the greater the grass production from the treatment and the longer the life of the treatment.

If we assume normal climate conditions and average canopy cover but let the top kill vary, the results are illustrated (Fig. 2.). As

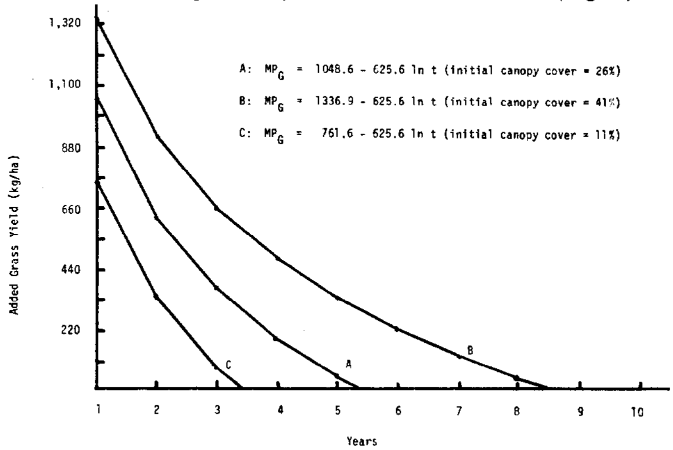

Fig. 1. *Estimated grass yield functions with independent variables at mean values and canopy cover varying one standard deviation.*

the top kill increases one standard deviation from its mean, from 74.88% to 89.12%, the relationship shifts from that of equation (7) to

$$MP_G = 1389.2 - 625.6 \ln t \quad (10)$$

The greater the top kill the greater the added production per year and the longer the life of the treatment. This demonstrates the effect of proper application methods, spraying under good environmental conditions, and other management practices which affect top kill.

To convert the added grass production to added beef production, the factor of 1 kg of grass = .0145 kg of marketable calf was used. To convert to dollar values, the estimated added cost of producing the marketable calf of \$.5467/kg was used. The price of beef is subject to variation from numerous sources, but for purposes of this analysis, the price quotations for the San Angelo market for medium frame #1 feeders, 136.1–181.4 kg and 181.4–226.8 kg reported on June 12, 1982, were used (Texas Dep. Agr.). Based on those prices, a calf price of $1.62/kg was assumed. Thus, P_L = $1.62 – .5467 = $1.073, or an additional kg of marketable beef produces $1.073 income above added costs. Each added kg of grass produced thus has a value of (.0145) ($1.073) = $.01556.

If average conditions hold and the above production cost and market price conditions hold, derivation of the present value of mesquite treatment with 2,4,5-T are shown (Table 2). A discount rate of 10% was assumed over the 5-year life of the treatment. Under these conditions, the treatment would produce a present value of additional income of $29.85/ha. If the treatment cost is less than $29.85/ha, investment in the treatment is economically feasible because the expected additional revenue from treatment exceeds the expected additional costs. If it cost more than $29.85/ha to treat, the treatment is not economically feasible. Cost of treatment with 2,4,5-T in the Texas Rolling Plains is about $22/ha.

Table 2. Calculation of value of added grass production.

Year	Additional grass production[1]	Value of additional grass production[2]	Discounted value of additional grass production[3]
	kg/ha	—$/ha—	
1	1048.8	16.63	15.12
2	615.0	9.76	8.06
3	361.4	5.73	4.30
4	181.4	2.87	1.95
5	41.8	.67	.42
	2246.4	35.66	29.85

[1]Conditions: 26% initial canopy cover, 75% top kill, 25.1 cm pre-season rainfall, 34.3 cm growing season rainfall, 9 days/year with high temperature >37.8°C.
[2]Assumes 9,526 kg grass produces 137.9 kg of calf for market, variable calf production cost of $.55/kg, and calf market price of $1.62/kg.
[3]Assumes 10% discount rate.

