10. Seeded species of grasses and legumes made up half the total herbaceous vegetation the first year after brush removal. They made up only 17 percent 4 years after brush removal, due primarily to the almost total disappearance of annual ryegrass by the third year and a drastic reduction in Blando brome.

11. Seeded species made up a greater proportion of the herbaceous vegetation in the burned fields than in the bulldozed field for every year of record.

12. The results of the project point out ideas and proposals that should be considered for making greater gains in future brush range improvement programs:

    a. Increasing seeding rates of some species, such as rose clover and Hardinggrass, and reducing or eliminating some species, such as annual ryegrass and Blando brome, may provide a longer lasting and more desirable type of forage that might also be more responsive to fertilizer treatments.

    b. Increased seeding rates also might have decreased the invasion by yerba santa after the burns. Where seeding rate was heavier in the airplane swath, yerba santa was less noticeable.

    c. Seeding methods might be improved to provide seed coverage, particularly where there is not a good ash seedbed.

    d. Chemical treatment of brush sprouts or seedlings, tested only to a limited extent in this project, should be considered for widespread use after the first burn or bulldozing or after a reburn. This may provide a more complete and permanent conversion of the vegetation.

    e. The potential benefits of fertilization should be considered, as response to different fertilizers will be influenced by the vegetation present as well as nutrient deficiencies of the soil.

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BRUSH RANGE IMPROVEMENT

A Report of the Cooperative BACKBONE PROJECT

UNIVERSITY OF CALIFORNIA
AGRICULTURAL EXTENSION SERVICE

SHASTA COUNTY

STATE OF CALIFORNIA

THE RESOURCES AGENCY DIVISION OF FORESTRY

Cover photo: Grass production on burned area a year afterward. The area was studied for 10 years.

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The authors recognize and gratefully acknowledge the work done by many people during the 10-year course of the study.

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Co-operative Extension work in Agriculture and Home Economics, College of Agriculture, University of California, and United States Department of Agriculture co-operating.
Distributed in furtherance of the Acts of Congress of May 8, and June 30, 1914.
George B. Alcorn, Director, California Agricultural Extension Service.

JULY 1967

CONCLUSIONS

1. Removal of brush by all three methods, followed by reseeding, increased livestock production three and one-half to four times.

2. Controlled burning of standing brush was the most profitable treatment; burning crushed brush ranked second. Mechanical clearance did not return enough to repay costs during four grazing seasons. Costs of control burning of brush were paid off in 3 to 4 years of grazing, while costs of mechanical clearance probably would have paid off in 6 years of grazing.

3. The greatest production per acre followed mechanical clearance, although the increase over other treatments was not enough to cover the substantially higher costs of mechanical clearance.

4. The cost of reburning was less than 30 percent of the cost of preparing for and making the original burn.

5. At the end of 10 years, there appears to be more brush in the burned fields than in the bulldozed field. It is difficult to state whether this is a result of treatment or the differences in composition of the woody vegetation at the start of the project.

6. Brush cover was reduced 90 percent by the first burn and more than 80 percent by the bulldozing treatment.

7. Manzanita was nearly eliminated in 4 years by burning or bulldozing, followed by a reburn, but this species increased 34 percent in the untreated field during a 3-year period.

8. Yerba santa, relatively unimportant in the original woody vegetation, appeared to be the major component of the woody vegetation at the end of the 10-year period.

9. Herbaceous vegetation more than doubled the first year after brush removal and reseeding, and had quadrupled by the third year.

PERCENTAGE OF SEEDED SPECIES IN TOTAL HERBACEOUS VEGETATION

Species	1956				1958				1959			
	Burn Stand	Crush Burn	Bulld Windr	Av.	Burn Stand	Crush Burn	Bulld Windr	Av.	Burn Stand	Crush Burn	Bulld Windr	Av.
Blando brome*	25	30	18	24	42	45	25	37	11	23	6	13
Annual ryegrass	19	32	8	20	T**	T	T	T	0	2	0	1
Hardinggrass	T**	T	T	T	2	1	T	1	3	2	0	2
Rose clover	8	5	2	5	2	11	9	7	0	2	0	1
All species	52	67	28	49	46	57	34	45	14	29	6	17

*Some resident soft chess present before seeding

**T = Trace

SUMMARY

Controlled burning of brush was shown to be a practical, economical, efficient, and, above all, profitable method of clearing brush for range improvement. Even though cattle production records were obtained for only four grazing seasons during the 10 years of the study, increased production more than offset costs where brush was burned standing or after mashing.

