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THE LIVESTOCKMAN'S HANDBOOK

FOR

MANAGEMENT AND IMPROVEMENT

OF

RANGELAND

IN

WESTERN

COLUSA, GLENN AND TEHAMA

COUNTIES

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THE STOCKMAN'S HANDBOOK FOR MANAGEMENT AND IMPROVEMENT OF RANGELAND IN WESTERN COLUSA, GLENN AND TEHAMA COUNTIES

Developed by Cooperative Extension Service and
Soil Coservation Service Personnel

Prepared and Edited by Monte Bell, Glenn-Colusa Farm Advisor

Introduction

This handbook was written to consolidate and organize range improvement recommendations currently being made by the Cooperative Extension Service farm advisors and the Soil Conservation Service technicians in this tri-county area.

The recommendations are as specific as possible to be of maximum use to landowners and managers. The looseleaf form of the handbook lends itself to making copies of specific site-objective recommendations as well as facilitating revision as needed.

These recommendations will not replace, but should assist, on-the-site analysis by ranchers and rangemen. Those concerned with rangeland improvement, management and use are urged to discuss their ideas with local Cooperative Extension and Soil Conservation personnel.

Nutrition is the most important factor influencing reproductive efficiency and growth rate in livestock. The livestock industry in Colusa, Glenn and Tehama Counties is largely dependent upon rangeland to supply this critical nutrition.

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ACKNOWLEDGMENTS:

The evaluation and general management of Rangeland Resources was assembled and written by Barry Wallace and Warren Brown.

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Section I. EVALUATION AND GENERAL MANAGEMENT OF RANGELAND RESOURCES

Modern ranching requires large investments in land and improvements. The modern rancher must be knowledgeable in scientific breeding of superior animals, in efficient production, management and marketing of livestock and in sustaining an optimum level of quality range feed. These goals for a successful enterprise demand the application of improved grazing practices.

First think through, develop and write down a management plan. Follow these steps.

Step 1. Land Use Suitability

Carefully consider the selection of property for your livestock operations. This is particularly important to the prospective land buyer. Not all lands are adaptive to livestock grazing or browsing. Some may be too steep or too brushy to make them suitable for livestock uses. Others may be rich, fertile and more profitable in other land uses, such as cropland or hayland. Rangeland is defined as land on which the plant community is composed of grasses, grass-like plants, forbs and shrubs valuable for grazing and available in sufficient quantity to justify grazing use.

Step 2. Resource Inventory

After the determination has been made that the selected area is suitable for livestock grazing, the next step is to do an inventory of the natural and cultural resources. Part of the resource inventory has been completed in Step 1, determining the suitable land use. The primary objective of a range inventory is to assemble all important facts needed for a sound management plan.

An aerial photo map is the best tool to use in a resource inventory. These maps will be made at no charge for ranchers in a ~~soil~~ resource conservation district upon request to the district ~~soil~~ conservationist. Information placed on the map should include:

(a) Soil type and capability class boundaries, fertility status, rock outcrops, saline, gravel and eroded or slip areas.

(b) Vegetation analysis - species, condition and percent ground cover.

(c) Acreages of each grazing unit.

(d) External and internal fencing, corrals and gates.

(e) Buildings, mines, air strips, roads, trails and crossings.

(f) Lakes, stock ponds, streams, ditches, springs, marshes, windmills, troughs and tanks.

The resource inventory should provide all of the information necessary to make management decisions.

Step 3. Selection of Livestock

To obtain efficient use of the range, the kind of stock must be selected that is best suited to the area. Range lands differ greatly in the character of the forage. They also differ in the extent to which they need protection of their resources other than forage.

The factors that chiefly determine the kind of stock for which a range is best suited are:

(a) Character of forage.

(b) Common uses of forage with wildlife.

(c) Topographic features.

(d) Presence of noxious plants.

(e) Predators and diseases.

(f) Distribution of water.

(g) Economic factors - labor, capital, markets, transporation, service and supply.

Step 4. Livestock Distribution

Distribution of livestock for more uniform use of forage can be accomplished in several ways.

A. Using different kinds and classes of livestock. As an example, sheep usually can graze steep rocky land more uniformly than cattle. Sheep and goats require less frequent water intake than cattle. Goats will thrive on brushy areas better than sheep or cattle. Cattle and horses will utilize coarse grassy swales the best. Horses will travel farther than the other animals. Larger animals are less vulnerable to coyote predation. Mature and non-lactating animals can maintain themselves on less and poorer quality feed than younger or high producing stock.

On most ranges the use of several kinds of livestock results in the most efficient use and maintenance of the vegetation as well as the most efficient animal production per acre.

