The Optimum Retreatment Schedule for Established Crested Wheatgrass Stands

L. Allen Torell and E. Bruce Godfrey

ABSTRACT: This paper outlines and describes research conducted at Utah State University on the optimum length of time before invading brush and timber species should be removed from established crested wheatgrass stands. The primary purposes are to 1) analyze the economically optimal frequency of long-term improvements of crested wheatgrass stands, and 2) include the interaction of grazing in the dynamic pasture and range investment decision.

INTRODUCTION

Crested wheatgrass (Agropyron cristatum, Agropyron desertorum) seedings have come to provide a significant amount of the grazing resource for the western livestock industry. In Nevada, as an example, about 1 million of the 27 million acres (10.9 million ha) of sagebrush rangeland in the state have been seeded. The seeded area constitutes only 2 percent of the total rangeland in the state but produces 10 percent of the harvestable animal unit months (AUM's) of grazing (Young and McKenzie 1982). A similar contribution of crested wheatgrass is also found in other western states. Given the importance of crested wheatgrass as a source of forage to the western livestock industry, the management of these stands will continue to be a vital concern.

At least three interrelated management decisions concerning crested wheatgrass stands are of primary importance. First, the optimal stocking rate and second, the best season of use of the stand must be determined. Taken together, these management decisions relate to optimal use of the grazing resource. A third management decision that must be considered deals with optimal timing of stand improvement and rejuvenation. As stand productivity declines over time, the manager has the following alternative management options. First, the stand can be allowed to deteriorate with no additional range improvements, or second, stand productivity can be rejuvenated by clearing invading brush and nonforage species. If the second option is followed, then the question as to when to retreat the stand must also be considered.

There are two primary purposes of this research. First, the retreatment problem (e.g., choosing optimal frequencies of long-term improvements) is extended to an analysis of crested wheatgrass growth and production over time. Second, the interaction and impact of grazing on the dynamic pasture and range investment decision is considered. The following discussion will 1) outline the nature of the problem, 2) discuss the basic economic theory underlying the optimal decision rule for making long-term improvements in natural resource problems, and 3) outline the proposed procedure which will be used to define and formulate the various functional relationships needed to address the retreatment problem. The approach is developed fully in Torell (1984).

NATURE OF THE PROBLEM

Complete control of big sagebrush (Artemisia tridentata), e.g., 100 percent brush eradication, is seldom achieved at the time of seeding. In southwestern Montana, Johnson and Payne (1968) estimated that from 0.1 to 0.7 sagebrush plants/m^2 survived eradication treatments. Johnson (1969) estimated that initial sagebrush kill of a spray project in central Wyoming ranged from 45 to 87 percent. Given a general inability to completely eradicate the brush canopy, brush surviving the treatment provides an important seed source for reestablishing species.[1]

L. Allen Torell was a Research Assistant, and E. Bruce Godfrey an Associate Professor, Economics Department, Utah State University, Logan; Torell is now an Assistant Professor, Agricultural Economics and Agricultural Business Department, New Mexico State University, Las Cruces.

[1] The economically optimum rate of control at the time of stand rejuvenation was studied by Tanaka (1985), reported in a companion paper in this volume.

Other environmental factors affecting the rate of brush encroachment onto crested wheatgrass stands include soil and topography, precipitation, time of treatment in relation to sagebrush seed maturity, and grazing practices (Johnson and Payne 1968). The effects of grazing have been documented with conclusive but still inadequate quantitative definition to allow economic analysis.

Bleak and Plummer (1954) reported on crested wheatgrass pastures in central Utah that had been grazed by sheep in the spring for seven consecutive years. In this study, the heavily utilized pastures (88 percent use) showed a decrease in grass production with most grass clumps having died in the middle. Crested wheatgrass plants were small, and there was a marked increase in growth of Russian thistle (Salsola kali). Light (59 percent) and moderate (71 percent) uses resulted in maintenance of "good" production, with some decline with age of the stand noted.

