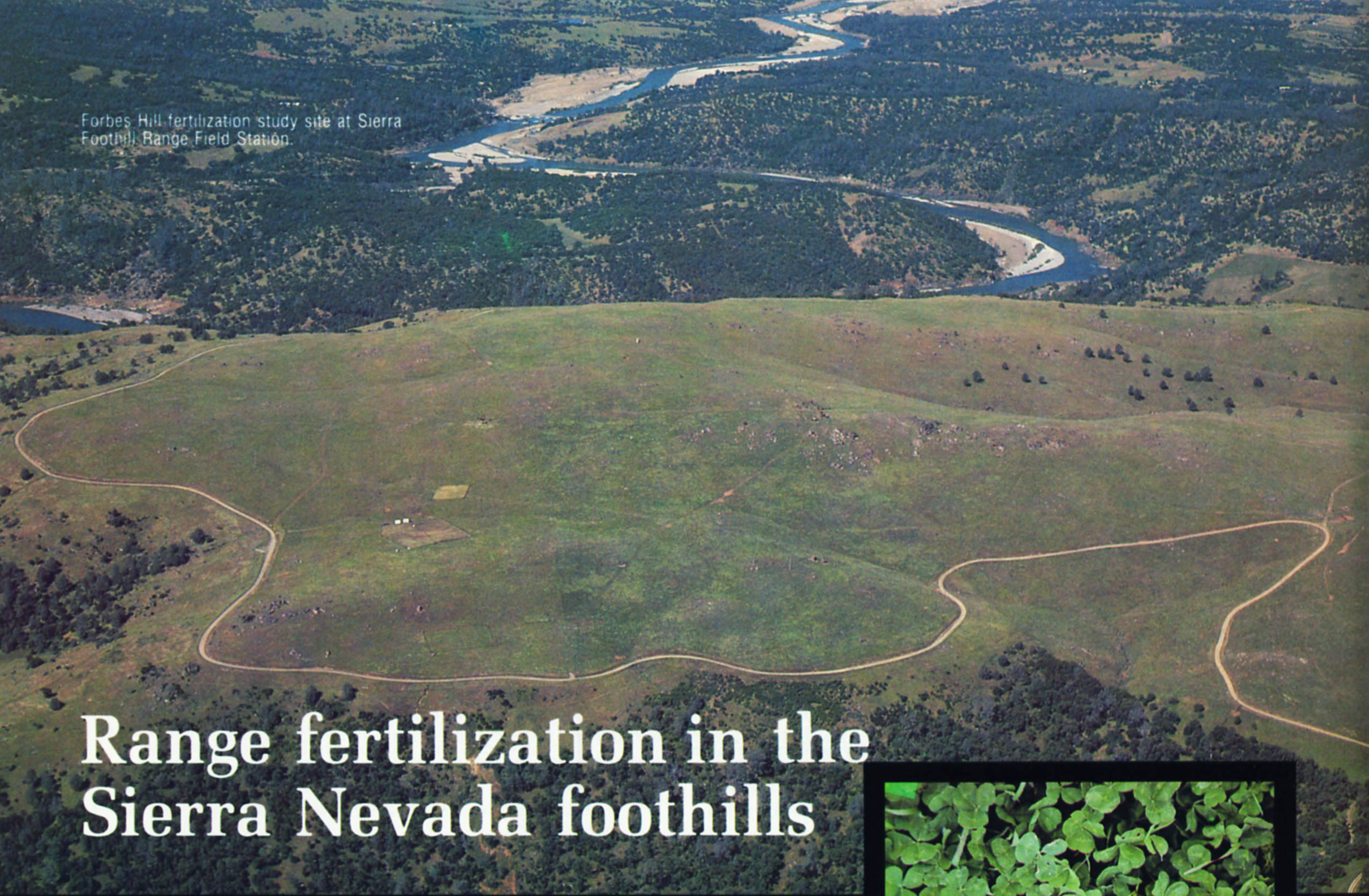

Forbes Hill fertilization study site at Sierra Foothill Range Field Station.

Range fertilization in the Sierra Nevada foothills

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Enough additional beef in pounds per acre had been produced on fertilized rangeland within a year to almost cover costs of fertilization. Addition of phosphorus and sulfur resulted in luxuriant growth of subclover and rose clover (above right). The use of an electronic capacitance forage meter made it possible to adjust stocking rates to match forage biomass level (right).