B. Fencing. This is a positive way of controlling and confining livestock to certain areas. The number and size of pastures needed on any given operation will depend to a large extent upon:

1. The kinds and classes of livestock. For example: if an operator runs both sheep and cattle, or runs commercial and registered stock, he will generally need more pastures than if he ran only one kind of livestock. Separating livestock in different stages of their production cycles is very important, particularly during supplemental feeding, in order to avoid "the fat getting fatter and thin getting thinner."
2. Size, shape and topography of the entire unit.
3. The number of soil groupings and the production from each.

4. The amount, location and dependability of livestock water supplies.

5. Investment relative to return.

C. Livestock Water Facilities. Properly located, adequate, clean and dependable water supplies are essential for good range management and sustained livestock production. Walking long distances to water over rough terrain can double the energy requirement of livestock.

1. Guide for spacing water facilities:

Cattle

Type of Terrain	Travel Distance, Feed to Water
Rough	1/4 to 1/2 mile
Rolling	3/8 to 3/4 mile
Level	3/4 to 1 mile

Sheep

Type of Terrain	Travel Distance, Feed to Water
Rough	1 to 2 miles
Rolling	2 to 3 miles
Level	2 to 4 miles

2. General livestock water requirements per day are 1/4 to 1 gal/lb dry feed ~~eaten~~ consumed.

Cows	3 - 25 gal
Sheep	1/2 to 4 gal
Goats	1/2 to 3 gal
Horses	3 to 20 gal

D. Location of salt, mineral and supplemental feeding. The planned location of salt and mineral facilities with water in properly fenced pastures can further encourage grazing distribution. Do not place all of the salt and/or supplement

away from water because the result is a reduction of salt and supplement consumption. Salt and mineral containing phosphorus should be available at all times in this area.

General salt use on pasture:

Cows	1 1/2 to 3 lbs. per month
Horses	2 to 3 1/2 lbs. per month
Sheep and Goats	1/4 to 1/2 lbs. per month

E. Herding. This is the most positive and effective method of getting livestock to graze where desired. Sheep and goats may be moved in bands by herders whereas cattle may be scattered or pushed into new country by riders.

F. Stock Trails. In many areas of brushy, steep and/or rocky land, the construction of stock trails will encourage better distribution of grazing by providing access to areas that have been isolated due to natural barriers.

G. Fertilizing. Proper fertilization increases the palatability and amount of feed and modifies the season of growth and species composition of range vegetation. Fertilizing can be very effective in distributing livestock. (See Fertilizing Range Section II).

Step 4. Coordinating Range Forage Production and Livestock Production.

Efficient use of range resources depends on the use of good quality livestock and effectively coordinating range management and livestock management. To achieve a balance of these, the following factors should be evaluated in developing an annual grazing plan.

A. Forage Preferences and Proper Use Factors. Forage preference shows the relative palatability of different forage species by grazing animals. The term "proper use" implies the degree of grazing that an individual plant species can endure without damage to it or the soil.

B. Key Areas. The key area concept is based on the fact that it is essentially impossible to achieve absolute uniform grazing over a diversified range

Soil Group	Major Soil Series, Complexes and Associations	Total Lbs. Dry Matter Produced Per Acre[1]	Range of Animal Unit Months[2] (AUM) and Acres (Ac) Required		
			AUM's/Ac.	Ac's/AUM	Ave. Ac/Head 4-7 mo. season
A	Newville, Corning, Red Bluff Dibble, Perkins, Redding, Pleasanton and Chamisal	300-1500	.4 - 1.9	2.7 - .5	20
B	Altamont, Nacimiento, Ayar, Myers	1500-3500	1.9 - 4.4	.5 - .2	5
C	Millsholm, Sehorn, Contra Costa, Millsap	1000-2500	1.3 - 3.1	.8 - .3	10
D	Maymen, Parrish, Stonyford, Lodo, Los Gatos	100- 800	.1 - 1.0	8.0 - 1.0	35
E	Maxwell (venado), Leesville, East Park	200-2500	.3 - 3.1	4.0 - .3	15

[1]Based on test plot clippings.
[2]AUM = Amount of feed necessary to maintain a 1000 lb. cow for one month. It is equivalent to .4 ton or 800 lb. of hay, 540 lb. concentrate, 1.2 ton silage, 400 lbs. TDN.

Step 5. Range Management Plan

This step is combining the previous four steps into a working document for the ranch. The success of a management plan will hinge largely on four conditions: (1) the accuracy of the resource inventory upon which it is based; (2) the willingness of the manager to apply the plan; (3) the thoroughness of recording and (4) the effectiveness of making and implementing needed adjustments in the plan.