Similar results were reported by Currie and Smith (1970), Sharp (1970), Springfield (1963), Frischknecht and Bleak (1957), Frishknecht and Harris (1968), and Robertson and others (1970). While the impact of grazing intensity on forage production and brush invasion was variable, the general conclusions were that heavy grazing reduced both crown cover and vigor of crested wheatgrass while encouraging return of sagebrush.

The literature generally indicates that production of crested wheatgrass will likely decline over time. This is due to brush canopy increasing with establishment of new plants and increase in size of surviving shrubs. However, the rate of brush encroachment will likely be affected by environmental influences as well as grazing management.

Stand longevity can be extended by light to moderate grazing use (Currie and Smith 1970, Sharp 1970). Therefore, the economic question of concern is the tradeoff between extended stand life resulting from light to moderate use and the additional returns which could be realized by heavier stocking. If heavy stocking is practiced, the grass stand will eventually be damaged, herbage production will be reduced, and beef production and annual profits will decline (Springfield 1963). However, the range manager generally has the option of undertaking range improvements which will rejuvenate stand productivity, and thus, mitigate detrimental impacts from heavy use.[2] The goal of the profit-seeking range planner comes down to determining the grazing-use pattern and stand-retreatment schedule that will maximize the net present value (NPV) of future net returns from use of the crested wheatgrass stand. To address the question properly, dynamic aspects of grazing impact on the rate of brush encroachment must be explicitly considered, as well as the time aspect of rejuvenating stand productivity.

[2] This may not be true on public rangelands because Federal and State regulations may limit the use of some improvement practices.

OPTIMAL DECISION RULE FOR LONG-TERM INVESTMENTS

Techniques for determinig the optimum replacement pattern for long-lived assets have been studied, debated, and improved upon by agricultural economists for a number of years. Pioneer work in the area was published in 1960 by Faris. This was followed by Winder and Trant (1961), Cotner (1963), Chisholm (1966), Burt (1971), and Perrin (1972).

The general premise is that selection of the particular production period yielding the maximum NPV of future net returns over a specified planning horizon is the central aim (Chisholm 1966). One must compare the gains from keeping the current asset for another time interval with the opportunity gains which could be realized from replacement of the asset during the same period.

The problem of choosing the optimal frequency for rangeland improvements has an added dimension compared to the classical replacement problem, wherein the age of an asset has no affect on the value of its replacement (e.g., the age of a tractor when replaced has no effect on the value that can be derived from the replacement tractor). For the dynamic rangeland and pasture improvement problem this is not necessarily the case. The longer the time interval before brush and timber removal the greater the amount of pasture deterioration and the more likely that forage values will be reduced in at least the next renewal cycle. If economic and biological conditions are such that pasture renewal implies complete reseeding with destruction of the old stand, then the lagged effect is completely wiped out, and the problem is the same as that of the classical replacement problem. This lagged effect of the last renewal cycle on recovery rate of the stand was discussed in detail by Burt (1971) using an example of pinyon-juniper encroachment onto native rangeland in the southwestern United States.

For native rangeland invaded by pinyon-juniper, the recovery to full potential can vary from just a few years with control at the 15th year of depletion to over 15 years if control is postponed until the 45th year of depletion (Cotner 1963). Control of small trees at the 15th year of encroachment provided benefits mostly in the form of protection against future forage loss. Conversely, control at a date late in the renewal cycle primarily benefited increased forage production in the present.

While the lagged effect is important for range improvement decisions on native rangeland, its importance for improvement decisions of crested wheatgrass stands is not so clear. Robertson (1969) estimated that aerial spraying of sagebrush within a crested wheatgrass stand in Nevada, which formed a 12 percent canopy cover before the spray, resulted in production levels of 1,163 pounds (527 kg) per acre within four years, as compared with only 600 pounds (272 kg) per acre for the control area. The fourth-year production was regarded as peak production or full recovery[3].

[3] Personal communication with J.H. Robertson, Range Scientist, University of Nevada - Reno; October 26, 1983.

