Economics of Fertilizer Application on Range and Meadow Sites in Utah

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Highlight: *Forage production response to nitrogen and phosphorus application on six Utah range and meadow sites was subjected to economic analysis. There was no response to phosphorus application, but nitrogen resulted in significant increases in forage production on three sites. When forage was harvested as hay, nitrogen application proved to be a profitable practice on semiwet meadow and mountain loam sites. Fall application was more profitable than spring on both sites. Nitrogen application proved unprofitable when increased production was valued in terms of range forage. Nitrogen application would become profitable, however, if there was either a slight increase in AUM prices or a small decrease in nitrogen price.*

Numerous studies during the past 30 years have demonstrated that on many range sites the application of fertilizer is an effective means of increasing livestock forage production (Bentley, 1946; Dickey et al., 1948; Lang, 1956; Cook, 1965; Dwyer, 1971). However, economic analyses of this promising range improvement practice have not kept pace with biological research. Hooper (1969) found range fertilization to be economically feasible on several California sites, but his work was confined to annual grasslands. A later economic study by Hooper et al. (1969) dealt with fertilization of Utah mountain rangelands, but application consisted of only a single rate of nitrogen and the analysis did not deal with either optimum application rates or optimum combinations of nutrients. In view of the lack of economic analyses of rangeland fertilization, a study was initiated in 1970 to investigate the economic aspects of nitrogen and phosphorus application on several Utah range and meadow sites.

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The work is published with the approval of the director, Utah Agricultural Experiment Station, as Journal Paper No. 1824. The authors gratefully acknowledge the donation of fertilizer materials by United States Steel Corporation, Kansas City, Mo., and reviews of the manuscript by Don D. Dwyer, Department of Range Science, and Darwin B. Nielsen, Department of Economics, Utah State University.

Manuscript received January 6, 1974.

Site Descriptions

Five Utah range and meadow sites and one Idaho range site were selected for study. Included were two moderately dry mountain loam sites (which for purposes of the study were designated Swan and White), a semiwet meadow site (Jensen), a wet meadow site (Theurer), and two dry foothill silt loam sites (Junction and Curlew).

The Swan mountain loam site is located at an elevation of 7,200 ft 15 miles northeast of Huntsville, Utah, on a southwest slope of 10%. The soil is a silt loam and dominant grasses include Great Basin wildrye (*Elymus cinereus*), Kentucky bluegrass (*Poa pratensis*), bearded wheatgrass (*Agropyron subsecundum*), Junegrass (*Koeleria cristata*), and Idaho fescue (*Festuca idahoensis*). Annual precipitation averages 22 inches, occurring primarily during the winter. During 1971, the year studied, 28.08 inches were received. Grazing by cattle occurs during the summer and fall.

Located 1/2 mile west of Paradise, Utah, at an elevation of 4,800 ft, the White mountain loam site slopes slightly to the north. The soil is a silt loam and the vegetation is composed primarily of seeded intermediate wheatgrass (*Agropyron intermedium*). Average annual precipitation is 16 inches, most of which occurs during the winter. During 1971, 19.14 inches were received. Cattle normally graze the area in both spring and fall.

The Jensen semiwet meadow site is situated at an elevation of 4,420 ft 1/2 mile north of Young Ward, Utah. Currently in use as irrigated grass hay, the vegetation consists of a pure stand of tall wheatgrass (*Agropyron elongatum*). The soil is a silt loam. Precipitation averages 14 inches annually, and 19.14 inches fell in 1971. Because of irrigation, precipitation does not limit forage production.

The Theurer wet meadow site is situated on a perennial stream at 4,450 ft elevation 1 mile southwest of Logan, Utah, and is often under water for up to 6 weeks each spring. Annual precipitation averages 14 inches, while in 1971, 19.14 inches were received. The soil is a silt loam and the vegetation is composed primarily of reed canarygrass (*Phalaris arundinacea*), timothy (*Phleum pratense*), redtop (*Agrostis alba*), and foxtail (*Hordeum jubatum*). Hay harvest in July is followed by late fall grazing.

The Junction foothill silt loam site is situated 20 miles southwest of Snowville, Utah at an elevation of 4,700 ft. Average annual precipitation is 9 inches, and 10.16 inches fell in 1971. The vegetation consists of a seeded stand of crested wheatgrass (*Agropyron cristatum*) with scattered plants of big sagebrush (*Artemisia tridentata*) and halogeton (*Halogeton glomeratus*). Cattle graze the area in both spring and fall.

The Curlew silt loam site is located 11 miles north of Snowville, Utah,

Table 1. Production functions with independent variables significant at 90% or higher probability levels.

