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ESTIMATION OF A PERFORMANCE FUNCTION FOR EVALUATING RANGE IMPROVEMENT INVESTMENTS*

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Research methodology has been presented for the economic evaluation of range improvement investments [3,7,11,12], but there is difficulty in relating research results to decisions faced by managers of the range resource. A technique is needed for translating the data regarding a particular range site into information upon which an investment decision can be based. This paper proposes the use of a "performance function" to generalize research results by estimating the relationship between the decision criterion and the variables affecting it [4].

The decision of when to improve range is similar in structure to the classical replacement problem [3]. The range improvement problem involves determining whether it would be more profitable to invest now or to defer investment until some future date. However, comparing these alternatives as though the decision against improvement meant waiting indefinitely tends to overstate the profitability of investing now. It is reasonable to expect that the range site could be improved one year later if the alternative of improving now is foregone, i.e., the decision is recurring.

The purpose here is to (1) present the technique for evaluating range improvement investments through the use of a performance function, and (2) apply

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it to the economic analysis of investments to control big sagebrush (*Artemisia tridentata*) in crested wheatgrass (*Agropyron desertorum*) seedings on high desert range. The physical response of forage production to sagebrush control will be discussed first, followed by the specification, estimation, and interpretation of the performance function.

Forage Production Response to Sagebrush Control

Two relationships influence the response of crested wheatgrass production to the control of big sagebrush. These are (1) the effect of decreased competition from big sagebrush crown cover, and (2) the projected rate of big sagebrush invasion following control.

Effect of Reduced Big Sagebrush Competition

Although the competitive relationship of big sagebrush and crested wheatgrass has been researched [5,6,8,10], expression of this relationship in a manner suitable for economic evaluation has not been presented. The data for this analysis were from crested wheatgrass seedings made in 1950-51 on the Squaw Butte Experimental Range located 40 miles west of Burns, Oregon.

Data on sagebrush crown cover and crested wheatgrass production for 1963, 1970, and 1971 were adjusted, pooled, and analyzed by OLS regression.[1/] The regression of adjusted crested wheatgrass production on the percentage of big sagebrush crown cover was estimated as follows:

$$\hat{P} = 1032 - 41.5\ C \qquad (1)$$

where P is production in pounds per acre, and

C is crown cover of big sagebrush in percent.

The standard error of the estimate was 128 pounds per acre, which is 16 percent of the mean. Each one percent increase in big sagebrush crown cover reduced production 41.5 pounds per acre, or about 4 percent of the mean maximum production, i.e., the Y-axis intercept. A similar relationship was found by Cook [5]. His data indicated an average yield reduction of about five percent of the potential for each one percent increase in crown cover of big sagebrush.

Rate of Projected Big Sagebrush Invasion

The rate of big sagebrush invasion in crested wheatgrass is projected, based on admittedly limited data. Given the weather and grazing program of the Squaw Butte Experimental Range, the following relation is posited to explain the level of sagebrush invasion as a function of the age of the crested wheatgrass seeding:

$$C = \begin{cases} 0.066667\,T^2 - 0.001481\,T^3, & 0 < T < 30; \\ 20, & T \geq 30; \end{cases} \tag{2}$$

where C is crown cover of big sagebrush, in percent, and

T is age of the seeding in years.

This function assumes that in the first year the crested wheatgrass seeding has a very small and randomly dispersed cover of sagebrush. It is the characteristic of this function that the cover increases at an increasing rate for the first 15 years, and at a decreasing rate for the next 15 years. At 30 years of age the brush cover stabilizes at 20 percent.

With the control measures available, complete eradication of big sagebrush is uneconomic, if not impossible. Hence, reinvasion will occur. The benefits from control depend on the difference between the levels of brush cover with control now versus later. After control, it is assumed that the reinvasion rate is a function of the previous year's cover as indicated in Equation (2).

Modeling the Physical Relationships

The two above relationships together explain the forage production resulting from the control of big sagebrush. Table 1 presents the estimated annual production resulting from brush control now compared to control one year later. The present brush cover is 12 percent, and control now or later is assumed to be 70 percent effective. With potential yield of one AUM per acre, a one percent decrease (increase) in brush cover increases (decreases) production by 0.04 AUM per acre, based on the relationship indicated in Equation (1). To account for the lag in production response to reduced cover, the increase in AUM's in the first and second years after control is equal to 50 and 75 percent of the potential increase, respectively. No deferment of grazing after control is assumed.

Specification of the Performance Function

Candler and Cartwright [4] proposed expressing the relationship between a criterion, Y, and the variables affecting this criterion, the X's, in a "performance function". The specification of this performance function requires determination of (1) the measure to be used for the criterion, (2) variables to be included which affect the criterion, and (3) the appropriate functional form for relating the criterion to the variable values.

Discounted cash flow methods are valid for assessing the economic feasibility of range improvement practices [1,2]. The net present value (NPV) of the investment per acre was selected as the measure of the decision criterion.[2/] The NPV is calculated by discounting the annual increments in net return due to control now rather than later (Table 1) and then totalling.