Hull and Klomp (1974) estimated that, with normal precipitation, approximately two years of moderate use after brush control should bring a stand of crested wheatgrass to full productivity. This conclusion was reached for one study site which had a big sagebrush canopy cover of nearly 34 percent.

It appears that the age of the brush when controlled does not significantly affect the rate of crested wheatgrass stand recovery--given that an adequate grass understory exists. If this is the case, the dynamic investment problem is greatly simplified. Similar to the classical replacement problem, the problem becomes one of deciding how long the renewal cycle should be so as to maximize the net present value of future net returns from the land. It is not complicated by the problem discussed by Burt (1971), whereby replacement age (i.e., age of stand at rejuvenation) enters into the revenue function of following renewal cycles. While a dynamic analysis is still needed, it is not nearly so dynamic as an analysis of native rangeland.

THE "NO DATA" PROBLEM

Economic analysis of range improvements requires that physical and biological relationships be quantified. It is not enough to just assert or determine that heavy stocking rates shorten the life of crested wheatgrass stands or that increasing brush density reduces grass yields. Yet these are the conclusions reached through the design of most biological studies. Multiple rate treatments and long-term studies, which would allow one to quantify biological relationships in a functional form, are generally not conducted. While the researcher may conclude "beyond a reasonable doubt" that action A impacts desired production of B, the question of by how much has generally not been answered. While the literature indicates the direction of impact for most of the relationships discussed, functional specification is generally not available. Rigorous mathematical specificiation of the investment problem from on-the-ground studies in the literature is not possible.

Given this limitation, a second best alternative must be used, such as the use of simulation models. One of these models SPUR (standing for Simulation of Production and Utilization of Rangelands[4]) was used in this study to simulate the multiple rate long-term data needed to address the investment question. Using these simulated data, an economic model was developed to analyze optimal timing of control of sagebrush invading crested wheatgrass stands.

Multiple simulations of crested wheatgrass production under alternative stocking rates and brush densities provide what has been called "pseudo data" by Griffin (1977). These points on a simulated production surface are used to estimate the functional form of equations depicting 1) the relationship between brush density and crested wheatgrass production, 2) the relationship between livestock grazing and brush invasion into a crested wheatgrass stand, and 3) other relationships which may be deemed important to the problem.

[4]For a complete description of SPUR see Wight (1983).

The obvious problem with this pseudo data approach is that the results ultimately rest on the quality and completeness of the underlying process model (SPUR in this case). The results of these simulations are also typically difficult to validate. However, the pseudo data approach also offers some important advantages relative to conventional time series and cross sectional data. First, data can be generated as needed for economic analysis. That is, relationships undefined in the literature but crucial to the economic analysis can be defined through simulation modeling. Second, as discussed by Griffin (1977), generated pseudo data is generally free of problems with multicollinearity and limited sample range.

While this approach may not be totally acceptable, depending upon the validity of SPUR simulation results, it appears to be the only approach which can be followed at this time. The challenge to researchers studying optimal management of crested wheatgrass stands is to design long-term studies with multiple rate applications which can be used to quantify the various relationships needed for making sound economic decisions. In the meantime, computer modeling provides a second best solution to the no data problem. Furthermore, given the expense of conducting long-term range studies, simulation modeling may provide answers of adequate resolution. That is, long-term on-the-ground studies may not be justified from a benefit/cost perspective.

RESULTS

Figure 1 provides an example of the type of information that can be obtained through simulation modeling. In this application, peak crested wheatgrass production over time as affected by stocking rate was simulated using SPUR. Simulation results indicate that the long-run trend of grass production will be downwards at all three stocking rates considered, but grass production is estimated to decrease the fastest at the heavier rates. However, it should be noted that the stand is estimated to be very long lived and able to withstand even heavy grazing pressure.

