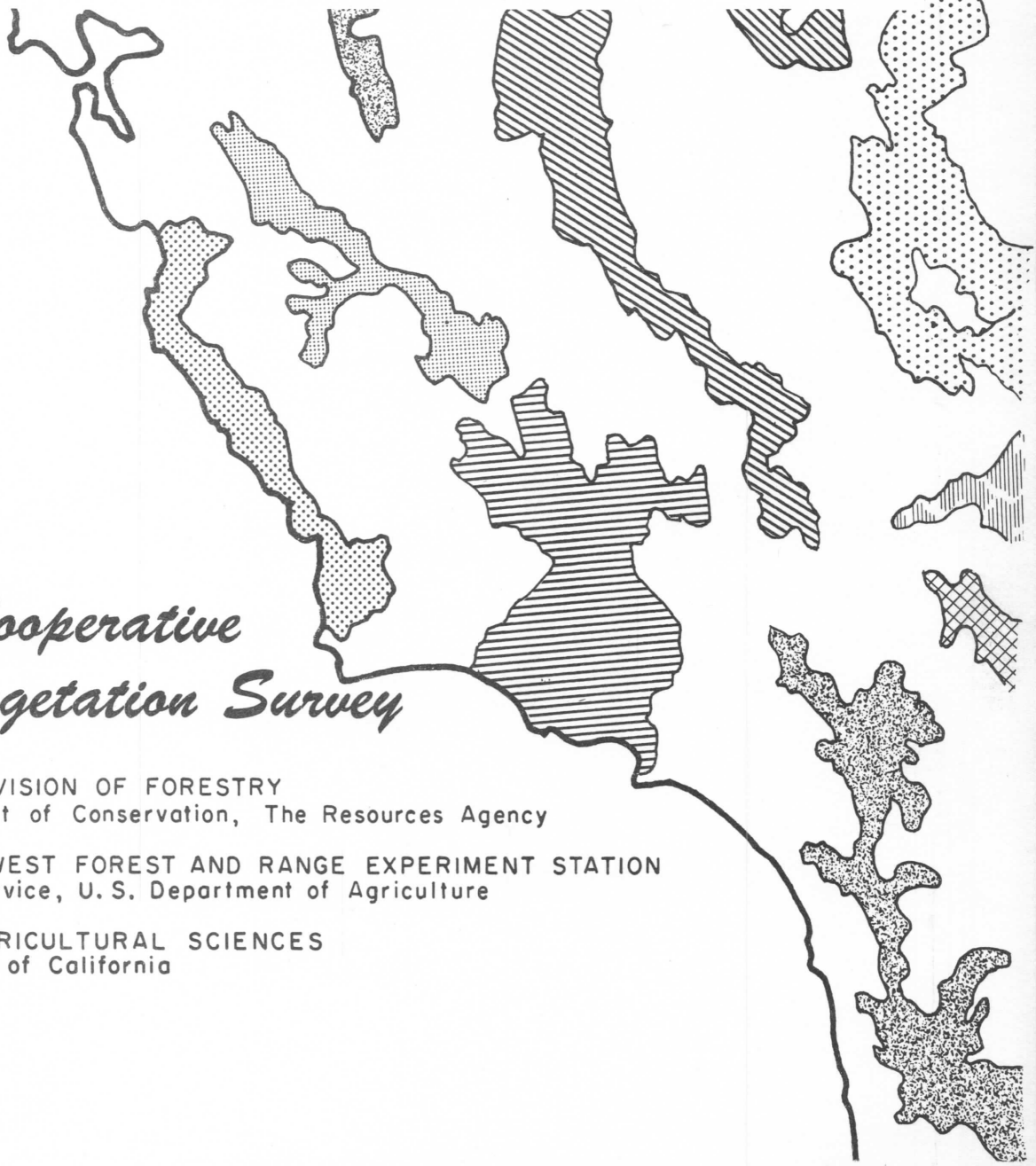
RELATION OF SPECIES COMPOSITION, HERBAGE PRODUCTION, AND FERTILITY ON MILLSAP SOILS



State Cooperative Soil-Vegetation Survey

CALIFORNIA DIVISION OF FORESTRY
Department of Conservation, The Resources Agency

PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION
Forest Service, U. S. Department of Agriculture

DIVISION OF AGRICULTURAL SCIENCES
University of California

EDMUND G. BROWN
Governor

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Raymond A. Evans

W. Robert Powell

and

R. Merton Love

Published by

California Division of Forestry

Sacramento, California December, 1962

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FOREWORD

The State Co-operative Soil-Vegetation Survey in California is a co-operative undertaking of the California Division of Forestry, the University of California, and the Pacific Southwest Forest and Range Experiment Station. The principal objective of the survey is to obtain basic information on the kind and distribution of upland soils and vegetation, their relationships, and their characteristics and uses as an aid in better management of wild lands.