Following a year of preliminary experiments, a long-term, field-scale foothill range fertilization study began in 1982 with a series of precise applications to 385 acres of foothill rangeland comprising 12 fields on Forbes Hill at the University of California Sierra Foothill Range Field Station, Browns Valley. Because deficiencies of three major elements — nitrogen, phosphorus, and sulfur — limit production on soils of the region, we established the study to compare nitrogen alone, phosphorus plus sulfur, and combinations of the three elements. Since results from these treatments could be expected to differ from each other over time (irrespective of level of nutrient applied) it was essential to initiate treatments simultaneously, so that comparisons could be made within the same weather years.

The study "Phase I" period of three years will permit assessment of nitrogen carryover from the first-year application of nitrogen, a well as provide an opportunity for the phosphorus-sulfur influence on annual clovers to be expressed through clover growth, symbiotic nitrogen fixation, and the expression of nitrogen carryover from the clover source.

We are using yearling steers and heifers to evaluate yield and quality differences in a randomized complete block design with two replications. Although initially designed as a three-year study, the work may be extended by re-application of treatments if appropriate.

Site characteristics

The Forbes Hill site consists of approximately 520 acres of totally cleared foothill rangeland with an average elevation of about 1,000 feet (ranging from 700 to 1,288) and slopes generally not exceeding 30 percent. Aspects are east/north-easterly or south/south-westerly. Soils, as is typical for this region, are highly diverse, but generally of the Sobrante-Las Posas-Auburn-Argonaut series complex.

Vegetation conversion had been carried out between 1961 and 1974, in which blue oaks were cleared, fence, land, and stockwater facilities were added to provide 16 fields of equal size (about 33 acres), and the area was seeded with an annual legume mixture, primarily sub and rose clovers. Since then, several range livestock management experiments have been conducted on the fields. Measurements of botanical composition since 1975 indicate that, after a three- to four-year period of stand increase, annual clover populations have stabilized at 35 ± 10 percent.

During the 1981-82 season, extensive soil samples were taken in all 16 fields. Test values include soil pH (5.9), ppm phosphorus (5.1), and milliequivalents per 100 grams of calcium, magnesium, potassium, and cation exchange capacity (15, 3.5, 118, and 21, respectively). Soil sulfur was not analyzed because of the uncertain relationship between soil tests and plant growth for this element.

Preliminary fertilizer rate experiments (nitrogen, phosphorus, and sulfur) were conducted at eight locations, four each of the east/north-easterly- or south/south-westerly-facing aspects. Simultaneously, enough soil was collected from these eight plot sites to do a greenhouse pot experiment, wherein a simulated mixture of resident grasses and legumes was subjected to a series of nitrogen, phosphorus, and sulfur rates and combinations (table 1). Finally, a preliminary calibration grazing, from March 9 to June 8 (following earlier grazing use), used yearling beef steers at a constant and uniform stocking rate of 2.75 acres per steer.

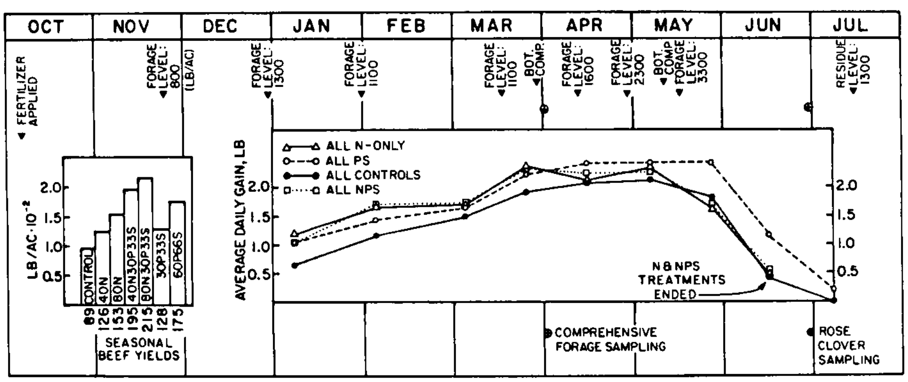

Fig. 1. Diagram of first-year schedule and selected livestock responses.

