Optimal Vegetation Conversion—How Much, How Often?

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Some of the more difficult aspects of planning and analyzing rangeland improvements involve predicting forage response, how long the improvement will last, what value the forage has in each of its many uses, and whether benefits from the improvement outweigh costs. Range ecologists typically have focused on the first two questions while economists have emphasized the last two.

Research into the biology of overstory-understory relationships in a wide variety of ecosystems will allow reasonable estimates of the economic feasibility and optimality of given vegetation conversion projects. The economist attempts to answer two basic questions. First, is it rational to allocate limited resources of a ranch business (e.g., land, labor, capital, and management skills) to a particular range improvement project? Second, if it is, then how much should be invested in vegetation conversion and how often should it be repeated?

This paper examines these questions for the suppressive effects of big sagebrush overstory on crested wheatgrass understory production in the intermountain region of the western U.S. The described approach could be applied to any overstory-understory vegetation project. As in any economic analysis, the underlying assumptions are important in terms of the results and conclusions, and must be specified.

A Typical Ranch—The Analytical Basis

A typical Utah cow-calf-yearling operation was used as the basis for this analysis. The typical ranch runs 206 brood cows with a 15% replacement rate, a 24:1 bred cow:bull ratio, and an 82% calf crop based on Jan. 1 brood cow inventory. The feed sources are native foothill range, crested wheatgrass foothill range, hay meadows, crop aftermath, federal grazing permits, and private range leases (Capps and Workman 1981, Dickie and Workman 1987).

Most of the early spring forage is provided by crested wheatgrass that was seeded following sagebrush control. Two factors combine to make this a key range improvement: first, controlling sagebrush and seeding grasses is expensive, and second, because crested wheatgrass grows during the most limiting season, it can control herd size. To keep the economic analysis relatively simple, average production rates and prices are used.

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The Overstory-Understory Model

The conversion of big sagebrush in the 1950s and 1960s to crested wheatgrass range has had varied success. In some areas, sagebrush has not re-established itself and does not appear likely to re-establish in the near future. In other areas, it is difficult to find a crested wheatgrass plant among the sagebrush. Explanations for this variation in response can be grouped into two categories: ecological and management. Ecologically, if the controlled sagebrush occupied a marginal sagebrush area, the establishment of a vigorous grass cover could prevent the reinvasion of sagebrush. However, if the controlled area was a prime sagebrush site, re-establishment is expected to occur. In terms of management, if the seeded grass is grazed each year during a critical growth period, reestablishment of sagebrush is enhanced. But if the seeded grass is carefully grazed, it may be possible to maintain the health of the grass even on a prime sagebrush site. In many cases, a combination of these two factors likely determines whether big sagebrush will become re-established.

The "How Often" Question

In areas where re-establishment does not occur under any management regime, sagebrush conversion can be a one-time decision. But if re-establishment is known to occur, the recurring question becomes: how *often* should the sagebrush stand be converted to crested wheatgrass in order to maximize profits? The important assumptions are: (1) the typical ranch includes a crested wheatgrass stand that is subject to big sagebrush re-establishment, (2) cow herd size is constrained by limited spring forage, and (3) the manager must decide under what conditions it is feasible to control big sagebrush.

The "how often" decision hinges on several factors: percentage of the big sagebrush stand initially killed, subsequent stand management (season of use, utilization rate), and kind and class of animal grazing the grass. In applying research results, it must be recognized that these factors are interactive. Thus, the combined effects of all factors may be different than the sum of the individual effects.

The "How Much" Question

Hull and Klomp (1974) studied the effect of initial percentage kill of big sagebrush re-invading an established southern Idaho crested wheatgrass stand. Prescribed burning, 2,4-D spraying, and hand grubbing were used to reduce stands of basin big sagebrush and Wyoming big sagebrush by 0, 50, 75, and 100%. Crested wheatgrass response was measured over 6 years. Figure 1 shows the relationship between crested wheatgrass production and percent kill of basin big sagebrush averaged over the last four years of their study. There were no statistical differences between treatments in the first two post-treatment years compared with the control. Yield was converted to usable forage by applying a utilization factor and an availability factor (i.e., a percentage reduction). Hull and Klomp concluded that killing the final 25% of the big sagebrush resulted in 135% more grass production than did killing the first 75%.

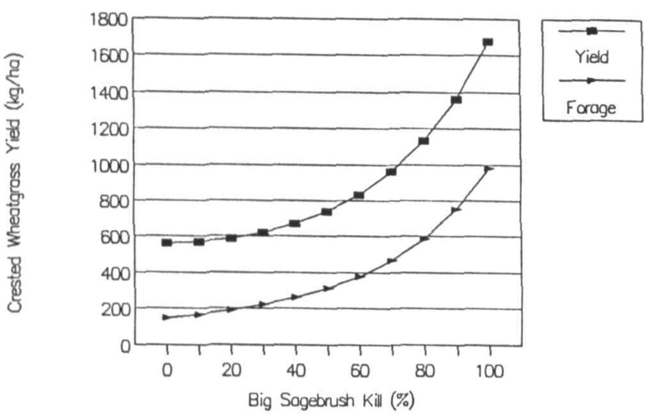

Fig. 1. *Estimated annual crested wheatgrass and usable forage yields at big sagebrush percent kill levels.*