The Survey, which was begun in 1947, was expanded in 1953 to include a more intensive inventory of grassland areas, for which the Department of Agronomy, University of California, Davis, assumed responsibility. The types of information developed and methods used in the grassland inventory are described on the following pages.

RELATION OF SPECIES COMPOSITION, HERBAGE PRODUCTION, AND FERTILITY ON MILLSAP SOILS 1/

Raymond A. Evans, W. Robert Powell, and R. Merton Love 2/

Information needed for more intensive management of wild land areas is being compiled by the State Co-operative Soil-Vegetation Survey. This paper describes the kind of information that will be useful particularly on rangeland. Objectives of this paper are to describe methods used in obtaining grassland information in the Survey, and to illustrate the information obtained by presenting data collected for one soil series--Millsap.

The methods were designed to assess existing conditions with regard to vegetation composition, soil fertility, and herbage production on Millsap soils, and to investigate changes which occurred when the soil fertility level was manipulated by addition of certain nutrients.

The information developed is being used by service organizations such as the California Division of Forestry and the University of California Agricultural Extension Service as a basis for making recommendations for land management. This information is also opening avenues of research in the problems of more intensive management of California range lands.

1/ Based on paper given before the Western Society of Soil Science, Logan, Utah, June 18, 1958.

2/ Range Conservationist, Crops Research Division, Agricultural Research Service, U.S. Department of Agriculture, Reno, Nevada (formerly Assistant Specialist, University of California, Davis, California); Assistant Specialist, and Professor of Agronomy, respectively, University of California, Davis, California. The authors acknowledge the technical assistance and advice on soils given by Kenneth D. Gowans and Eugene L. Begg, Department of Soils and Plant Nutrition, University of California, Davis, California. Appreciation is extended to Lin V. Maxwell, Tehama County Farm Advisor, for help with the field fertilizer trial.

GRASSLAND ASPECTS OF THE SOIL-VEGETATION SURVEY

One phase of the grassland study relates per cent cover of herbaceous species to soil series and phases. With knowledge of soil-vegetation relations, together with recent grazing history, composition and cover of woody vegetation, aspect, and slope, one may estimate, within broad limits, the herbage yield and grazing capacity of individual soils under an extensive level of management.

The other phase of the study is determination of the effect of fertilization on herbage production of these soils. Most soils of upland areas in California are low in nitrogen; many are also low in phosphorus and sulfur. Objectives with respect to fertility are (a) to determine nutrient-deficiency patterns within and among soil series with respect to nitrogen, phosphorus, and sulfur, (b) to measure yields produced by addition of various nutrients and nutrient combinations to the soil, and (c) to determine the effect of added nutrients on botanical composition--measured in per cent cover. Greenhouse pot tests of soils provide information about nutrient-deficiency patterns. Field fertilizer trials provide a measure for evaluating total herbage productivity and changes in botanical composition resulting from nutrient treatments, under field conditions.

With this information, plus the known characteristics of the soil as defined by a soil series and given in each standard soil series description, one may predict, within limits, the productivity potential of individual soils under more intensive management involving manipulation of fertility levels.

DESCRIPTION OF SOIL SERIES AND STUDY AREA

Soils of the Millsap series occur at elevations of 900 to 2,000 feet in the eastern foothills of the North Coast Ranges along the western side of the Sacramento Valley (fig. 1). About 50,000 acres of Millsap soils have been mapped in Glenn and Tehama counties, the vast majority being in Tehama County. Narrow strips extend north into western Shasta County and probably also south into Colusa County. They are derived from the Shasta Formation, in which sandstones and shales are the dominant rocks. Millsap soils, belonging to the Noncalcic Brown great soil group, are well-drained and medium-textured. They are moderately shallow with a well developed textural B horizon. Reaction is slightly acid to neutral throughout the profile. A typical profile of Millsap clay loam has an A horizon of loam, about eight inches thick; and a B horizon of light clay about 11 inches thick which contains shale fragments.