The performance function posited here specifies the NPV for sagebrush control as dependent on five variables describing the site in question. These are

Table 1. Forage Production and Net Return for Control Now Versus One Year Later, at 12 Percent Initial Cover, 70 Percent Cover Reduction, Potential of 1 AUM Per Acre at $4, and $2 Control Cost

Year	Forage Production		Net return		Increment in net return
	Now	Later	Now	Later	
	(AUM's)	(AUM's)	(cents)	(cents)	(cents)
0			- 200		- 200
1	0.688	0.480	275	- 8[a]	+ 283
2	0.748	0.663	299	265	+ 34
3	0.788	0.728	315	291	+ 24
4	0.750	0.775	300	310	- 10
5	0.713	0.738	285	295	- 10
6	0.675	0.700	270	280	- 10
7	0.635	0.660	254	264	- 10
8	0.595	0.620	238	248	- 10
9	0.555	0.580	222	232	- 10
10	0.515	0.540	206	216	- 10
11	0.475	0.500	190	200	- 10
12	0.438	0.463	175	185	- 10
13	0.403	0.425	161	170	- 9
14	0.368	0.390	147	156	- 9
15	0.335	0.355	134	142	- 8
16	0.305	0.325	122	130	- 8
17	0.280	0.297	112	119	- 7
18	0.255	0.270	102	108	- 6
19	0.235	0.248	94	99	- 5
20	0.220	0.230	88	92	- 4
21	0.208	0.215	83	86	- 3
22	0.200	0.205	80	82	- 2
23	0.200	0.200	80	80	0

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[a] Value of production at 192 cents minus 200 cents for control cost.

(1) initial brush cover, (2) control effectiveness, i.e., reduction in crown cover, (3) potential forage value, (4) cost of control, and (5) cost of capital. Table 2 summarizes the definition of these variables, and the values used in estimating the function.

The functional form selected was a second-order polynomial, which requires estimation of the 16 coefficients in the following equation:

$$(3) \quad \begin{aligned} Y = {} & b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_{11}X_1^2 \\ & + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{15}X_1X_5 + b_{22}X_2^2 \\ & + b_{23}X_2X_3 + b_{25}X_2X_5 + b_{35}X_3X_5 + b_{45}X_4X_5 + b_{55}X_5^2 \end{aligned}$$

Although this function is not simple, its use does represent a smaller computational chore than calculating the NPV by conventional methods.

Estimation of the Performance Function

The performance function's estimation requires (1) a procedure for generating the criterion values, (2) an experimental design, and (3) a method for estimating the coefficients.

A deterministic computer simulation model was programmed to find the NPV in cents per acre associated with each combination of variable values indicated in Table 2. Data were generated for a full factorial experiment of 243 observations. Then the OLS method of regression was employed to estimate the coefficients.

The coefficient estimates (Table 3) must be interpreted carefully, due to the deterministic nature of the observations. The standard errors of coefficients are irrelevant. However, the R^2 of 0.979 provides a measure of how well

Table 2. Definition and Values of Variables Affecting Investments to Control Big Sagebrush in Crested Wheatgrass Seedings

Variable	Definition	Variable values Low	 Midpoint	 High
X_1	Initial brush cover (%)..........	6.00	12.00	18.00
X_2	Control effectiveness (%)........	50.00	70.00	90.00
X_3	Potential forage value ($/acre)..	1.00	4.00	7.00
X_4	Cost of control ($/acre).........	1.00	2.00	3.00
X_5	Cost of capital (%)..............	4.00	8.00	12.00

Table 3. Performance Function Relating Net Present Value (Cents per Acre) of Big Sagebrush Control in Crested Wheatgrass Seedings

Coefficient	Value	Coefficient	Value
b_0	142.6461	b_{13}	1.7780
b_1	-4.7054	b_{15}	-0.0839
b_2	-2.8924	b_{22}	0.0025
b_3	-28.1298	b_{23}	0.1395
b_4	-0.4546	b_{25}	0.1199
b_5	-1.5087	b_{35}	1.2207
b_{11}	-0.1620	b_{45}	-0.8585
b_{12}	0.1323	b_{55}	-0.3672

this second-order polynomial approximates the shape of the actual function.

Interpretation of the Performance Function

Suppose the manager is considering spraying a crested wheatgrass seeding with a 12-percent crown cover of big sagebrush. The cost of chemical control is $2 per acre, and 70-percent effectiveness is expected. The potential productivity is estimated at one AUM per acre, and the value of each additional

AUM is $4. The cost of capital is 8 percent. Substituting these values into the performance function (Table 3) gives an estimated NPV of 43 cents per acre for the investment in control now rather than later.

In addition to this point estimate, the performance function can be analyzed to measure the sensitivity of the criterion to marginal changes in the variable values. Also, the function can be solved to determine the "break-even" variable values associated with a target return to capital. However, the primary advantage is the ability to estimate the NPV for an infinite combination of variable values without recourse to complicated budget calculations.

Footnotes

[*] Oregon State University, Agricultural Experiment Station, Technical Paper No. 3362.

1/ All data were adjusted for yearly effects according to the formula of Sneva and Hyder [13]. Including the data for 1963 was justified by subjecting the differences in regression coefficients and Y-axis intercept of the data sets for 1963 and 1970-71 to a "t" test. The differences were not statistically significant ($P > 0.05$).

2/ For a discussion of the advantages and disadvantages of the alternative measures of investment criterion, see Aplin and Casler [1, pp. 28-29].

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