Mechanical clearing resulted in greater increases in total production and gross returns, but these increases were not sufficient during the course of the study to offset the much greater costs of mechanical clearance.

Followup treatment was necessary after all methods of brush clearance.

Reseeding to adapted grasses and legumes improved the quality and quantity of feed and contributed to a longer forage season.

Fertilization increased forage production, but the economics of this practice were not thoroughly studied in the project.

California's millions of acres of brushlands provide a great potential for an expanded livestock industry to supply increasing amounts of meat and other livestock products for the state's rapidly exploding population. More and more valley areas are being developed for intensive cropping and for residential and commercial use, forcing livestock production to move to higher ground. The need to investigate and demonstrate methods of improving brushlands was apparent to many of those concerned with range improvement.

Rancher experience over the years had shown the values of controlled burning and other methods of brush clearance, but there was little information comparing economic aspects of different brush control methods.

The Backbone Range Study was a 10-year project to study and compare the economics of burning standing brush, burning mashed or crushed brush, mechanical clearance by bulldozer, and untreated range. This was a cooperative study by the University of California Agricultural Extension Service and the California Division of Forestry, Department of Natural Resources.

THE STUDY AREA

The area selected for study is located approximately 13 miles northeast of Redding, lying between US Highway 299 and the Pit River Arm of Shasta Lake. It represents 3 to 4 million acres of land covered primarily by manzanita, live oak, poison oak, ceanothus species, and yerba santa. Elevation is from 700 to 950 feet. Topography is rolling, with slopes generally less than 30 percent.

Precipitation averaged 46.8 inches during the 8 years of measurement on the project site; 77 percent fell from November through March. The highest seasonal rainfall was 66 inches and the lowest 26.8 inches.

The soils have been surveyed and mapped by both the Soil Conservation Service and the Soil-Vegetation Survey (reports not yet published). Soils of the Auburn series were found on the majority of the area (about 75 percent) of the three test fields. The remainder was of the Goulding series, except about 10 percent of the mechanically cleared field that was Churn gravelly loam. The control field was mapped as approximately 60 percent Auburn and 40 percent Millsholm.

The vegetation before treatment was primarily brush and trees, with grasses and forbs covering less than 20 percent of the ground. About 60 percent of the area was under a brush or tree

RESIDENT AND SEEDED SPECIES BEFORE AND AFTER BRUSH REMOVAL
(percentage ground cover)

		Burned Standing	Crushed & Burned	Bulldozed & Windrowed	Av. All Treated Fields
Resident	1954	22	5	22	16
	1956	17	11	36	21
Seeded	1954	0	0	0	0
	1956	19	26	14	20
Total	1954	22	5	22	16
	1956	36	37	50	41

The proportion of the herbaceous vegetation made up of seeded species remained at a little less than 50 percent in 1958, and then dropped to 17 percent in 1959. Annual ryegrass had been a large portion of the vegetation in 1956 but had nearly disappeared by 1958. Blando brome was the only other seeded species making large contributions to the herbaceous cover (37 percent in 1958), but it had been reduced drastically by 1959. Rose clover, although never making up a large proportion, was drastically reduced in 1959 after gradually increasing in prior years. Hardinggrass increased its proportion very slightly from 1956 to 1959.

The proportion of the herbaceous vegetation provided by seeded species was greatest for every year of record in the crushed and burned field, next in the standing burned field, and least in the mechanically cleared field.

Observations at the close of the project in 1963 indicated that Hardinggrass was holding its own and that rose clover had greatly increased to become a major source of forage. Subterranean clover had come into the picture and was well established in some locations.