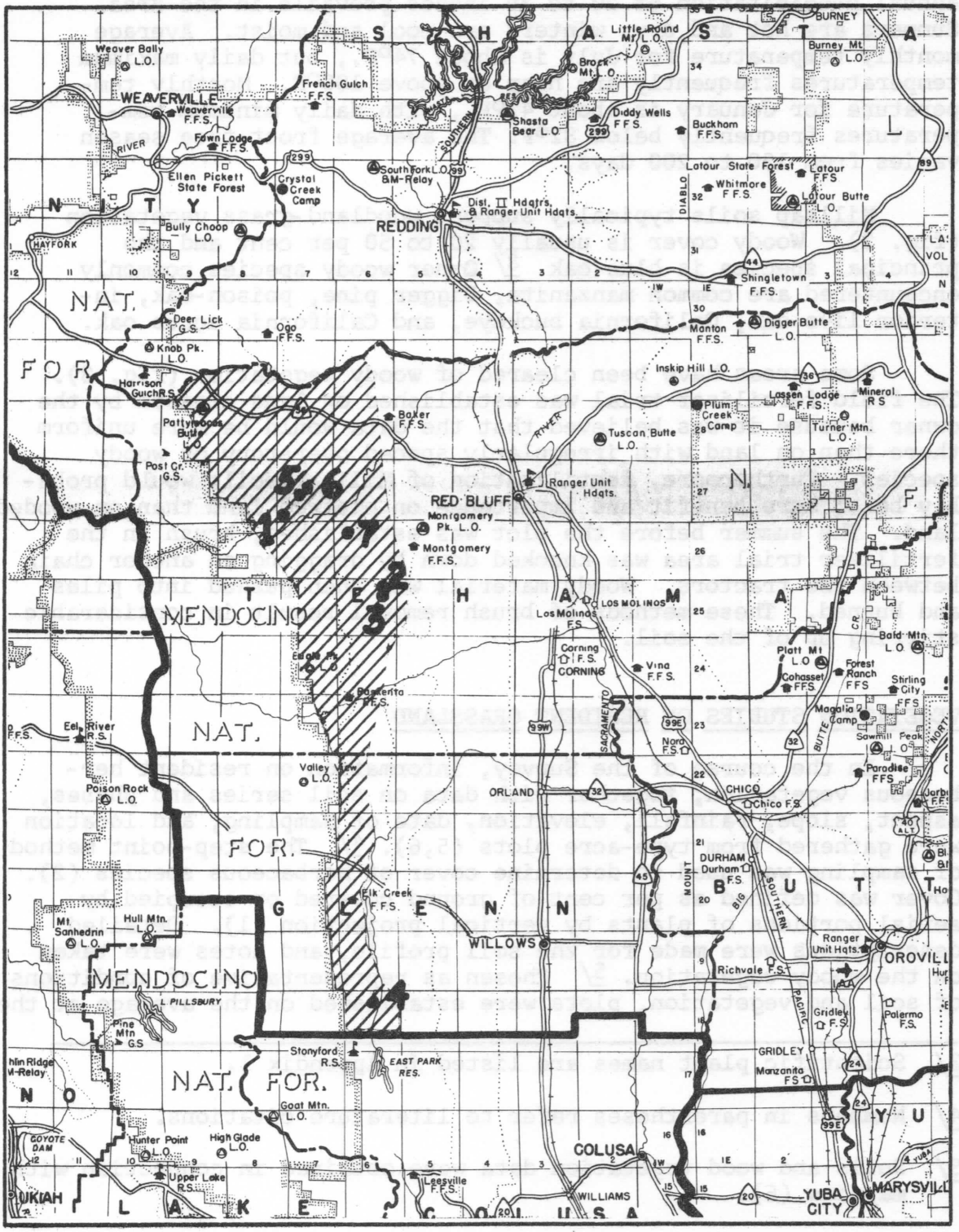

Fig. 1. Location of type-acre plots, and general extent of the Millsap soils.

A humid, mesothermal (Mediterranean) climate having a mean annual precipitation of 20 to 30 inches prevails in the area. Summers are hot and dry; winters are cool and moist. Average monthly temperature for July is about 74°F., but daily maximum temperatures frequently are near or above 100°F. Monthly temperature for January is about 42°F., with daily minimum temperatures frequently below 32°F. The average frost-free season varies from 130 to 200 days.

Millsap soils typically support woodland-grass vegetation (fig. 2). Woody cover is usually 20 to 50 per cent and the principal species is blue oak. 3/ Other woody species commonly encountered are common manzanita, Digger pine, poison-oak, interior live oak, California buckeye, and California scrub oak.

Some areas have been cleared of woody vegetation (fig. 3). The field fertilizer trial was established on land cleared by the owner because it was believed that the data would be more uniform there than on land with irregularly spaced overstory of woody species. Furthermore, fertilization of Millsap soils would probably be of more benefit and importance on cleared land than on wooded land. The summer before the plot was established, brush in the fertilizer trial area was knocked down by dragging an anchor chain between two tractors. Woody material was then pushed into piles and burned. These methods of brush removal result in considerable stirring up of the soil.

VEGETATION STUDIES ON RESIDENT GRASSLAND

In the course of the Survey, information on resident herbaceous vegetation, together with data on soil series and phases, aspect, slope, rainfall, elevation, date of sampling, and location were gathered from type-acre plots (5,6). 4/ The step-point method of sampling was used to determine cover of herbaceous species (2). Cover was defined as per cent of ground covered or occupied by aerial portions of plants by vertical projection (1). Detailed descriptions were made for the soil profile, and notes were taken on the woody vegetation. 5/ Chosen as representative of conditions of soil and vegetation, plots were established on the average at the

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3/ Scientific plant names are listed in Appendix 1.

4/ Numbers in parentheses refer to literature citations.

5/ Soils and wood vegetation data were obtained in connection with mapping (6).

Fig. 2. Typical open woodland-grass vegetation associated with Millsap soils. Blue oak is the woody species.