Site	Season of application	Function production	R^2
Curlew foothill silt loam	Spring	$Y = 1268 + 17.42N - .0623N^2$	.56
Semiwet meadow	Spring	$Y = 5392 + 28.26N - .0278N^2$	.66
	Fall	$Y = 6070 + 27.96N - .0266N^2$	.67
White mountain loam	Spring	$Y = 1897 + 29.88N - .0462N^2$	.81
	Fall	$Y = 2515 + 26.46N - .0392N^2$	.73

near the Utah-Idaho border at an elevation of 4,800 ft. The vegetation is composed of a pure stand of crested wheatgrass. Annual precipitation averages 11 inches, and 16.89 inches fell in 1971. The area is grazed by cattle on a rotational basis from April through December.

Methods

Six rates of ammonium nitrate and six of treble superphosphate were applied on each site during the spring of 1971. Fall applications were also made on the semiwet meadow and the two mountain loam sites during 1970. The experimental design consisted of three replications of a randomized block factorial.

Ammonium nitrate (N) application rates were 0, 25, 50, 100, 200, and 400 lb N/acre on the White mountain loam site; 0, 50, 100, 200, 400, and 800 lb N/acre on the Swan mountain loam site, semiwet meadow site, and wet meadow site; and 0, 12.5, 25, 50, 100 and 200 lb N/acre on the two foothill silt loam sites. Per acre application rates of treble super phosphate (P) were 0, 12.5, 25, 50, 100, and 200 lb P_2O_5 on the two mountain loam sites, the semiwet meadow site, and the wet meadow site; and 0, 6.25, 12.5, 25, 50, and 100 lb P_2O_5 on the two foothill silt loam sites.

During the summer of 1971, each 10 ft X 15 ft sub-plot was clipped and weighed in the field to determine total forage production. Sub-samples of forage from each sub-plot were oven dried for conversion of green weights to air dry forage production per acre.

The functional relationship between forage production and fertilizer application was estimated by stepwise multiple regressional analysis. Standard marginal economic analysis was employed to determine the most profitable rates of fertilizer application (Heady and Pesek, 1954).

Fertilizer application and forage harvest costs followed custom machinery rates listed in Doanes Agricultural Report (1972). Fertilizer and hay prices were taken from Christensen and Richards (1969). The price per AUM of range forage reported by Hooper et al. (1969) was employed after being adjusted to 1972 price levels.

Results and Discussion

Biological Response

The production function tested by stepwise multiple regression analysis was as follows:

$$Y = a + bN + cN^2 + dP + eP^2 + fNP$$

where **Y** = pounds air dry forage production per acre, **N** = pounds nitrogen applied per acre, and **P** = pounds phosphorus applied per acre. Independent variables which showed *t* test significance at 90% probability levels or higher were retained in the predictive equations. Only the production function models yielding an R^2 value of .50 or higher were subjected to economic analysis. The five production functions meeting these criteria appear in Table 1. Application of phosphorus had no significant effect on forage production on any of the six sites studied. The influence of nitrogen on forage production was significant at three sites as shown in Table 1.

The production function for the fall application on the White mountain loam site is shown graphically in Figure 1. This graph may be interpreted to mean that in the absence of nitrogen application, 2515 lb of air dry forage are produced. The initial application of 1 pound of nitrogen yields 26.46 pounds of additional forage, but due to the "law of diminishing returns," forage production response decreases with each additional pound of nitrogen applied. At application rates exceeding 337.5 lb N/acre, air dry forage production begins to decrease.