Of the 68 species of grasses, legumes, and forbs planted in a variety trial in 1955, only Hardinggrass, rose clover, and tall wheatgrass remained in 1960.

Herbaceous vegetation continued to increase on the treated fields to 1958 and declined during the dry year of 1959.

HERBACEOUS VEGETATION BEFORE AND AFTER BRUSH REMOVAL
(percentage ground cover)

Year	Burned Standing	Crushed & Burned	Bulldozed & Windrowed	Av. All Treated Fields
1954 (before clearing)	22	5	22	16
1956	36	37	50	41
1958	64	64	69	66
1959	63	62	62	62
Percentage increase 1954-59	186	1,140	182	288

Even after the dry year of 1959, herbaceous vegetation had increased 288 percent after treatment of the three fields.

RESEEDING

Seeding methods, dates, and species used have been described. The importance of seeded species is evident by the record showing that these species accounted for about half of the total herbaceous vegetation the first year after brush removal. They also accounted for 80 percent of the increase in herbaceous vegetation the first year after brush removal.

canopy. Whiteleaf manzanita, interior live oak, lemmon ceanothus, and poison oak made up almost 80 percent of the brush and tree cover; dead material in the crowns made up another 12 percent; the rest consisted of several other species.

The project area and surrounding country had been used for many years for livestock grazing, although grazing had been greatly reduced as brush covered more and more of the area. Feed supplies were reported to be good for a few years following the last wildfire to burn the study area (1937). A herd of elk also uses the area as range.

STUDIES MADE

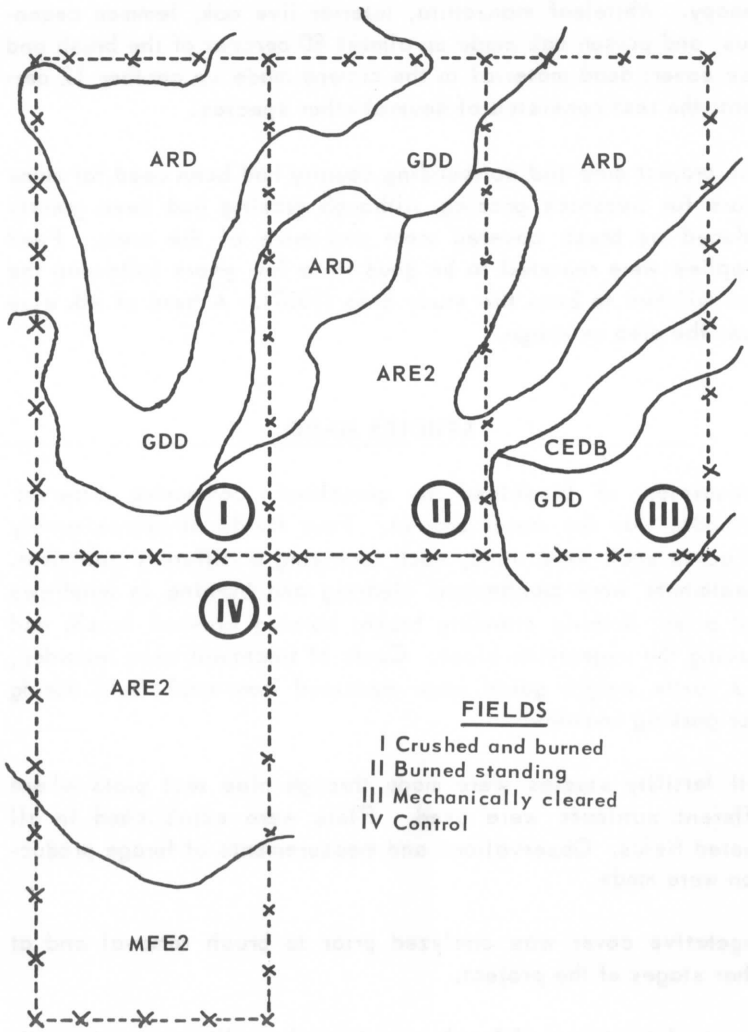
Conversion of brushland to grassland, comparing different methods, was the major project. Four fields of approximately 40 acres each were used, each receiving a different treatment. Treatments were mechanical clearing and burning in windrows and piles; burning standing brush; burning crushed brush; and leaving the vegetation alone. Costs of treatment were recorded, and cattle weight gains were measured from each field during four grazing seasons.