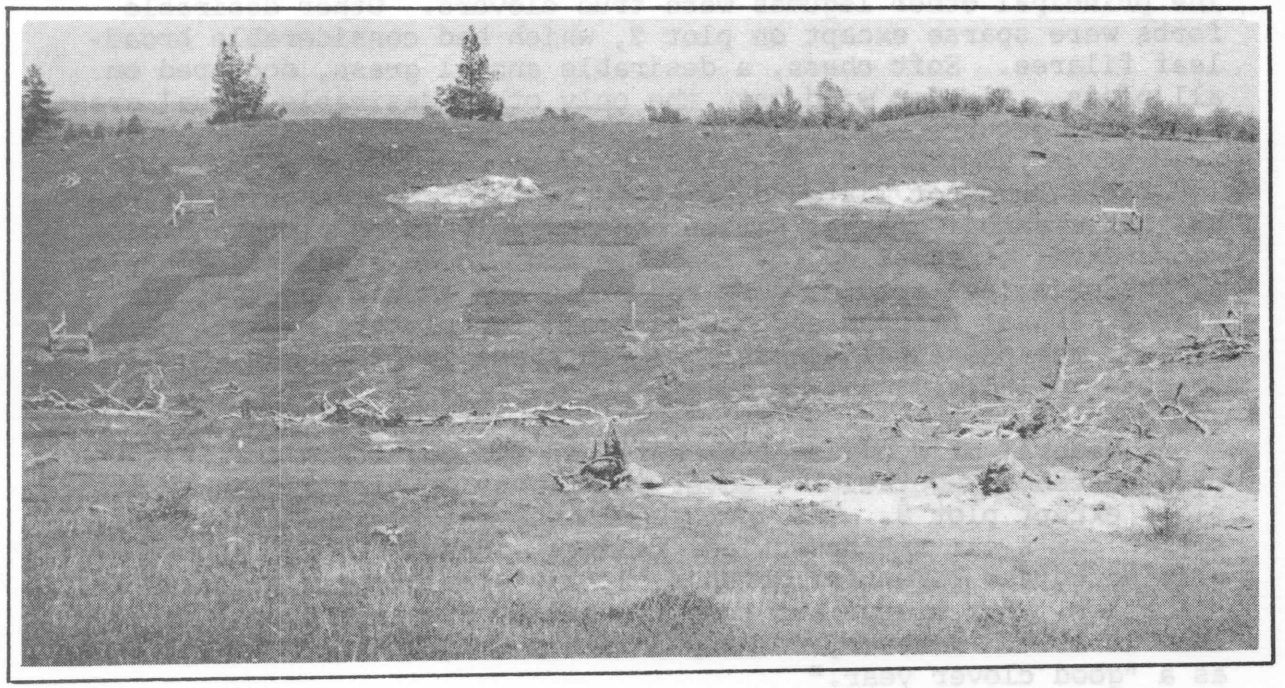

Fig. 3. A cleared area of Millsap soil. The field fertilizer trial is shown in the center of the photo. Dark blocks in the fertilizer trial are early spring growth of broad-leaf filaree in response to nitrogen application.

rate of one for every 2,000 acres. Type-acre plots were not established in a regular pattern in the Survey area and appeared to be scattered at random. Such plots occurred on Millsap soils 11 times. Seven of these are discussed here. At four plot locations, soil samples were collected for greenhouse tests; and the field fertilizer trial was established adjacent to one of these four (fig. 1 and appendix 2).

While most plot sites were intended to be representative of soil and vegetation of an area delineated for mapping purposes, a plot site would not necessarily have a soil profile that agrees modally with a soil series description. In fact, some plots were established for study because conditions were unusual, different, or extreme. However, the four sites selected for fertility studies reported in this paper were considered to be typical of the Millsap series.

Cover of herbaceous vegetation is shown in table 1. Some plots were sampled at more than one date. All except plot 7, from which woody vegetation had been removed, had a woody overstory of 20 to 50 per cent cover. Total cover is for herbaceous vegetation only, and disregards cover of woody species.

Although herbaceous vegetation on Millsap soils varied greatly in cover and botanical composition, certain general statements can be made. Consider first the plots with woodland overstory. Total cover was low except on plot 3. Perennial grasses constituted a negligible proportion of the composition. The legume component was minor except again on plot 3, which had considerable bur clover. The principal other legumes were true clovers. Other desirable forbs were sparse except on plot 2, which had considerable broad-leaf filaree. Soft chess, a desirable annual grass, occurred on all plots. Slender wild oat, the only other desirable annual grass recorded, occurred on most plots.

Although not listed separately in the table, species of undesirable annual grasses varied considerably among plots and also among dates of sampling for the same plot in some cases. For plot 1, the principal species were red brome and annual fescues; for plot 2, annual fescues and medusa-head; for plot 3, ripgut. For plot 4, the principal species was red brome in 1955, but annual fescues in 1957.