As any changes in the physical conditions occur, the economic feasibility may change. Consider a greater-than-average initial mesquite infestation. If all conditions are the same as above except the infestation is increased to 40.83% canopy cover (one standard deviation above the mean), the PV_{VMP} increases from $29.85 to $52.90/ha. Thus, the manager could invest up to $52.90/ha for treatment under these conditions. This increase in value results from greater additional grass production and a longer life of return from the treatment. Since rangeland is a dynamically changing resource and mesquite infestation tends to increase over time, treatment which is not feasible under a set of conditions at one point in time may be feasible under the same set of conditions at a later time.

Consider also the effect of a greater-than-average top kill on the economic returns. Factors such as spraying under more advantageous soil moisture, atmospheric temperature, etc., conditions may affect top kill and are under control of the ranch manager. If all conditions are average except for top kill, which is at 89.12% (one standard deviation above the mean), then PV_{VMP} increases from $29.85/ha to 54.85/ha.

As with changes in the physical conditions, changes in economic condition likewise affect the economic feasibility. Economic factors which affect beef prices, costs of producing beef, and discount rates may have a substantial effect on the returns from and feasibility of mesquite control (Table 3). The data indicate that the value of mesquite control with 2,4,5-T in the Texas Rolling Plains increases as beef prices increase, decrease as discount rates increase, increase as the initial canopy cover increases, and increase as the percentage top kill increases. The price of cull cows, included in the calculation of VC_c, was assumed to be constant in this analysis. To the extent the cow prices vary directly with calf prices, the discounted values (Table 3) are under-estimated at higher calf prices.

Table 3. Discounted present values of additional grass production ($/ha) under alternative situations.[1]

Calf price ($/kg)	Average conditions[2] Discount rate: 10%	15%	Heavy intial canopy cover[3] Discount rate: 10%	15%	High top kill[4] Discount rate: 10%	15%
1.43	24.54	22.26	46.34	35.44	45.02	38.18
1.54	27.63	25.08	46.55	38.83	50.33	42.72
1.65	30.69	27.89	51.69	44.23	56.31	47.74
1.76	33.78	30.64	56.86	48.73	61.50	52.21
1.87	36.82	33.43	61.97	53.08	67.06	56.88
1.98	39.91	36.25	67.21	57.55	73.19	61.70

[1]Conditions: 25.1 cm pre-season rainfall, 34.3 cm growing season rainfall, 9 days/year with high temperature >37.8°C, $.55/kg calf production cost.
[2]26% initial canopy cover, 75% top kill.
[3]41% initial canopy cover, 75% top kill.
[4]26% initial canopy cover, 89% top kill.

Implications

The economic feasibility of controlling mesquite with 2,4,5-T in the Rolling Plains of Texas depends on many variables; some are environmental, some are economic and some may be influenced or manipulated by managers. Among the environmental variables which affect added grass and beef production, and therefore, economic feasibility associated with mesquite control are initial canopy cover, degree of top kill achieved with treatment, pre-season and growing season rainfall, and number of high temperature summer days. Of these variables, ranch management may manipulate initial canopy cover by choosing the time to engage in spraying and influence top kill by choosing conditions at the time of spraying which promote high top kill. Among the economic variables which affect economic feasibility are livestock prices, costs of production, and discount rates. While an individual ranch manager is quite limited on the degree to which he may influence these variables, some impact on them through livestock production management, financial management, and marketing strategies may occur. This analysis shows the relative magnitudes of effects from the various factors on the economic returns from treatment of mesquite with 2,4,5-T. To determine economic feasibility, the discounted added returns from treatment must be compared to the added costs of treatment. Economic feasibility may, therefore, vary with time, among ranches, and among pastures within ranches. The MP_G relationship estimated in this study is believed to be generally reliable for the Rolling Plains region. The appropriate values of the variables within the relationship, the appropriate factor to convert to marketable product, and the appropriate values for the economic variables will vary from one situation to another. The analytical framework, along with the MP_G relationships, should be applicable to individual decision situations.

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