An Economic Analysis of Optimum Rates of Grazing in the California Annual-type Grassland[1]

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Highlight

In the early days of the west, marketing practices, low costs associated with grazing and lack of knowledge about range management led to heavy and sometimes destructive utilization of range vegetation. As the field of range science developed, control of grazing to achieve "moderate" utilization became an important management tool. However, too little attention has been given to the economics of "moderate use" recommendations. This study indicates the optimum rate of utilization on a Sutherlin soil in the annual-type grassland of California leaves approximately 500 lb./acre of plant residue. Examination of opportunity costs indicates the economic loss from heavy grazing is several times that of light use. Thus, range managers who recommend "moderate" or even "light" grazing are in effect advocating a small loss (opportunity cost of light grazing) as insurance against a larger loss (opportunity cost of heavy grazing).

When hides were a principal range livestock product and cattle sold by the head, operators owned large numbers of animals and believed that heavy utilization of natural grasslands was economically expedient. Later, when meat production was important, but livestock were still sold primarily by the head, heavy grazing continued. The price per head was virtually independent of the animal's physical condition. Still later, when an animal's condition affected price, the practice of "first come first served" on public domain lands resulted in heavy use. Low costs associated with range use also dictated that grazing be heavy (Hooper, 1967).

Beginning about the turn of the century, both fixed and variable costs associated with grazing of range lands began to increase, raising the marginal costs of grazing. Thus, a more moderate degree of utilization was required to obtain an operation where marginal revenue equaled marginal cost (Hooper, 1967). Also, as lands came under private ownership, or government trusteeship, management for sustained grazing was associated with moderate use.

Under the technological and economic conditions prior to World War II, control of stocking rates, utilization, and distribution were the most expedient methods of grassland management. Today, fencing on extensive range land, seeding with introduced species, fertilization, brush control, and other practices neither technically nor economically possible even thirty years ago are feasible. Applications of these practices have tended to de-emphasize the importance of livestock control as a grassland management tool. However, management of stocking rate and rate of herbage utilization still have an important place in range ecology and in economics. That place is likely to become more important because prices and property taxes are forcing livestock operators to seek methods of spreading fixed costs; one of these methods is increased stocking rates. This study was designed to ascertain the economic impact of leaving various amounts of herbage residue (mulch) on subsequent herbage production in the California annual-type grassland.

Variables Affecting Herbage Production

In an economic analysis the technical relations between inputs and outputs (the production function) must be known or estimated before prices can be applied to determine optimum levels of inputs and outputs for profit maximization. Thus, the variables affecting herbage production in this study are identified as follows:

Soils, being the reservoir of nutrients and water, are an important variable in determining forage production. Therefore, separate functions must be derived for different soils or groups of soils. Data analyzed here come from one soil (Sutherlin gravelly clay loam) in one location on the Hopland Field Station in California. The site had less than 5% slope and little erosion hazard.

Weather, especially rainfall, is an important determinant of forage production. In the California annual-type grassland, total rainfall and especially timing of the rain seem to be more important in determining total production, than other climatic factors. Rains occurring in March, April, and May, when temperatures are ideal, influence production more than comparable amounts at other seasons. Consequently forage production functions are expected to differ year by year and they certainly vary season by season.

Natural mulch is one of the most important determinants of forage production in the California annual-type grassland. Even in the absence of grazing, removal of all mulch by clipping before the first rain in the fall: (1) reduced the proportion of desirable forage species in the stand, (2) lowered forage quality, and (3) reduced subsequent forage production as compared to

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areas where mulch had not been removed (Heady, 1956, 1965).

The grazing animal exhibits preferences for certain forage species (Heady and Torell, 1959; Van Dyne and Heady, 1965). These "preferred species" tend to be grazed more heavily than less desirable species and may tend to decrease in the annual grassland community. Among the preferred species are the perennial grasses such as *Stipa pulchra*, and annual grasses such as *Avena barbata*, *Bromus mollis*, and *Bromus rigidus*. Under heavy grazing, these tend to be replaced by annual grasses of lower stature such as *Aira caryophyllea* and *Festuca dertonensis*. If extra heavy use and trampling occur, annual forbs such as *Baeria chrysostoma* dominate. Thus, herbage production is lowered and species composition changed as a result of selective grazing and intensity of grazing. Heavy grazing also reduces to low quantities the amount of mulch which remains on the ground at the time of fall seed germination.