Removal of woody species affected the cover and composition of herbaceous vegetation. Cover was higher on plot 7 than on other plots except plot 3. The increased cover was composed mainly of smooth cat's-ear and broad-leaf filaree. Brush removal apparently eliminated the perennial grasses, if any were present prior to the operation. Bur clover and true clovers were more abundant in 1958 than in 1957. However, in many areas of California, 1958 was known as a "good clover year."

In the case of the undesirable annual grasses, differences in composition were apparently the result of differences inherent in

Table 1. Cover of herbaceous species on type-acre plots on Millsap soils.

Species or groups	Plot number and date(s) of sampling												
	1	2	3	4			5		6		7		
	Sep 55	May 59	Mar 55	May 55	Apr 57	Jun 57	Apr 57	Jun 57	Apr 57	Jun 57	Apr 57	Jun 57	May 58
	(- - - -

the location of the sample. Location differences most probably accounted for the uniqueness of plot 3 with its high total cover and substantial proportion of bur clover. On the other hand, differences among samples taken at the same location in different years must be attributable to weather or to livestock and land management. To have "good clover years" distribution of rainfall and temperature are outstandingly important. Also to be kept in mind is that livestock and land management may contribute to differences not only within the same plot from year to year but also among plots (4).

GREENHOUSE POT TESTS

Four surface samples (0-8inches) of Millsap soils were collected and pot tested for nitrogen, phosphorus, and sulfur deficiencies. Results of the tests were subjected to statistical analysis to indicate the deficiency patterns.

Soft chess was used as the indicator plant because of its wide distribution on California range lands. The plant is easy to grow and reflects the soil nutrient level with respect to nitrogen,6/ phosphorus, and sulfur. A four-replicated, randomized block, factorial design with four replications was used, with three rates 7/ of nitrogen (none, 50 pounds, and 200 pounds per acre), and three rates of phosphorus (none, 22 pounds, and 88 pounds per acre). Sulfur (100 pounds per acre) was used in combination with high nitrogen and high nitrogen-high phosphorus applications. Nitrogen was applied as ammonium nitrate, phosphorus as phosphoric acid, and sulfur as sodium sulfate in water solutions to soil in 6-inch flower pots. Nutrient applications were calculated on the basis of soil weight; it was assumed that the top 6 inches of soil on an acre weighed 2 million pounds.

Each pot was filled with 1,600 grams of air-dry soil that had been processed through a soil-shredder and then put through a ¼-inch screen to remove pebbles and gravel. Pots were painted on the inside and bottom with black asphaltum varnish and on the outside with aluminum paint. Pot saucers were painted with varnish on the inside. Pot tests were conducted in the greenhouse under favorable growing conditions. Enough distilled water was supplied so that plants were never under moisture stress. Temperatures were also partially controlled. All top growth was harvested and oven-dried 8 weeks after planting (3).

6/ When the element is written out it refers to the element in general. When the chemical symbol is used it means a particular treatment: thus, N_1 is a low nitrogen application; N_2P_1 is a high nitrogen plus low phosphorus application.

7/ Rates are given in pounds of the element: 22 and 88 pounds of phosphorus are 50 and 200 pounds of P_2O_5, respectively.

Results from the pot tests (table 2) indicated sample A to be distinctly deficient in nitrogen and slightly deficient in phosphorus and sulfur; sample B distinctly deficient in nitrogen and slightly deficient in sulfur; sample C distinctly deficient in nitrogen and sulfur; and sample D distinctly deficient in all three nutrients.

Table 2. Top growth of soft chess from four surface samples of Millsap soils (per 4 pots, oven-dry).

Treatment 1/	Sample A		Sample B		Sample C		Sample D 2/	
	grams		grams		grams		grams	
Check	5.4	a 3/	10.8	ab	7.4	a	7.4	a
P_1	5.3	a	7.9	a	6.2	a	6.9	a
P_2	5.8	a	11.2	ab	7.2	a	7.4	a
N_1	12.8	b	14.1	bc	13.9	b	12.1	b
N_1P_1	13.9	b	15.0	bc	13.9	b	14.4	bc
N_1P_2	11.9	b	16.4	c	15.4	bc	16.1	bcd
N_2	23.7	c	24.0	d	17.6	bc	15.9	bcd
N_2P_1	25.7	cd	25.0	de	19.6	cd	16.1	bcd
N_2P_2	26.1	cd	27.1	de	23.1	d	18.8	cd
N_2S	24.9	c	29.6	e	31.5	e	19.3	d
N_2P_2S	29.3	d	27.1	de	35.7	e	31.7	e

1/ N_1 = 50 lb. N_2 = 200 lb. of nitrogen per acre
P_1 = 22 lb. P_2 = 88 lb. of phosphorus per acre
S = 100 lb. of sulfur per acre

2/ Sample D collected at site of the field fertilizer trial

3/ Weights within a sample not followed by the same letter are significantly different, .05 level, Duncan's multiple range test.