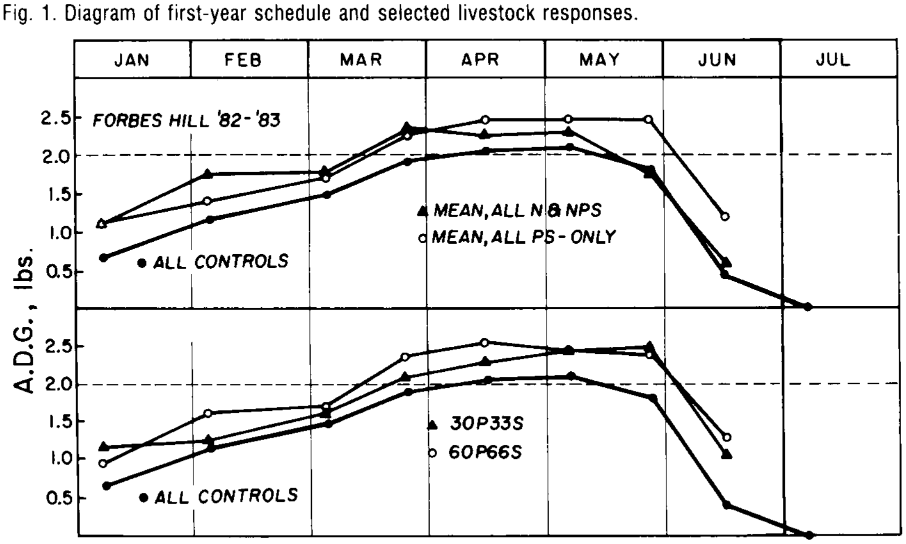

Fig. 2. Range fertilization with nitrogen alone or with phosphorus and sulfur increased gains early in season; phosphorus and sulfur used alone also extended the period of gains.

TABLE 1. Yields of a grass-clover mixture grown in soil composited from eight locations on Forbes Hill research site: preliminary studies*

Equivalent application rates† N	P	Yield: Grass	Clover	Total
kg/ha		mg/pot		
0	0	420	440	860
40	0	590	490	1080
80	0	600	460	1060
120	0	680	500	1180
0	15	600	620	1220
40	15	1010	600	1610
80	15	1110	680	1790
120	15	1150	640	1790
0	30	620	740	1360
40	30	1130	700	1830
80	30	1260	740	2000
120	30	1430	700	2130
0	45	700	750	1450
40	45	1180	710	1890
80	45	1380	710	2090
120	45	1620	810	2430
	$\bar{X}$	960	640	1600
	$lsd_{.05}$	130	100	160
	$lsd_{.01}$	170	130	210

Sulfur exploratory

N	P	S	Grass	Clover	Total
0	0	100	430	430	860
40	15	100	1190	610	1800
80	30	100	1900	820	2720
120	45	100	2530	950	3480
		$\bar{X}$	1510	700	2210
		$lsd_{.05}$	120	100	170
		$lsd_{.01}$	160	140	230

*Greenhouse pot experiment by M. B. Jones at UC Hopland Field Station.

†Nitrogen (N) and phosphorus (P) rates in kilograms per hectare (x0.89 = pounds per acre) equivalent.

TABLE 2. Preliminary analysis of first year economic returns and selected livestock responses to range fertilization rates: field study, Forbes Hill, UC-SFRFS.

Treatment	Treatment cost*	Extra gain needed†	Beef produced 03/25/83‡	Net return from treatment 03/25/83	Beef produced 06/16/83§	Net return from treatment 06/16/83	Total seasonal beef gain	Peak seasonal ADG	Stocking rate Mar 4-May 6
lb/acre	*$/acre*	*lb/acre*	*lb/acre*	*$/acre*	*lb/acre*	*$/acre*	*lb/acre*	*lb/day*	*acre/animal*
Untreated control	—	—	45	—	88	—	89	2.10 (5-6)	2.7
40N	17	27	71	-0.60	126	6.20	126	2.31 (5-6)	2.0
80N	28	47	92	0	153	10.50	153	2.49 (3-25)	1.6
40N+30P+33S	32	51	107	6.80	195	34.10	195	2.35 (4-15)	1.26
80N+30P+33S	44	71	127	6.80	215	34.10	215	2.34 (4-15)	1.09
30P+33S	15	24	53	-9.90	128	9.30	128	2.45 (5-27)	2.7 **
60P+66S	25	41	70	-9.90	175	27.90	175	2.51 (4-15)	2.0 ††

* Includes costs of fertilizer materials, plus $4.25/acre application cost ($8.50 for N + PS treatments), and interest charges at 12% for eight months. Values rounded to nearest dollar.
† Lb/ac beef over control at $0.62/lb. Values rounded to nearest lb.
‡ Rounded to nearest lb.
§ Grazing on all treatments except 30P + 33S and 60P + 66S was ended on June 16, 1983.
** Increased to 1.3 on May 16, 1983.
†† Increased to 1.0 on May 16, 1983.