The fact that grass production increases at an increasing rate as sagebrush is reduced has a significant effect on initial investment feasibility. It may also be an important determinant of project life (project life is defined as the point at which no additional production is realized from the treatment). If complete control is attained, a significant sagebrush seed source for the re-establishment is removed. Less than complete control allows a seed source to remain in the stand and effective project life may be shortened. Other influences on the rate of sagebrush re-establishment include deferment length, initial range condition, post-treatment grazing management, big sagebrush subspecies, density, height, age, associated species, topography, soil type, slope, aspect, precipitation, kind of grazing animal, and treatment method.

Economic Optimization

The goal of economic optimization is to identify solutions where the cost of increasing the intensity of input use is just equal to the benefits that are added from that increase. Analysis of vegetation conversion consists of balancing the variables (e.g., initial kill, utilization rate, and project life) to find the profit maximizing solution. Each variable can be examined independently by holding the others constant.

Beginning with the case of a ranch short on spring forage, and with an existing stand of crested wheatgrass being overtaken by sagebrush, the first question is whether retreating sagebrush is the best alternative to alleviate the forage shortage. Other options may include leasing additional pasture, buying more land, or feeding hay during the spring green-up period. Once it has been determined that retreating sagebrush in the existing crested wheatgrass stand is the best alternative, the remaining questions are what percentage of the sagebrush should be killed, how many acres should be treated, and what the forage utilization rate should be in future years?

The economic analysis requires valuation of both additional forage and the investment to obtain that forage. Forage can be valued in several ways depending on seasonal ranch need and how additional forage is used in the operation (Workman 1986). Most forage valuation techniques involve either a direct application of the market value of leased forage and substitute feeds or the forage is priced in terms of how much additional new revenue it provides. The second method accounts for differences between ranch operations. Termed "derived demand" by economists, this method recognizes that each individual ranch has a specific need for forage based on available resources, herd size, and herd composition.

The final part of the analysis is to balance the initial cost-of-kill with the expected time path (relationship of yield to time from project implementation) of increased forage value to determine the profit maximizing combination of kill rate and utilization rate. Forage utilization rate affects project life as well as livestock performance. Figure 2 shows the expected relationship between spring forage utilization and steer production over time when

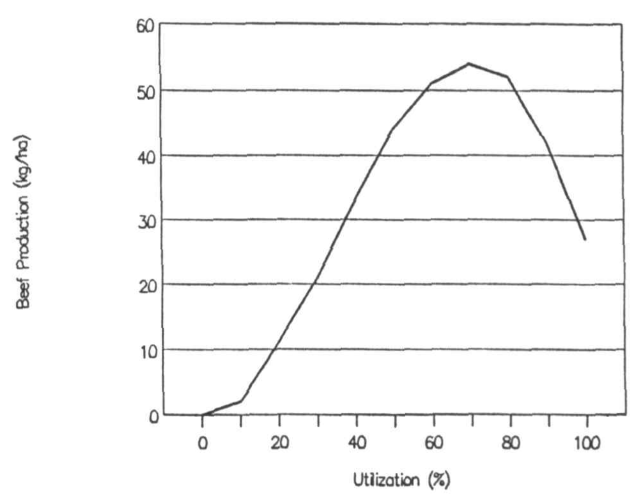

Fig. 2. *Estimated beef production as a function of percent forage utilization assuming 90-95 percent initial big sagebrush kill. Adapted from Torell (1984).*

sagebrush was reduced by 90–95% (Torell 1984). Beef production reached a maximum at a forage utilization rate of 75–80%.

The model is further complicated by introducing the effects of initial investment level on project life and expected returns. Figure 3 illustrates estimated time paths for yields of crested wheatgrass grazed at 65% utilization for four initial kill levels. Two relationships are evident. First, the higher the initial kill level, the higher the expected grass yields. Second, the higher the initial kill

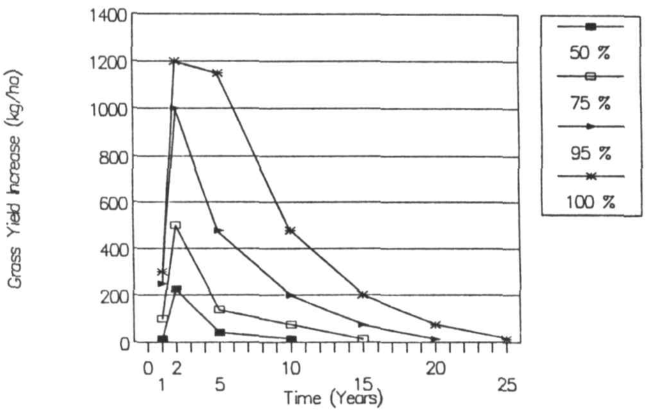

Fig. 3. *Estimated crested wheatgrass production through time after selected big sagebrush kill levels.*

level, the longer the expected project life.