There was no difference between the low and high rates of phosphorus with or without nitrogen for any sample. In sample C, there was a significant difference between N_2 and N_2P_2 but the meaning is doubtful since N_2P_2S is not significantly better than N_2S. N_1 and N_2 were significantly different for samples A and B but not for C and D. Before drawing conclusions about rates, however, one should conduct further studies of nitrogen and phosphorus rates in presence of sulfur, since sulfur interactions were

indicated in samples C and D.

On the basis of these pot tests one would recommend nitrogen as the only needed fertilizer nutrient in areas of Millsap soils characterized by samples A and B. In areas characterized by sample C, nitrogen and sulfur would be necessary, and in areas characterized by sample D the application of all three nutrients would be essential for maximum yield.

Obviously then, all Millsap soils cannot be characterized as having a similar availability of nutrients. Therefore, an accurate blanket fertilizer recommendation for the soil series cannot be made.

Sample D was taken from an area from which woody vegetation had recently been removed. The method of brush removal might have been a factor in the deficiency pattern for phosphorus. If the woody material had been left in place and burned, a different nutrient pattern might have been obtained. Stirring of the soil could be responsible for the response of phosphorus since it was determined that lower layers of Millsap soils are more deficient in available phosphorus than the surface layers in undisturbed sites (table 3).

Table 3. Available phosphate in two Millsap soil profiles.

Profile Number	Depth, inches	PO_4, p.p.m. 1/
1	0-6	.23
	6-17	.03
2	0-2	.91
	2-9	.35
	9-21	.04
	21-31	.14
	31-39	.08

1/ Determined by Bingham water-extraction method at Cooperative Soil Survey and Soil-Vegetation Survey Laboratory, University of California, Berkeley.

Pots for sample D just before harvesting are illustrated in figure 4. The reader's attention is called to the robustness of plants in the $N_{200}S$ (=N_2S) and $N_{200}PS$ (=N_2P_2S) pots. Note, however, the additional height of plants in the $N_{200}PS$ pots compared with those in $N_{200}S$. In general, added nitrogen produced plants of distinctly darker green color.