Practicability and flexibility are essential requirements of a successful grazing plan.

A grazing plan must be checked frequently in the field for comparison with actual use. It is of great importance to obtain and maintain complete and accurate data. These records become a permanent part of the management plan.

unit. Excessive use around watering places, salt grounds and driveways is unavoidable. Underuse or nonuse is common on steep hillsides and remote areas from water. Full, but allowable use of the inaccessible areas would result in extreme abuse of the easily accessible areas. For these reasons the intermediate areas, those not overly steep or remote from water, which furnish most of the feed, should constitute the key or representative areas upon which to gauge proper use of the range as a whole. A good key area should be moderately easy rather than too easy for the stock to reach, and soil and vegetation should be as representative as possible of the unit. Concerted effort should be made to reduce the size of the so-called sacrifice areas, those normally overgrazed or undergrazed, as far as possible.

C. Initial Stocking Rate Guide. Because of the wide variability in soil conditions and weather conditions, the forage production varies greatly from one year to the next. The following is a range of estimated stocking rates for the soil groupings discussed in this handbook. Heavy brush or tree cover will reduce these rates. A general description of these soils is presented in the section on major range soils. Soil maps are available to consult in the Soil Conservation and Farm Advisors offices in each county which give detailed location and characteristics of each soil series classification.

Step 6. Re-evaluation and Range Improvement Plan

This step is really a continuation of Step 5 except the previous plan is annually re-evaluated in light of changing goals, economic conditions and technological advances in range improvement. An annual summary graph showing actual production compared to planned production should be "on the wall" of every ranch office.

A comparison between the present ranch productivity and available resources with potential productivity will point out areas for improvement.

Improvement priorities can be established by assessing the costs of improvement against benefits toward the ranch production goals. The type and distribution of livestock needed and the most limiting season of feed are key factors in this assessment.

This handbook should assist range managers and livestock operators in choosing the proper and most economical range improvement techniques that fit the ranch and range feed improvement objectives.

Ways to improve range feed are to:

(1) Correct plant nutrient deficiencies in the soil.

(2) Improve soil water retention or drainage characteristics.

(3) Remove unwanted plants, shrubs and trees.

(4) Establish desirable plants, shrubs and trees.

(5) Manage livestock to maximize sustained production.

(6) Control range pests, predators and wildlife. Wildlife and wildland may be economically and aesthetically beneficial to the landowner as well as desirable to others. This value must be considered in the plan.

Section II. FERTILIZING RANGELAND

The following are general considerations on fertilizing. For specific recommendations see the section on range improvement recommendations.

Proper fertilization is one of the most important practices needed in realizing the great potential from the annual grasslands of this area. These grassland areas are not irrigated and the vegetation is dominated by species which reseed themselves each year. Summers are very dry and hot. Rains generally begin in late October with heaviest amounts coming in the winter period. Little effective rainfall comes after April. Wide variation in amount and distribution of rain is characteristic. The green grass season commences with the first fall rains, but forage available for livestock is very limited during the winter because of slow plant growth induced by cool temperatures. Forage is plentiful and of excellent quality during the spring. As the plants mature and die quality of the forage becomes poor. Protein is the most limiting factor to high animal production during the summer and fall period.

Nitrogen is deficient almost universally in annual grassland areas and phosphorus and sulfur deficiencies are very widespread. By the proper use of these three fertilizer elements large increases in production can be realized. Also since animals select feed high in protein and essential minerals the palatability of the feed is greatly enhanced.

The magnitude of the benefit will depend upon the fertility of the site, species of plants present, physical characteristics of the soil and rainfall and temperature patterns. In general, grass and filaree will benefit from nitrogen and sulfur, clovers from phosphorus and sulfur.

Nitrogen Fertilization

Extensive research has indicated that nitrogenous fertilizers are most effective in the 15 to 25 inch rainfall zone. Nitrogen should be applied in the fall in the ammoniacal form to reduce leaching. Fall applied nitrogen broadcast before the first fall rain results in more available feed during the cool winter period when it is needed most. A pasture fertilized with 60 pounds per acre nitrogen is usually ready for grazing about six weeks earlier than unfertilized pasture. Phosphorous and sulfur should be applied with nitrogen where needed. The later nitrogen is applied in the season following the first rain the less effective it is in stimulating winter forage production.

Local grazing tests show that for each pound of nitrogen fertilizer applied in the fall beef and lamb production increased one pound during the winter and spring season. Fertilization can be very profitable.