As vegetational responses to heavy grazing (changes in species composition, production, and forage quality) could be simulated with a single manipulation of mulch before the first fall rain, mulch or plant residue may be the most important controllable grazing factor in the California annual type (Heady, 1956). Being annual, the vegetation is more responsive to conditions of germination and establishment in the fall than to food accumulations in the spring and early summer.

Several investigators, recognizing the importance of mulch in the California annual type, have made the recommendation that under correct utilization two inches of stubble should be on the ground when new growth starts in the fall (Bently and Talbot, 1951; Hormay and Fawsett, 1942; Hormay, 1960). Heady (1956) in discussing the importance of mulch did not make a recommendation, but estimated the relation between forage production and mulch in lbs./acre to be $Y = 1214 + 0.354X$ where Y = forage production in the spring and X = forage residue or mulch left the preceding fall. However, nowhere in the literature are there ecological and economic evaluations of mulch amounts which could suggest optimum rates of utilization.

Table 1. Average forage production (lb./acre) in relation to mulch 1956 through 1960.

Years	Pounds of mulch per acre					
	0	500	1000	1500	2000	2500
1955–56	794	2012	2118	1724	1966	1974
1956–57	1800	2477	1947	2840	2777	2534
1957–58	576	3498	3361	3344	3682	3571
1958–59	411	2092	2117	2046	2353	2063
1959–60	897	1808	1955	1834	1907	1873
Average	895	2377	2300	2358	2543	2403

Estimating the Herbage Production Function

The fact that the results of grazing could be duplicated so strikingly through mulch removal provided a vehicle for assessing the relationship between utilization and production; for estimating a herbage production function as influenced by grazing. Herbage could be clipped and weights taken of both "forage" and mulch. For this study production data were obtained from a clipping study which was conducted at the University of California, Hopland Field Station in the years 1955 through 1960. Six mulch quantities in a Latin square design (plots 10 × 10 ft) on Sutherlin soil were obtained in September and measured for herbage production the following May. The treatments were: (1) all mulch removed; (2) 500 lb./acre of mulch returned; and (3) 1000 lb. returned; (4) 1500 lb. returned; (5) 2000 lb. returned; and (6) 2500 lb. returned. Production is on a basis of oven-dry weights from square foot plots.

Advantages and disadvantages of using clipping studies to simulate grazing have been reviewed by Culley, Campbell, and Canfield (1933). They concluded that when the amount and kind of forage removed are the same, grazing is probably more harmful than clipping. Heady (1961) concluded that continuous clipping may be more harmful because an individual plant is not necessarily grazed continuously even though the pasture may be. In the California annual-type grassland, where amount of mulch at the time of germination plays such a dominant role, it is assumed for this study that differences attributable to grazing or clipping are of little consequence.

An attempt was made to fit the clipping data to a statistical production function as suggested by Heady and Dillon (1961). Except for the zero mulch treatment, all others gave approximately the same herbage yield (Table 1). As many biological functions exhibit curvilinear relationships the results were unexpected. Since there were no observations between zero and 500 lbs., one cannot be positive where the breaking point occurs. Apparently, however, the breaking point (and the curvilinear portion of the relation if it exists) is in the neighborhood of 500 lb. of mulch per acre.

Of interest but not to be explored in this paper, is that even 2500 lb./acre of mulch did not depress herbage production. The curve of herbage production has a broad-flat surface.

Pricing Herbage

To make an economic analysis, the relationship between the value of herbage and the value of mulch must be established. There are at least three methods for pricing herbage: (1) rental value; (2) hay equivalent; and (3) cost of owning land. Based on rentals at $3.00 to $6.00/AUM (AUM = 1000 lbs. of usable forage), herbage is valued at from $0.003/lb. ($3.00 ÷ 1000 lb.) to $0.006 ($6.000 ÷ 1000 lb.). Based on unharvested "wild" hay values of from $10.00 to $30.00/ton, herbage would be valued at from $0.005/lb. ($10.00 ÷ 2000 lb.) to $0.015 ($30.00 ÷ 2000 lb.). With land selling at prices in excess of $1000/AUY (AUY = 12,000 lbs of usable forage) the price of herbage would be about $0.005 (interest on investment @ 6% = $60/AUY = $0.005/lb.). Thus, herbage values range from $0.003 to $0.015/lb. These are reasonably realistic assumptions which bracket actual prices over much of the range country. In analyzing an actual ranch situation, local circumstances would determine the appropriate price of herbage. In this study $0.005 ($5.00/AUM or $10/ton hay) is used as a representative figure.