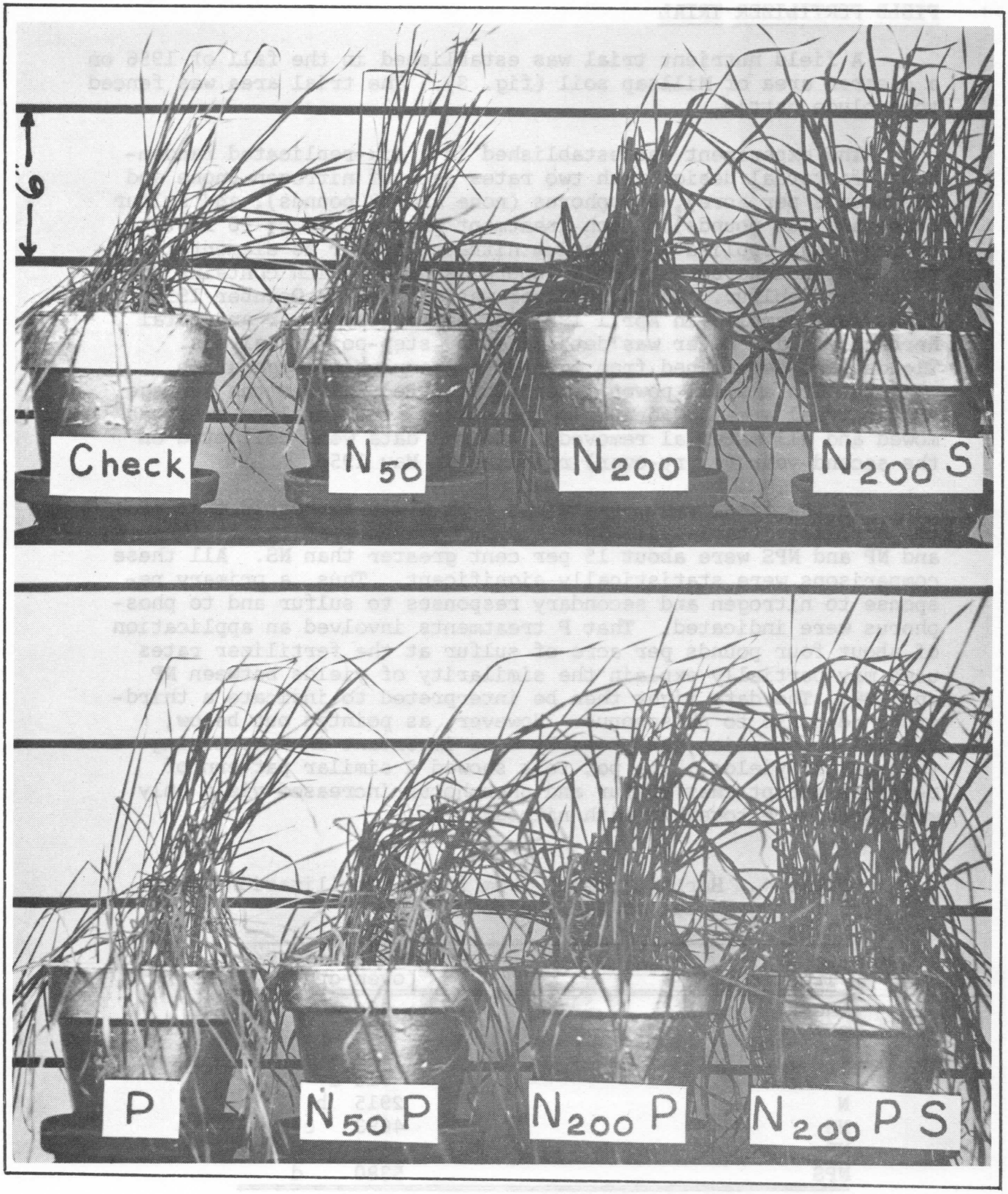

Fig. 4. Differential growth of soft chess in response to various nutrient combinations added to soil sample D. Numbers indicate rates of application of nitrogen. Phosphorus was applied at 88 pounds and sulfur at 100 pounds per acre.

FIELD FERTILIZER TRIAL

A field nutrient trial was established in the fall of 1956 on a cleared area of Millsap soil (fig. 3). The trial area was fenced to exclude cattle.

The experiment was established in a six-replicated random-block factorial design with two rates each of nitrogen (none and 150 pounds per acre), phosphorus (none and 88 pounds), and sulfur (none and 100 pounds). Each treatment plot was 10 by 20 feet. Nitrogen was applied as ammonium nitrate, sulfur as elemental sulfur, and phosphorus as treble superphosphate, which contains about 1 per cent sulfur. The fertilizer was applied in October 1956. Plots were sampled in April 1957 for herbaceous cover and total herbage yield. Cover was determined by step-point analysis. Yields were determined from oven-dried samples of vegetation clipped with a small power mower (Scythette). After the herbage on the trial area had dried in the summer, the complete area was mowed and all material removed. Limited data were collected on the second-year (carry-over) response in May 1958.

In the first year, the yield from N was threefold that from no fertilizer (table 4). NS was about 60 per cent greater than N; and NP and NPS were about 15 per cent greater than NS. All these comparisons were statistically significant. Thus, a primary response to nitrogen and secondary responses to sulfur and to phosphorus were indicated. That P treatments involved an application of about four pounds per acre of sulfur at the fertilizer rates used may partially explain the similarity of yields between NP and NPS. The data might then be interpreted to indicate a third-order response to phosphorus. However, as pointed out below, species composition was probably more important in determining the similar yields. The pot test showed a similar pattern of response except that sulfur and phosphorus increased yield only when both were together with nitrogen.

Table 4. Herbage yields from field fertilization trial on Millsap soil.

Treatment 1/	Pounds per acre 2/ (oven-dry)
Check	894 a
S	709 a
P	980 a
PS	916 a
N	2915 b
NS	4693 c
NP	5368 d
NPS	5380 d

1/ N = 150 lb. of nitrogen, P = 88 lb. of phosphorus, and S = 100 lb. of sulfur per acre.

2/ Weights not followed by same letter are significantly different, .05 level, Duncan's multiple range test.

Table 5. Cover of herbaceous species on various fertilizer treatments of the field trial.

Species or groups	1st year response 26 April 1957								2nd year response (carryover) 8 May 1958		
	Check	S	P	PS	N	NS	NP	NPS	Check	NS	NPS
	(- - - -

Sulfur alone appeared to depress yield, although not significantly so. This depression was also reflected in the total herbaceous cover (table 5).

The most striking changes in botanical composition (table 5) resulting from fertilizer treatment were in relation to nitrogen application. Broad-leaf filaree increased about fourfold, soft chess increased about fivefold, while most forbs, notably smooth cat's-ear, decreased. Undesirable annual grasses were sparsely present throughout. Soft chess increased most with NS and broad-leaf filaree most with NP.

A more detailed inspection of species of treatments NP and NPS may reveal why the total yields were so similar. There was more soft chess with NPS than with NP, while the reverse was true for broad-leaf filaree. Thus, NPS would be expected to produce the greater net difference in yield. However, smooth cat's-ear was fairly abundant with NPS. This species forms a flat rosette close to the ground and, while contributing substantially in species composition, it contributes very little to the yield with sampling methods used.

Table 5 also has second-year data for several treatments. The greatest differences between years were more bur clover and other legumes (almost entirely true clovers) and less broad-leaf filaree in 1958. Smooth cat's-ear increased with no fertilizer and grasses increased with NPS when 1958 is compared to 1957.