Field study, year 1

The fertilizer treatments applied by helicopter in the field study are given in table 2 and figure 1. During the 1982-83 season, weather favorable to annual legume growth resulted in striking responses of the previously seeded subterranean and rose clover to the phosphorus-sulfur treatments, particularly at the higher rate. Spring clover biomass levels approaching 2 tons per acre were measured as forage growth rates of up to 100 pounds per acre per day outstripped rates of livestock utilization.

Stocking rates, set initially (early December) at 5.5 acres per steer (average weight 478 pounds), were increased on January 7, 1983, and again on March 4. Within the overall experiment, stocking rates varied by about 2.5-fold, with the highest rates at or slightly over 1 acre per animal. Since forage levels had been monitored throughout the season, with a capacitance forage meter, it was possible to adjust stocking rates on the basis of equalized grazing pressure (weight of animal per unit weight of forage available). The final adjustment in stocking rate was on May 16, after it became apparent that additional stocking would be needed in the phosphorus-sulfur-treated fields to use the late-season flush of clover growth and equalize residue levels. Grazing ended on June 16 on most treatments following two consecutive weigh periods of declining average daily gain. Grazing on the two phosphorus-sulfur treatments and two control fields ended on July 7.

Seasonal patterns of average daily gain were clearly defined (see examples in fig. 2), since cattle weights were taken at three-week intervals during the period of rapid changes in plant growth and livestock performance. The use of nitrogen, alone or with the lower level of phosphorus and sulfur, increased average daily gain during the early part of the grazing season, while the use of phosphorus and sulfur alone extended the period of maximum average daily gains.

Since it was not possible to employ multiple stocking rates for all the treatments, some uncertainty remains as to the influence of grazing pressure on average daily gain. The use of defined low- and high-end biomass levels to delineate critical stocking rate adjustment levels is well accepted in other countries, and this relationship deserves additional study as it applies to California variants of the Mediterranean annual range plant system.

It was apparent that three distinct phases of livestock performance existed for the conditions of this experiment. A low to moderate, and steadily rising, average daily gain characterized the winter season, typified by "washy feed" or inadequate intake levels and stresses of cold, wet weather on the livestock. This period was followed by a plateau of optimal average daily gains representing the peak integration of forage growth and quality with the genetic and physiological potential of the animal for conversion. Finally, sharply declining gains marked the period of rapidly declining forage quality. Marked expression of animal selective consumption of plants was apparent, making management at this stage difficult, since forage biomass levels are also likely to be at their highest. Increasing weight of the consuming animal also plays a role (average weight on May 27 was 810 pounds) as the potential for conversion declines.

Economic analysis

Of paramount importance to the livestock producer are the economic implications and associated risks of various management and resource input alternatives. Table 2 shows the dollars and cents outcome of the various treatments, as they were stocked, for this first year of the study.

On March 25, 1983, sufficient beef (pounds per acre) had been produced to almost cover costs of fertilization for nitrogen alone and nitrogen-phosphorus-sulfur treatments, while the phosphorus-sulfur treatments had not yet paid for themselves.

At the end of the grazing season (June 16), all treatments had a positive net return. The nitrogen alone and lower rate of nitrogen-phosphorus-sulfur had the lowest net return, although these treatments reached the break-even point in late March before the phosphorus-sulfur treatments. The phosphorus-sulfur treatments maintained their productivity longer than the nitrogen and nitrogen-phosphorus-sulfur treatments, thus narrowing the difference in net return by June 16.

In years two and three, we will evaluate the effects of fertilizer carryover, legume seeding, and weather variability. Using additional data from this experiment Olson and George will employ advanced economic models to analyze both the expected returns and the variation in those returns.

Given favorable growing weather, we expect the second year to provide an assessment of benefits from the nitrogen fixed by the past season's growth of clover. Since the rainfall total for 1982-83 was about 45 inches, little carryover effect is likely to occur from the nitrogen initially applied. We expect to pay particular attention to the period when rapid growth changes occur in the forage, along with heightened selective consumption and sharply declining livestock gains. We did some sampling in the 1982-83 season using fistulated steers. Results from these samples, as well as from others taken for chemical constituent and rumen analyses will be used as a basis for a more definitive investigation of the relationships between agronomic characteristics of seasonally maturing range forage, its selective consumption, and performance of the consuming animal.

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