Most Profitable Application Rates for Hay Harvest

Standard marginal economic analy-

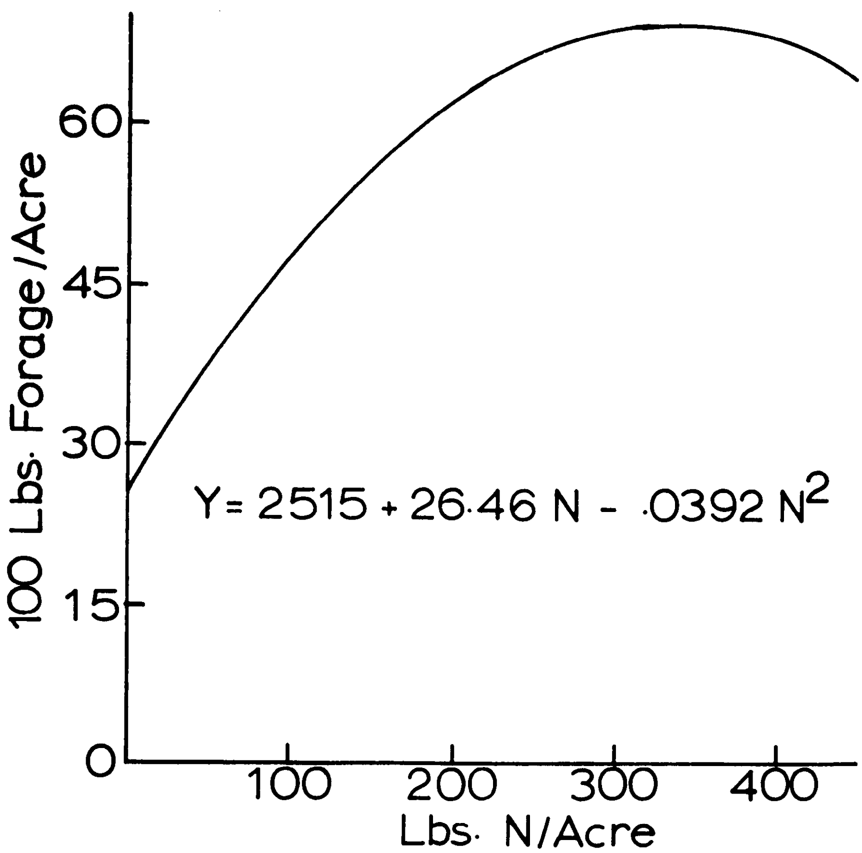

Fig. 1. *Production function for White mountain loam site fall application.*

Table 2. Summary of costs and prices employed in marginal analyses.

Fixed costs	
Fertilizer application	$1.50/acre
Swathing	$3.50/acre
Variable costs	
Nitrogen fertilizer ($82.08/ton of ammonium nitrate)	$ .1207/lb
Baling hay ($4.29/ton of hay)	$ .0021/lb
Hauling hay ($3.30/ton of hay)	$ .0017/lb
Prices	
Baled hay ($22.28/ton)	$ .0111/lb
Grazed forage ($5/AUM)	$ .0044/lb

sis was employed to locate the maximum profit point on the production function curve (Heady and Pesek, 1954). Simply stated, maximum profit from fertilizer application is obtained when the last dollar spent on fertilizer application yields one dollar's worth of additional forage. In the case of the White mountain loam site shown in Figure 1, this is accomplished by equating the first derivative of forage (Y) with respect to nitrogen, $\frac{dY}{dN}$ = 26.46 - .0784N, with the ratio of the price of nitrogen to the price of forage, $\frac{P_N}{P_Y}$. Costs and prices employed in the marginal analyses are shown in Table 2. Forage mowed and baled for hay was valued at $.0111/lb based on the average Utah price of $22.28/ton for the period 1958-1968. The net price of hay is the appropriate price to use in valuing forage if the opportunity exists to harvest and sell hay from the site in question (as it does for the White mountain loam site) or if the only alternative to grazing is feeding purchased hay. The net hay price is calculated by subtracting the costs per pound of baling and hauling from the market price for hay. Thus, the net price per pound of hay is $.0111 minus $.0021 minus $.0017 equals $.0073/lb. Since the cost of swathing must be paid whether or not nitrogen is applied, it is classified as a "fixed" cost and does not enter into the marginal analysis. Nitrogen price was set at $.1207/lb based on the average price of $82.08/ton paid in Utah for ammonium nitrate (34% N) during the period 1963-1968.

Substituting the above values into the marginal analysis equation:

$$26.46 - .0784N = \frac{.1207}{.0073}$$

and solving for N, we obtain 127 lb/acre which is the optimum application rate for maximum profit. Optimum application rates for hay production and resulting profits for all three sites analyzed appear in Table 3.

Fixed Costs and the Decision to Apply Fertilizer

Although the fixed cost of fertilizer application does not enter into the determination of maximum profit application rates, this cost must be taken into account when the decision is made as to whether or not to apply fertilizer at all. As shown in Table 3, if the land manager decided to apply nitrogen on the Curlew foothill silt loam site, 7 lb N/acre *will* yield a larger profit than any *other* application rate. However, fertilizer should not be applied at all on this site since the value of the extra forage produced is exceeded by the fixed costs of fertilizer application. Profit in the absence of nitrogen fertilization is 1268 lb forage per acre (from the production function in Table 1) priced at $.0073/lb = $9.26/acre minus the swathing cost of $3.50/acre = $5.76 as compared to $4.27/acre when the optimum rate is applied. It should also be emphasized that forage on the Curlew site is currently harvested by grazing cattle and, due to the low productivity of the site, it is unlikely that it will ever be harvested as hay. Thus the price per AUM of range forage discussed in the following section is a more appropriate measure of the value of forage produced on the Curlew site than is the price of hay. As indicated in Table 3, considerably more profit is obtained at the optimum rate than at the control on both of the other sites analyzed.

Table 3. Maximum profit nitrogen application rates, pounds of forage produced, and profit per acre when forage is harvested as hay.