Pricing Mulch

Attaching a value to mulch is a more difficult matter than pricing herbage. One way to view mulch is that it is simply herbage which could have been used, but wasn't. In this case, mulch would have the same price as herbage.

Although the argument is not resolved, there is considerable evidence to indicate that the best system of grazing in the California annual-type grassland is a yearlong continuous grazing system (Heady, 1961). Under this system, species, plants, and plant parts (such as seeds and leaves) are grazed selectively and the preferences change through the season (Heady and Torell, 1959; Van Dyne and Heady, 1965). By the end of the grazing season (near the time of the first rain), the most desirable species, plants and plant parts have been utilized leaving the least desirable species, plants and plant parts as residue or mulch. Protein content of clipped herbage samples indicates the quality in September is about ⅔ that in June. Chemical analyses of dietary samples collected with esophageal fistulated cattle and sheep also indicated quality decreased by ⅓ from June to September (Van Dyne and Heady, 1965A). Several studies (Hart, Guilbert, and Goss, 1932; Gordon and Sampson, 1939; Van Dyne and Heady, 1965A) indicate protein levels in the period July–October to be less than 5% of the herbage weight, while for late winter to early summer the protein content averages above 10%. Other measures likewise suggest lower quality in the July–October herbage residue than in the forage during November–June. Based on these data, herbage residue would have to be priced at the average yearlong value of herbage ($0.005 at $5.00/AUM or $10/ton) to one half the herbage value ($0.0025).