The comparison of data for the two years emphasizes two points which must be kept in mind when interpreting the results of this fertilizer trial. First, fertilizer-weather interactions may have important effects on the botanical composition (4). Had the fertilizer trial been established in the fall of 1957, P, S, or PS may have caused significant yields because of the high proportion of bur clover in the stand. Second, the absence of grazing by livestock on the plot may affect the botanical composition (4). However, these limitations do not detract from the value of the data for indicating production potentials.

SUMMARY

From the general procedures of the Co-operative Soil-Vegetation Survey in California and methods presented here, information is being obtained concerning present and potential grassland productivity of soils involving manipulation of soil fertility. Results from studies with the Millsap soils illustrate the kinds of information being developed.

The Millsap soils generally support a woodland-grass vegetation. The woody overstory of 20 to 50 per cent cover consists mainly of blue oak. Herbaceous vegetation is composed of soft

chess, slender wild oat, red brome, annual fescues, medusa-head, ripgut, a small amount of other annual grasses, a very small amount of perennial grasses, broad-leaf filaree, cut-leaf filaree, bur clover, true clovers, and a number of other forbs. The composition varies from one location to the next and from year to year. Removal of woody vegetation increases herbaceous cover.

Pot test results of four samples of Millsap soils showed all to be primarily deficient in nitrogen. One sample was further deficient in sulfur and another in both sulfur and phosphorus.

Results of a field fertilizer trial on an area cleared of woody vegetation indicated increased herbage yield and species composition changes in relation to N, NS, NP, and NPS. In general nitrogen increased the percentage of broad-leaf filaree and soft chess. Bur clover and true clovers could be important on the plot in "good clover years," as a result of a favorable combination of weather factors.

LITERATURE CITED

1. BROWN, Dorothy. 1954. Methods of surveying and measuring vegetation. Commonwealth Bur. of Pasture and Field Crops Bul. 42. 223 pp.

2. EVANS, R. A. and R. M. LOVE. 1957. The step-point method of sampling - a practical tool in range research. Jour. Range Mangt. 10(5): 205-212.

3. JENNY, H., J. VLAMIS, and W. E. MARTIN. 1950. Greenhouse assay of fertility of California soils. Hilgardia 20(1): 1-8.

4. JONES, Milton B., and Raymond A. EVANS. 1960. Botanical composition changes in annual grassland as affected by fertilization and grazing. Agron. Jour. 42: 459-461.

5. UNIVERSITY OF CALIFORNIA (Davis), DEPARTMENT OF AGRONOMY. 1955. Field manual, grassland sampling. (Supplement No. 1 to Field Manual, Soil-Vegetation Surveys in California.) 14 pp. Processed, revised September 1959.

6. U.S. FOREST SERVICE, PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION. 1954. Field manual, soil-vegetation surveys in California. 95 pp. mimeo.

Appendix 1. List of Species

Common Name	Scientific Name
Annual fescues	Festuca spp.
Blue oak	Quercus Douglasii H. & A.
Broad-leaf filaree*	Erodium botrys (Cav.) Bertol.*
Bur clover	Medicago hispida Gaertn.
California buckeye	Aesculus californica (Spach) Nutt.
California scrub oak	Quercus dumosa Nutt.
Common manzanita	Arctostaphylos manzanita Parry.
Cut-leaf filaree	Erodium cicutarium (L.) L'Her.
Digger pine	Pinus Sabiniana Dougl.
Foothill plantain	Plantago Hookeriana F. & M. var. californica (Greene) Poe.
Interior live oak	Quercus Wislizenii A. DC.
Medusa-head	Elymus caput-medusae L.
Poison-oak	Rhus diversiloba T. & G.
Red brome	Bromus rubens L.
Ripgut	Bromus rigidus Roth.
Slender wild oat	Avena barbata Brot.
Smooth cat's-ear	Hypochoeris glabra L.
Soft chess	Bromus mollis L.
True clovers	Trifolium spp.

* Includes Erodium obtusiplicatum (Maire, Weiller, & Wilez.) J. T. Howell

Appendix 2. Sampling locations.

The following table gives the geographic location where the several vegetation and soil samples were taken. The reader may quickly determine which samples were taken at the same location. The equivalent official Soil-Vegetation Survey numbers are given for soil samples and the field nutrient trial.

Location				Type-acre Plot No. (Table 1)	Pot Test Soil sample Number (Table 2)	Phosphorus Soil Profile No. (Table 3)	Field Nutrient Plot No. (Tables 4 & 5)
Quad	Sec.	Twp.	Range*				
31D-2	31,	27N,	7W	1			
31D-4	11,	25N,	6W	2			
31D-4	11,	25N,	6W	3			
47A-1	9,	18N,	6W	4	A=FA55-11-10	1=56-11-16	
31D-2	27,	27N,	7W	5	B=FA57-52-1	2=56-52-3	
31D-2	22,	27N,	7W	6	C=FA55-52-2		
31D-4	8,	26N,	6W	7	D=FA56-52-10		52-3

*Mt. Diablo Base and Meridian