Site	Season of application	Optimum rate of N (lb/acre)	Forage produced at optimum rate (lb/acre)	Profit at optimum rate ($/acre)	Profit without fertilizer ($/acre)
Curlew foothill silt loam	Spring	7	1386	4.27	5.76
Semiwet meadow	Fall	215	10852	48.27	40.81
	Spring	211	10117	43.39	35.86
White mountain loam	Fall	127	5243	17.95	14.86
	Spring	144	5240	15.87	10.35

Season of Application

Table 3 also offers the opportunity to compare the results of spring and fall seasons of application. The fall application (mid-October) proved to be more profitable than the spring application (mid-March) on both the White mountain loam and semiwet meadow sites. The Curlew foothill silt loam site did not receive a fall application until 1972, and the results have not yet been analyzed.

Nitrogen Application for Range Forage

On sites normally harvested by grazing animals and where forage produced through fertilization can be substituted for other range forage but not for purchased hay, the appropriate price to be used in valuing additional forage production is the lease rate per AUM. The current lease rate for privately owned range is $5 per AUM (Hooper et al., 1969). If 400 lb of total digestible nutrients (T.D.N.) are required per AUM (Shultis et al., 1970) and air dry forage of tall, intermediate, and crested wheatgrass is 50% T.D.N. (National Academy of Sciences, 1970), 800 lb of air dry forage are required per AUM. However, due to sustained yield considerations, only 70% of the standing crop of these grasses can be utilized. Thus 1143 lb of air dry forage are required per AUM, and the price per pound of forage is $\frac{\$5}{1143}$ = $.0044. Substituting this price into the marginal analysis

Table 4. Maximum profit nitrogen application rates, pounds of forage produced, and profit per acre when forage is harvested by livestock.

Site	Season of application	Optimum rate of N (lb/acre)	Forage produced at optimum rate (lb/acre)	Profit at optimum rate ($/acre)	Profit without fertilizer ($/acre)
Curlew foothill silt loam	Spring	0	1268		5.58
Semiwet meadow	Fall	10	6347	26.31	26.71
	Spring	15	5810	22.25	23.72
White mountain loam	Fall	0	2515		11.07
	Spring	26.5	2656	6.99	8.35

equation for the White mountain loam spring application:

$$29.88 - .0924\ N = \frac{.1207}{.0044}$$

and solving for N we obtain 26.5 lb N/acre, which is the maximum profit application rate *if* nitrogen is applied at all and if the forage is harvested by livestock rather than as hay. Optimum nitrogen application rates for range forage production and profit per acre at the optimum application rates appear in Table 4 for all three sites analyzed. Profit per acre at the optimum application rates must next be compared to profit obtained in the absence of fertilization in order to verify that the fixed costs of nitrogen application have been covered by the increased forage. For the White site spring application, profit without fertilizer is 1897 lb air dry forage per acre (from Table 1) priced at $.0044/lb = $8.35/acre. Since profit at the optimum nitrogen application rate is only $6.99/acre (2656 lb air dry forage per acre valued at $.0044/lb equals $11.69 minus $1.50 nitrogen application costs minus 26.5 lb N priced at $.1207), we may conclude that it is not profitable to apply nitrogen to the White site if the forage is harvested by livestock. As indicated in Table 4, at average AUM and nitrogen prices none of the three sites studied responded sufficiently to nitrogen application to cover the costs of the fertilization program. However, a small rise in AUM price (or a small decrease in nitrogen price) would allow fertilization to become a profitable practice on the semiwet meadow site.

This report analyses only the forage production response occurring the initial year following fertilizer application. If there is a significant carryover effect into the second or possibly the third growing season following nitrogen application, it is likely that fertilization to augment range forage will prove profitable on some sites studied. Our initial results also indicate that nitrogen application hastens spring range-readiness. Alleviating the spring range "bottleneck" may, by itself, economically justify nitrogen application. Both carry-over production and advanced range-readiness will be analyzed in detail in the second phase of our range fertilization work.

Summary and Conclusions

Although numerous studies have demonstrated that range fertilization is an effective means of increasing livestock forage, economic analyses of this practice have been few and inconclusive. This paper reports the results of an economic evaluation of nitrogen and phosphorous application on six Utah range and meadow sites. None of the sites studied responded to phosphorous application, but forage production of three of the sites was significantly increased by applying ammonium nitrate.

Standard marginal economic analysis indicated that when the forage was harvested for hay, nitrogen application was a profitable practice on the semiwet meadow and mountain loam sites. Fall application offered a definite economic advantage over spring application on both sites.

Nitrogen application to augment range forage harvested directly by livestock proved uneconomical on all sites studied. Application of nitrogen would become profitable on the semiwet meadow site if AUM price increased slightly or if there was a small decrease in nitrogen price. Initial results also indicate that nitrogen application hastens spring range-readiness. This benefit alone may provide economic justification for nitrogen fertilization of rangelands.

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