Soil fertility studies were made through nine test plots where different nutrients were used. Plots were established in all treated fields. Observations and measurements of forage production were made.

Vegetative cover was analyzed prior to brush removal and at other stages of the project.

Chemical treatment of brush sprouts and seedlings was investigated at ten different locations.

Various species were evaluated through the seeding of the three cleared fields and smaller trial plots.



SOILS

Symbol	Name	Slope, %
ARD	Auburn very stony loam	8-30
ARE2	Auburn very stony clay loam	30-50
CEDB	Churn gravelly loam	3-8
GDD	Goulding very stony loam	10-30
MFE2	Millsholm very rocky loam	30-50

Herbaceous Vegetation

Herbaceous vegetation (plants other than brush or trees) covered only 16 percent of the ground before brush clearance. This more than doubled the first year after brush removal.

HERBACEOUS VEGETATION BEFORE AND AFTER BRUSH REMOVAL
(percentage ground cover)

	Burned Standing	Crushed & Burned	Bulldozed & Windrowed	Av. All Treated Fields
Before (1954)	22	5	22	16
After (1956)	36	37	50	41

The increase was due to an increase in resident species and to the introduction of species seeded after brush removal.

RESIDENT AND SEEDED SPECIES BEFORE AND AFTER BRUSH REMOVAL

	Resident	Seeded	Total
Before (1954)	16	0	16
After (1956)	21	20	41
Percentage increase	31	--	156

The greatest increase the first year after brush removal was in the crushed field, where herbaceous vegetation increased more than seven times.

The best stand the first year after brush removal was in the cleared field. Forage yield measured by clipping was highest here, as was cattle production in 1957, the first year of grazing.

FORAGE WEIGHTS, AIR DRY, JULY 1956

Standing	294 lb per acre
Crushed	319 lb per acre
Cleared	398 lb per acre

The reburn of 1958 killed all manzanita seedlings in the mashed field. Only 0.5 percent of the ground cover in the standing field was manzanita seedlings before the reburn, and this same small percentage was found after the reburn.

Manzanita was nearly eliminated by 1959 (4 years after the original burn and 1 year after the reburn) regardless of treatment.

BRUSH BEFORE AND FOUR YEARS AFTER ORIGINAL BURN, AND ONE YEAR AFTER REBURN
(percentage cover)

Species		Burned Standing	Crushed & Burned	Bulldozed & Windrowed	Av. All Treated Fields
Manzanita	Before	27	33	16	25
	After	0	T	0	0
Poison oak	Before	6	2	8	5
	After	8	2	3	4
Yerba santa	Before	T	T	T	T
	After	3	8	5	5
Coffeeberry	Before	1	0	0	0
	After	5	0	0	1

Poison oak and coffeeberry changed very little over the 4-year period, and yerba santa made definite increases.

Manzanita cover increased 34 percent in the untreated field during the 3-year period (1956-59), while poison oak decreased and there was no change in yerba santa and coffeeberry.

BRUSH CLEARING METHODS

Four fields of approximately 40 acres each were used to test and demonstrate methods of brush clearance. Initial treatments started in the fall of 1954, with crushing of brush on one field and bulldozing and windrowing of brush on another field. A third field was left alone to burn standing brush, and the fourth field was left as a control to receive no treatment.

The fields of crushed and standing brush were burned together July 29, 1955, with excellent results. The crushed brush was burned clean, and about 90 percent of the standing brush was consumed.