Figure 4 shows the cost-of-kill functions for prescribed burning, 2,4-D spraying, and tebuthiuron application. The burning and tebuthiuron curves show that costs increase at a decreasing rate at low kill levels (due to spreading of set-up costs) and increase at an increasing rate as kill approaches 100% (due to the difficulty of achieving high kill rates). If we consider initial kill rate and utilization rate together, the situation is much different. Sagebrush will increase in a heavily grazed crested wheatgrass stand, especially when grazed in early spring. This could eventually occur even if a 100% sagebrush kill was achieved and no sagebrush seed source was initially available.

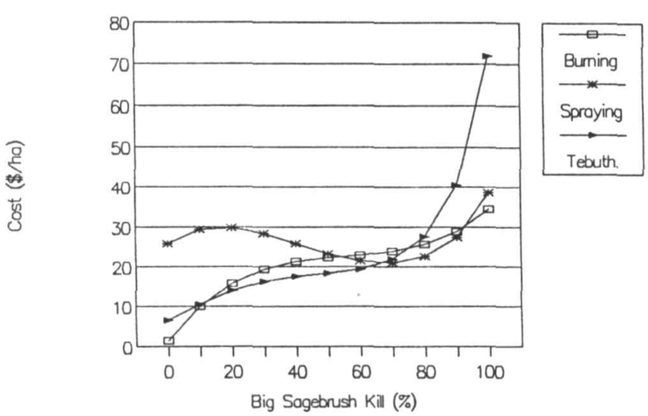

Fig. 4. *Cost of killing big sagebrush as a function of big sagebrush kill percentage (Tanaka and Workman 1988).*

The appropriate sagebrush kill percentage depends on expected returns. For example, holding utilization rate constant and using estimated project lives shown in Figure 3, killing 98% of a sagebrush stand with tebuthiuron with a life of 23-years would return 12.49 times the net present value as would killing 50% with a life of 10-years (Tanaka and Workman 1988). Even if the project lives are equalized (i.e., doing the 50% kill project 2.3 times), the higher kill rate results in 7.87 times more in net present value. The concept of project life is important when calculating project benefits. For example, at a discount rate of 10%, $1,000 to be received 10 years from now is worth $386 today. The same $1,000 received 50 years from now is worth only $9.

All factors may be combined to estimate the economically optimal retreatment (rotation) period. If each factor remains constant through time, a model may be developed that specifies the appropriate retreatment schedule. Model results are only predictions and no better than input data, but they do provide a reasonable guide to the appropriate retreatment schedule and a basis for economic analysis and decision-making.

Formal economic analysis of retreatment scheduling requires a complex approach designed to determine if waiting an additional year to retreat costs more in terms of the present value of lost benefits than retreating now. However, a simpler model may be used with factors that the manager can control—initial big sagebrush kill percentage and subsequent grazing use. Both factors impact optimal life of the project and expected returns. For example, making a large initial investment to obtain a high sagebrush kill will likely extend project life as will conservative grazing after treatment. But it may not be economically possible to recoup the initial investment at a low utilization rate. However, while an increased utilization rate may decrease project life, it may also increase the present value of returns over time. Benefits obtained early in the project life are worth more today than benefits received later. Taking more of the benefits early increases the likelihood of profits, but this advantage must be balanced against the disadvantage of a shorter project life. The analysis can become complicated even considering only these two factors.

Answers to the *combined* "how much" questions (how much of the sagebrush stand to kill and how much of the resulting crested wheatgrass to graze annually) can be obtained by several approaches ranging from complex optimization models to simple comparisons of net returns produced by a few reasonable levels and combinations of initial kill percentage and forage utilization rate. Electronic spreadsheets on microcomputers are useful in the latter approach. Of course, reasonable assumptions of initial kill, utilization rates, and project lives must be specified for each combination tested.

Estimating the optimal retreatment schedule (answering the "how often" question) requires a complex mathematical model (Torell 1984) and a large amount of data. With the number of factors that could depart from original expectations over project life, the specified optimal retreatment schedule is only an estimate, but a useful one for planning projects. Project life is of crucial importance in the analysis because of the "time cost" of money. A project with high annual benefits early in the project life is worth more in present value terms than a project yielding the same returns later. The longer the project life is extended through low utilization rates or higher initial kills, the less the *additional* returns will be worth in present value terms.

Summary

Planning range improvement practices involves predicting forage response, expected improvement life, value of additional forage production, and whether improvement benefits outweigh costs. Key questions that range economists attempt to answer include how much should be invested in vegetation conversion (i.e., the optimal kill rate) and how often the investment should be repeated.

This paper examines these questions for the specific case of reducing big sagebrush overstory to release crested wheatgrass understory production. A typical Utah cow-calf-yearling operation is used as the basis for analysis and an overstory-understory model provides the required biological information. The appropriate sagebrush kill percentage depends on the costs and returns of an additional kill percentage.

Using a model, such as the one described, in project planning can lead the decision-maker through a series of necessary steps. Thinking through the interrelationships may be more important than coming up with the exact solution. In any biological relationship, risk must also be incorporated into the analysis since the chance of project failure or success can have as large an effect on the results as any other factor considered above.

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