Testing of the SPUR model, as with other simulation models, has been a major problem. Field data are generally not available. However, one test of SPUR model results was made with data available from Harris and others (1968) for crested wheatgrass grazing trials conducted at Benmore, Utah. The trial considered the weight gain of yearlings grazing season-long (April 25 through December 7) on crested wheatgrass seedings. Both supplemented and non-supplemented options were considered.

For comparison purposes, this same grazing scheme was simulated using SPUR, on the assumption of no supplement being fed. Model results were amazingly close with no significant difference in accumulated weight gain until late in the grazing season (Fig. 2). While more model validation and testing is needed, these results are encouraging. Other tests of the SPUR model have been conducted and more are planned (Wight 1983).

The economic model developed using SPUR-simulated data indicates that crested wheatgrass is persistent and long-lived, and the optimal

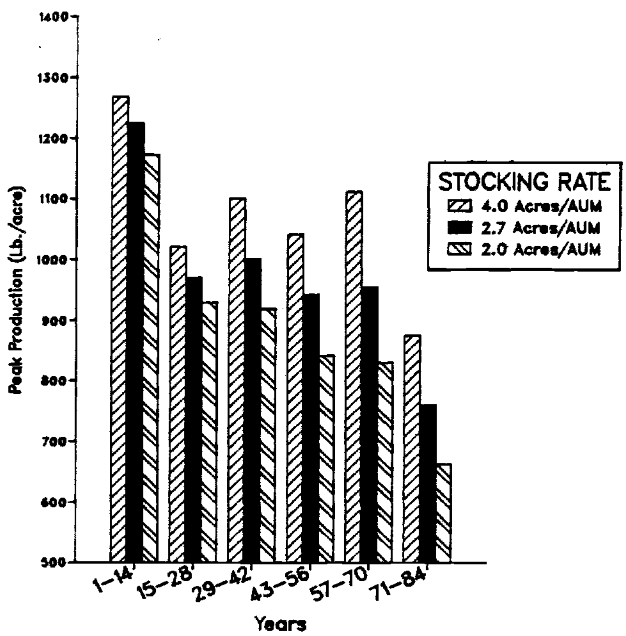

Figure 1. SPUR simulated crested wheatgrass production as affected by stocking rate.

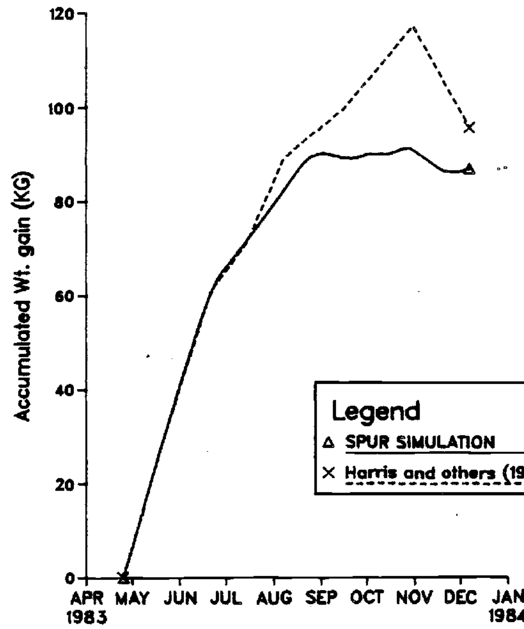

Figure 2.--SPUR simulated livestock gains as compared with Harris and others (1968).

retreatment schedule is at least 35 years long. NPV of the income stream derived from the seeding was increased greatly by extending the retreatment cycle to 35 years and beyond.

Optimal forage utilization rates were found to be slightly over 70 percent. This is not significantly different from the 65-70 percent rate recommended in the literature (Currie and Smith 1970, Springfield 1963, Sharp 1970, Smoliak et al. 1981, Frischknecht and Harris 1968, and Springfield and Reid 1967.

While the results of computer simulation analysis may always be suspect, simulation models such as SPUR do provide a tool for addressing relevant research and management questions. In some cases, it is the only option available and will provide useful information for managers who are trying to determine when to rejuvenate a stand of crested wheatgrass.

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