The three treated fields were seeded by airplane on September 23, 1955. The seed was simply dropped into the excellent ash seedbed in the two burned fields, but had to be covered by a brush drag in the bulldozed field. The seed mixture was:

	pounds per acre
Rose clover	2
Crimson clover	1
Subterranean clover*	½
Hardinggrass	1
Annual ryegrass	1
Blando brome	3
	8½ pounds per acre

*Mt. Barker was seeded on the west half of each field, Tallarook on the other half.

All three treated fields were reburned in July 1958 and reseeded on October 7, 1958. The burn was not considered very successful. The seed mixture, flown on by plane, consisted of 4 pounds of rose clover and 1 pound of Mt. Barker subterranean clover per acre, plus minor amounts of orchardgrass, pubescent wheatgrass, and Ladak alfalfa.

COSTS

State equipment and crews were used in land treatment. Accurate time records were kept, and these were applied to rates representative of ranchers' costs at that time.

LAND TREATMENT COSTS
(dollars per acre)

Operation	Burned Standing 41.1A	Crushed & Burned 43.6A	Bulldozed & Windrowed 38.2A
Crushing – .65 hr @ $12/hr	----	$ 7.78	----
Clearing – 2.02 hr @ $12/hr	----	----	$24.19
Burn preparation	$ 1.98	1.98	----
Burning (July 1955)	2.57	2.57	----
Seed (Sept. 1955)	4.87	4.87	4.87
Airplane seeding (Sept. 1955)	.60	.60	.60
Seed covering (Sept. 1955)	----	----	2.99
Reburn (July 1958)	1.33	1.33	1.33
Seed and seeding (Oct. 1958)	2.31	2.31	2.31
Totals	$13.66	$21.44	$36.29

Costs for burning standing brush twice, followed by seeding each time, were less than 40 percent of the cost of bulldozing and windrowing plus a burn and two seedings. The crushing and burning treatment cost less than 60 percent of the bulldozing and windrowing.

PRODUCTION

During the springs of 1957, 1958, 1960, and 1963, the three treated fields and the untreated (control) field were stocked with short yearling cattle to measure gains per animal and production per acre. Cattle were individually identified and weighed in and out of each field. Stocking rate ranged from 8 to 15 head on each treated field, and 3 to 5 head on the control field. Stocking rates were decided or determined by visual inspection of feed conditions.

Considering only the woody vegetation gives a better picture of the relative importance of the different species.

WOODY VEGETATION BY SPECIES (Percentage)

Species	Burned Standing	Crushed & Burned	Bulldozed & Windrowed	Control	Av. All Fields
Manzanita	43	47	29	52	43
Wedgeleaf ceanothus	0	3	0	0	1
Lemmon ceanothus	33	10	0	0	11
Interior live oak	0	19	20	22	15
Blue oak	1	T	18	4	6
Black oak	0	0	T	0	0
Poison oak	10	3	15	9	9
Yerba santa	T	T	T	2	1
Coffeeberry	1	0	0	0	T
Willow	1	0	4	0	1
Digger pine	0	0	0	11	3
Dead material in crowns	10	19	15	T	11

Manzanita was consistently the predominant species, although of less importance in the cleared field. Other species showed considerable variation in stand from field to field.

The brush cover was reduced greatly after burning and clearing. Brush, including sprouts and seedlings, covered only 6 percent of the ground 1 year after treatment, compared to more than 50 percent prior to treatment.

BRUSH BEFORE AND ONE YEAR AFTER TREATMENT
(percentage ground cover)

	Burned Standing	Crushed & Burned	Bulldozed & Windrowed	Av. All Treated Fields
Before	53	61	50	55
After	5	6	8	6

Woody Vegetation

The brush cover was successfuly removed by both fire and bulldozing.

The woody vegetation prior to treatment included 11 species, with variations in the stand of species from field to field. Still, whiteleaf manzanita, interior live oak, lemmon ceanothus, and poison oak generally made up 80 percent or more of the crown cover.