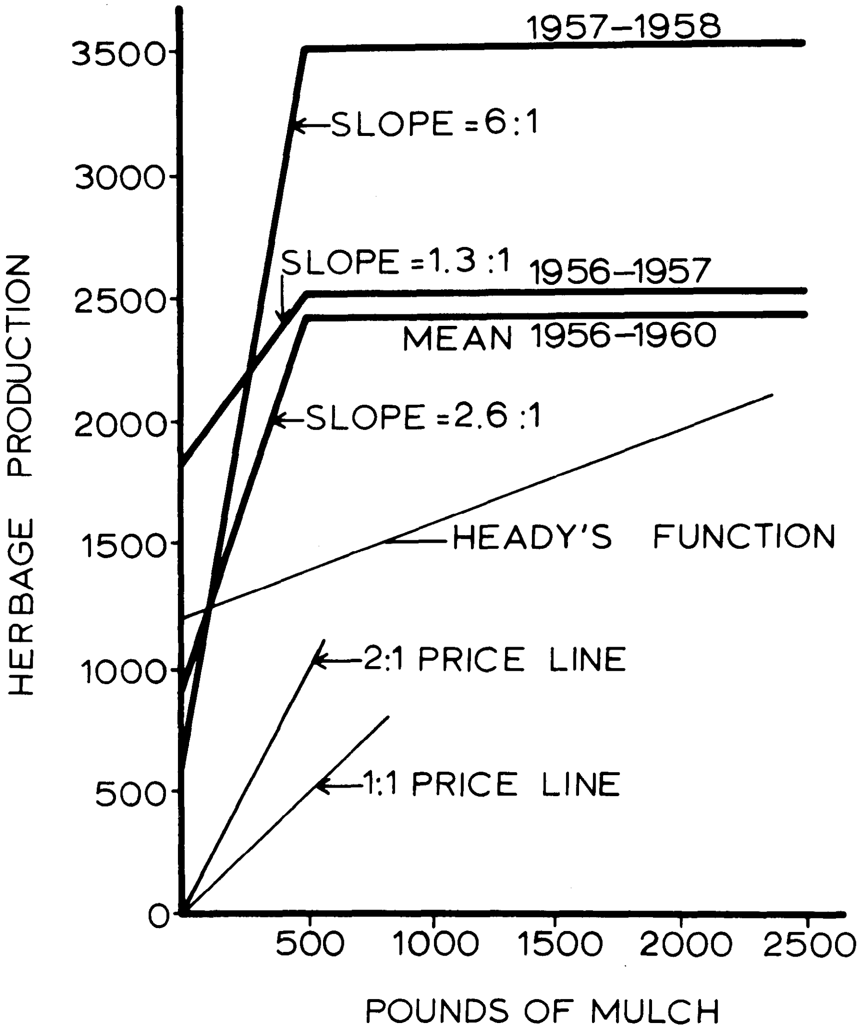

FIG. 1. Relationships of herbage production (lb./acre) in the spring to mulch the previous fall on Sutherlin Soil, Hopland Field Station, California.

Perhaps more important for purposes of economic analysis than deriving absolute prices for herbage and mulch is to establish ratios of prices. From the above analyses, the ratio of prices of herbage to mulch would appear to fall between 1 to 1 and 2 to 1.

One additional factor which must be included in fixing the price of mulch is its role in preventing erosion. In the mulch treatments mentioned above, no erosion occurred on any of the plots that had mulch. The bare plots showed erosion in early fall during the first rain, especially if that rain was intense. Within 3 or 4 weeks after the soil was wet, the new plants had grown enough to protect the soil and no further evidence of erosion was noted (Heady, 1956). Observation indicates erosion will occur with amounts of mulch near zero on Sutherlin soil. Perhaps, at amounts less than 200 lb./acre the role of herbage residue in preventing and reducing erosion may cause mulch value to be raised considerably. How high its price might rise in relation to herbage is pure conjecture at this point, as it is difficult to put a price on "prevention of erosion." Because erosion was not a serious factor on the Sutherlin soil, allowance for the value of mulch for erosion control was not considered.

The Optimum Rate

The data (Table 1) indicate that leaving more than 500 lb./acre of mulch would not pay. Although there are no data available for the range 0–500, the optimum amount of mulch to be left (the breaking point of the curves in Fig. 1) is probably less than 500 lbs on this Sutherlin soil.

If one assumes a breaking point of 500 lb., the sloping segment rises at a ratio of 2.6:1 for the average of the 5 years (Fig. 1), that is, 500 lb./acre of mulch returns about 1300 lb. of herbage. The most shallow slope, 1.3:1, was for 1956–57, and the steepest, 6:1, during these 5 years was in 1957–58. A price line indicative of a price ratio of 1:1 (45 degrees) between herbage and mulch would be tangent to any one of the curves in Figure 1 at the point of discontinuity (500 lb. of mulch). The point of tangency of the price line and the production response curve is the optimum amount of mulch to leave (Heady and Dillon, 1961). For the optimum to shift to zero mulch in a 1957–58 type relation, the price ratio of herbage to mulch would have to be 6:1. For a 1956–57 type year, if the price of herbage were 1.3 times that of mulch, the point of tangency and the optimum would be shifted to zero amount of mulch. For the average of the five years, the price ratio would have to be 2.6:1 in favor of herbage over mulch to justify complete utilization. Put another way, so long as herbage prices are not more than 2.6 times that of mulch, the last 500 lb. of mulch is worth more as a resource than as a product.

The shift to zero mulch (or complete utilization) might occur in a poor herbage year such as 1956–57, when the spread between the treatments is small. And then the shift to zero mulch would occur only if for some reason herbage can be valued at a price greater than 1.3 times the price of mulch. However, since the point of discontinuity probably occurs at a value less than 500 lb. of mulch, the price ratio may still be slightly greater than 1.3 to 1.

In the case of Heady's function $Y = 1214 + 0.354X$, with herbage valued at the same price as mulch (price ratio 1 to 1), or higher, the optimum degree of utilization is that which removes all mulch. Since, on a purely chemical basis, plant residue would never be valued higher than forage, one would conclude that all herbage and plant residue should be removed every year.

Heady's function was for only two years and did not include mulch treatments in the sensitive range between 0 and 1000 lb./acre. Even if these data are representative, one can still argue that some amount of mulch, say 200 pounds, is needed for erosion control. The susceptibility to erosion of different soils and its effect on future production, the value of down stream developments, and potential damage by siltation, would all be factors to be considered. Because these factors vary by soil and by geographic location, the value of mulch in erosion control will vary, the price line will vary, and the optimum amount will also vary.