CROWN COVERAGE OF WOODY VEGETATION BEFORE TREATMENT

Species	Burned Standing	Crushed & Burned	Bulldozed & Windrowed	Control	Av. All Fields
	%	%	%	%	%
Manzanita	27	33	16	24	23
Wedgeleaf ceanothus	0	2	0	0	T*
Lemmon ceanothus	21	7	0	0	7
Interior live oak	0	13	11	10	9
Blue oak	1	T	10	2	3
Black oak	0	0	T	0	0
Poison oak	6	2	8	4	5
Yerba santa	T	T	T	1	1
Coffeeberry	1	0	0	0	0
Willow	1	0	2	0	1
Digger pine	0	0	0	5	1
Dead material in crowns	6	13	8	T	7
	63**	70	55	46	57
Open	47	39	50	55	48

* T = trace

** Percentages of "crown cover" and "open" exceed 100 percent because of overlap of some of the crowns.

These fields were not grazed in all years of the project for several reasons: to allow seeded species to get established, to save grass for other reburns (that did not take place), and insufficient feed.

Efforts to measure production by cattle gains met serious difficulties. One problem was occasional exceptionally high water in the stream flowing through the project area that washed out fences, allowing cattle from different fields to mix. The elk herd that used the area also knocked down fences at times, making it difficult to keep the cattle where they belonged.

The 1958 and 1963 records required much interpolation. The following figures on production cannot be considered entirely accurate, in view of the problems in maintaining cattle identity and location. However, the figures are accurate in all possible instances, the estimates of some figures are realistic, and the overall comparisons are valid.

PRODUCTION PER ACRE – POUNDS OF GAIN

Year	Burned Standing	Crushed & Burned	Bulldozed & Windrowed	Control
1957	34.2	33.8	41.8	11.0
1958	33.0	33.0	34.8	8.6
1960	34.8	29.8	35.3	8.2
1963	20.1	32.9	28.8	7.4
Totals	122.1	129.5	140.7	35.2
Per year	30.5	32.4	35.2	8.8

Clearing brush and reseeding should increase feed production and cattle gains, and these records give a clear indication of the importance of the increase. The standing burn treatment increased animal gains per acre 3.5 times, crushing and burning increased gains 3.7 times, and the bulldozing treatment increased gains 4 times over the untreated field. These increases are particularly significant since measurements of cattle gains were made during only four seasons of the 10-year test period.

AVERAGE DAILY GAIN (Pounds); AND STOCKING RATE

	Burned Standing		Crushed & Burned		Bulldozed & Windrowed		Control	
Year	A/head	Gain	A/head	Gain	A/head	Gain	A/head	Gain
1957	3.7	1.75	3.6	1.68	2.9	1.68	10.0	1.51
1958	2.7	1.60	2.9	1.68	2.5	--	8.0	1.21
1960	3.4	1.86	3.6	1.65	3.8	2.10	10.0	1.28
1963	5.1	1.90	5.5	2.01	4.8	2.09	13.4	--

Average daily gains, though showing some variation, are reasonably consistent throughout the treated fields. The greatest difference was between the crushed and bulldozed fields in 1960, and there appears to be no logical explanation. The generally low daily gains in the control field indicate that this field may have been overstocked, even though the stocking rate was about one-third that of the treated fields.

SOIL FERTILITY STUDIES

Nine fertilizer test plots were established, at least two in each treated field, between the fall of 1955 and the fall of 1958. Nutrients included in the trials were nitrogen, phosphorus, sulfur, and potassium.

Different rates of application were used. Nitrogen rates varied from a low of 20 pounds per acre to a high of 130 pounds per acre; phosphorus from 25 to 170 pounds; sulfur from 60 to 150; and potassium rates were consistent at 146 pounds per acre.

For testing individual nutrients, urea was used as a source of nitrogen, treble superphosphate as a source of phosphorus, gypsum as a source of sulfur, and potassium chloride as a source of potash. In addition, several other commercial fertilizers were applied in test strips.

Nitrogen was the element consistently responsible for increased forage production of nonleguminous species. Phosphorus produced very little response when applied alone but increased production when applied in combination with nitrogen. The nitrogen-phosphorus combinations stimulated forage growth more than did either element alone, although treatments were not made on pure clover stands. No responses to sulfur or potassium were observed or measured.

The economics of range fertilization were not a major objective of the Backbone Study. Even though economic data on fertilization were not obtained, such information would be highly desirable.

VEGETATIVE COVER

Measurements of vegetative cover were made at different times through the use of 12 permanent transects in each field, a total of 48 transects. Measurements were taken along the same transects each time by the point-step method.

The much greater gross returns from treatment were expected. Since costs of the different treatments varied, it was necessary to deduct per acre costs of treatment from the increase in gross returns to determine the gain or loss from treatment in dollars and cents.

GAIN OR LOSS FROM TREATMENT PER ACRE

	Burned Standing	Crushed & Burned	Bulldozed & Windrowed
Gross return from treatment	$19.98	$21.69	$24.26
Total cost of treatment	$13.66	$21.44	$36.29
Gain or loss	$ 6.32	$ .25	-$12.03

Burning standing brush proved to be the most profitable treatment during the study, resulting in production increases great enough to pay off all costs of treatment in less than three grazing seasons. Mechanical clearance was not profitable, but would have paid off the costs in two more grazing seasons of average production. Burning crushed brush repaid all costs almost exactly in the four grazing seasons.

The return per grazing year was 37 percent for standing, 25 percent for crushed, and 17 percent for bulldozing.

RETURNS

Gross returns per acre are figured on the basis of cattle gains having a value of 23 cents per pound.

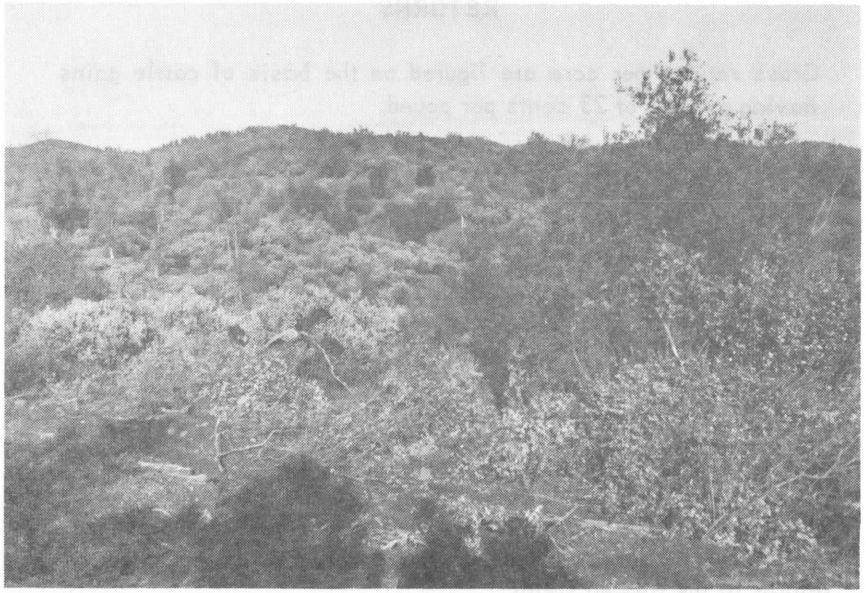
GROSS RETURNS PER ACRE

Year	Burned Standing	Crushed & Burned	Bulldozed & Windrowed	Control
1957	$ 7.87	$ 7.77	$ 9.61	$2.53
1958	7.59	7.59	8.00	1.98
1960	8.00	6.85	8.12	1.89
1963	4.62	7.58	6.62	1.70
Totals	$28.08	$29.79	$32.36	$8.10
Per year	$ 7.02	$ 7.45	$ 8.09	$2.03