Opportunity Cost of Light or Heavy Grazing

The optimum rate of grazing (utilization) on Sutherlin soil is that which leaves approximately 500 lb. of plant residue. What are the consequences of grazing at other than the optimum rate? The consequences can be evaluated in terms of opportunity costs which are the profits of one decision foregone by making a different decision (Heady, 1957). For light grazing it is the profits foregone by not using all the forage.

The 2-inch stubble height recommendation mentioned earlier was based on conditions in Madera County in the foothills of the Sierra Nevada Mountains. This recommendation, however, has become a rule of thumb for other parts of the state. It is therefore, of interest to see the effect of the application of this rule to the Sutherlin soil on which the previously described mulch experiments were conducted. A clipping study was conducted during the years 1957–58 and 1958–59. Treatment I was clipped at a stubble height of 1¼ inches while Treatment II was clipped at 2½ inches. All clipped herbage was removed so that only stubble remained. This stubble was then clipped to ground level, removed and weighed. The results indicate that under 1957–58 conditions a 2-inch stubble height corresponded to 1300 lb./acre of mulch. Under 1958–59 conditions, a 2-inch stubble height amounted to 1100 lb. of mulch.

If the optimum amount of plant residue to be left were 500 lb. and by the 2-inch rule approximately 1000 lb. were left, this would amount (with residue priced at \$0.0025/lb. or one-half the herbage value) to \$1.25/acre in foregone profits (500 lb. at \$0.0025). The opportunity cost would be \$2.50/acre if residue were priced at \$0.005, and \$3.75/acre if priced at \$0.0075. On 1000 acres, this is \$1250, \$2500, or \$3750.00. From the above, it is evident that the opportunity cost of light grazing becomes more important on ranches where herbage assumes a high value due to high land prices.

The opportunity cost of heavy grazing is expressed in terms of the lost forage the next year. In a

1956–57-type year, taking the last 500 lb. of mulch gives a return of 1800 lb. the next year (Fig. 1) and leaving the last 500 lb. as mulch gives a return of 2500 lb. the next year. The difference is 700 next year minus 500 harvested this year which equals a net loss of 200 lb. of herbage. Disregarding a discount rate, this is equal to a loss of \$1.00/acre (200 lb. at \$.005). At a price of \$0.0075, the loss is \$1.50. In a 1957–58-type year, the difference is 3500 – 600 = 2900 – 500 for a net loss of 2400 lb./acre, which is valued at \$12.00/acre (2400 at \$.005) or \$18.00/acre (2400 at \$.0075). For the five year average values, the opportunity costs of leaving no mulch are \$5.00/acre and \$7.50/acre at the two prices in comparison with leaving 500 lb./acre.

Conclusions

The optimum rate of grazing (utilization) on Sutherlin soil at the Hopland Field Station appears to be that which leaves approximately 500 lb. of herbage residue (mulch) at the time of the first rains in the fall.

Although the economic principle of spreading fixed costs is of importance in California grassland management, spreading of fixed costs and heavy utilization should not be confused. Spreading the fixed costs of investments and taxes by grazing to a point where the mulch is completely removed does not seem economically expedient on Sutherlin soils. The economic effect of complete herbage removal (overgrazing) appears to cost \$5 to \$7/acre in foregone returns while the cost of light grazing is \$2.50 to \$3.75. That is, the opportunity cost involved in heavy grazing (removing 500 lb. too much mulch) is several times greater than the opportunity cost of light grazing (adhering to the widely accepted 2-inch or 1000 lb. of mulch rule). One wants to graze at the correct (optimum) rate for maximum economic returns. However, if he makes a mistake, he wants to make it grazing too lightly. Adhering to the 2-inch rule is the lesser of two evils and may be rationalized as insurance against a larger economic loss.

It is dangerous to export these conclusions to other soils and other geographic areas within the California annual-type grassland. They should not be applied directly to perennial grasslands. These findings are an indication that definitive work needs to be done in several areas, each including a wide range of mulch treatments. The procedure potentially can place range forage utilization on sound economic as well as ecological grounds.

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