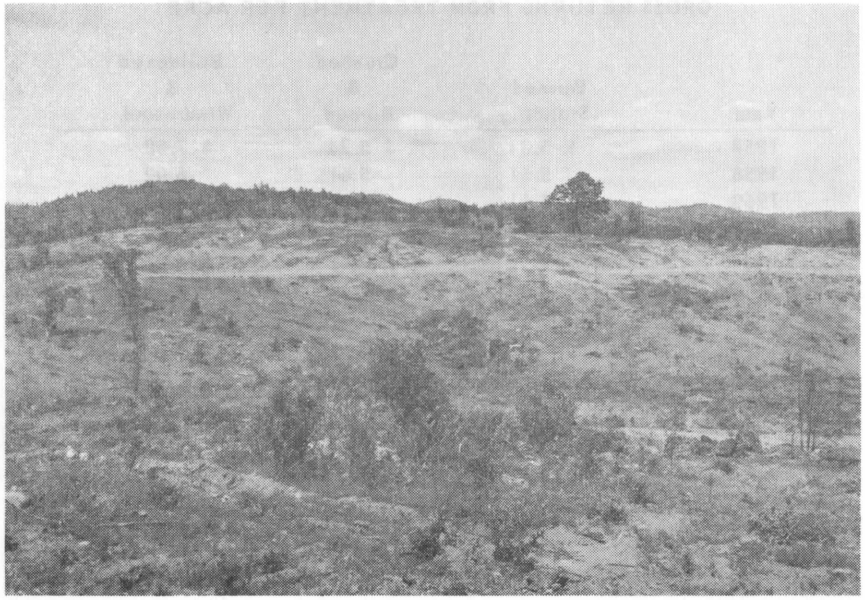
The increases in returns due to treatment were determined by subtracting the gross returns of the control field from the gross returns of the treated fields.

GROSS RETURNS FROM TREATMENT PER ACRE

Year	Burned Standing	Crushed & Burned	Bulldozed & Windrowed
1957	$ 5.34	$ 5.24	$ 7.08
1958	5.61	5.61	6.02
1960	6.11	4.96	6.23
1963	2.92	5.88	4.92
Totals	$19.98	$21.69	$24.26
Per year	$ 5.00	$ 5.42	$ 6.06

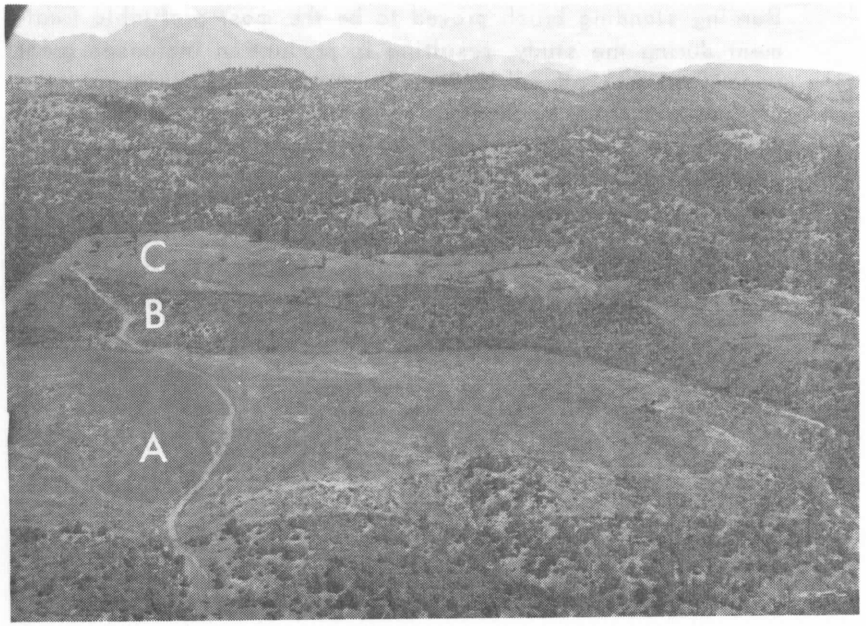


Typical brush coverage of the area before brush burning or clearing.



Same general area after being bulldozed to remove brush.

One day after control burning of standing brush.



Area 1 year after clearing. In foreground (A) brush was crushed and burned. In the middle part (B) the standing brush was burned. In the background (C) the brush was bulldozed. In other parts no brush control methods were used.