The use of nitrogen brings about important changes in the botanical and chemical composition of the pastures. Increases in production results mainly from an increase in the growth of annual grasses and broadleaf plants such as filaree. These species when fertilized with nitrogen generally grow rapidly during the early part of the season and crowd out the less competitive native legume plants. All of the species make their greatest growth during the spring, but under nitrogen deficient conditions the legumes make relatively greater growth during the spring when both moisture and temperature conditions are favorable.

The protein level in the plants is generally increased by nitrogen fertilization during the winter and early spring. This is not particularly beneficial since protein levels are adequate without applications of nitrogen

during this period. As the season advances protein levels drop more rapidly where nitrogen has been applied. Thus, at the end of the growing season protein levels where nitrogen was applied at the beginning of the season are usually about equal to or a little less than in the same species growing on unfertilized areas. The crowding out of legumes by grasses also lowers the percentage of protein in the forage. Where stocking rate is increased to utilize the increased winter growth of grass, nitrogen fertilization every 3 or 4 years in combination with sulfur has not depressed the legume stand. In fact, bur clover production increases under this regime.

In some instances where there has been insufficient rainfall, and moisture became limiting to plant growth early in the spring, the fertilized plants matured with higher levels of protein than the unfertilized plants. Also applications of nitrogen in the spring has increased the level of protein in the mature forage, but less dry matter production has been realized with spring applications. The resulting mature feed is highly palatable, however, and is readily eaten by stock.

Phosphorous

Many of the soils in the Colusa-Glenn-Tehama Westside are deficient in phosphorous and may require heavy applications to increase forage production to optimum levels. Where phosphorous is applied without nitrogen, legumes are the plants that show the most response. This is because if they are adequately inoculated the bacteria in the nodules on the roots make nitrogen from the air available to the plant.

Phosphorous may be applied in large amounts because in contrast to nitrogen it does not leach out of the root zone. In some soils, phosphorus is "tied up" in the soil and made unavailable to plants. In this case high rates of phosphorous may be needed to overcome this tie up.

Where response to lower rates of phosphorous is evident annual or biannual application are recommended. This is because the sulfate sulfur in single superphosphate (the fertilizer of choice) does leach out of the root zone and must be applied frequently. Another reason is that even where soil phosphorous is high light applications of phosphorous increased yields.

Methods for determining the phosphorous status of soil and plants are described later in this section.

Sulfur

Sulfur deficiency is widespread in this area and unless known to be adequate should always be included in the fertilizing program. Application of sulfur can bring large returns. Sulfur also must be applied where there are legumes. The application of sulfur not only increases production of the more desirable species but increases the percentage of protein in all of the feed as well. This increase was measured as the plants reached maturity. Thus, sulfur fertilization makes an important contribution to the quality of summer feed.

The source of sulfur applied is important. Two forms of sulfur are available for fertilizer use: sulfate sulfur which is found in gypsum, single superphosphate, ammonium sulfate, and others; and elemental sulfur which is being used increasingly alone and mixed with other fertilizers.

Sulfate sulfur is immediately available to plants but being water soluable may be rapidly leached out of the root zone.

Elemental sulfur, on the other hand, is not water soluble, not leached out of the soil and not available to plants without first being converted to the sulfate form of sulfur. Soil bacteria make this conversion and the smaller the particle size (thus greater surface area) the faster the elemental sulfur is

converted to soluable sulfate sulfur.

Sulfur status can be determined by plant tissue analysis as explained later.

Range fertilization is recommended only on areas that are open, free of brush or where trees are scattered enough to allow a good grass understory.

How to Determine Fertilizer Requirements

In order for chemical soil tests to be of value in guiding fertilization programs they must be made on representative samples, by meaningful methods, and they must be properly interpreted. Presented here are sampling instructions, and interpretive guides applicable to the rangeland of Western Colusa, Glenn and Tehama Counties.

A good sample is the first requirement for a reliable soil test. The first step in a sound sampling procedure is to subdivide the area into similar units. These units can be based on differences in the soil, crop, etc. 20 sub-samples should be composited from each area. The sampling tool should take a small enough volume of soil from each sampling site so that the composite sample will fit in a paper grocery bag. Samples are easier to take when the soil is moist but not wet and a soil tube is used. Soil tubes are available for loan at the Farm Advisors Office.

Sample the soil to a depth of 6 inches. Once the samples have been collected they should be taken to the lab immediately or air dried then stored in an air tight container until analysed. We are fortunate to have a local lab in Maxwell that is well equiped and uses methods as recommended by the University of California A complete soil analysis costs $12.00 (1976).

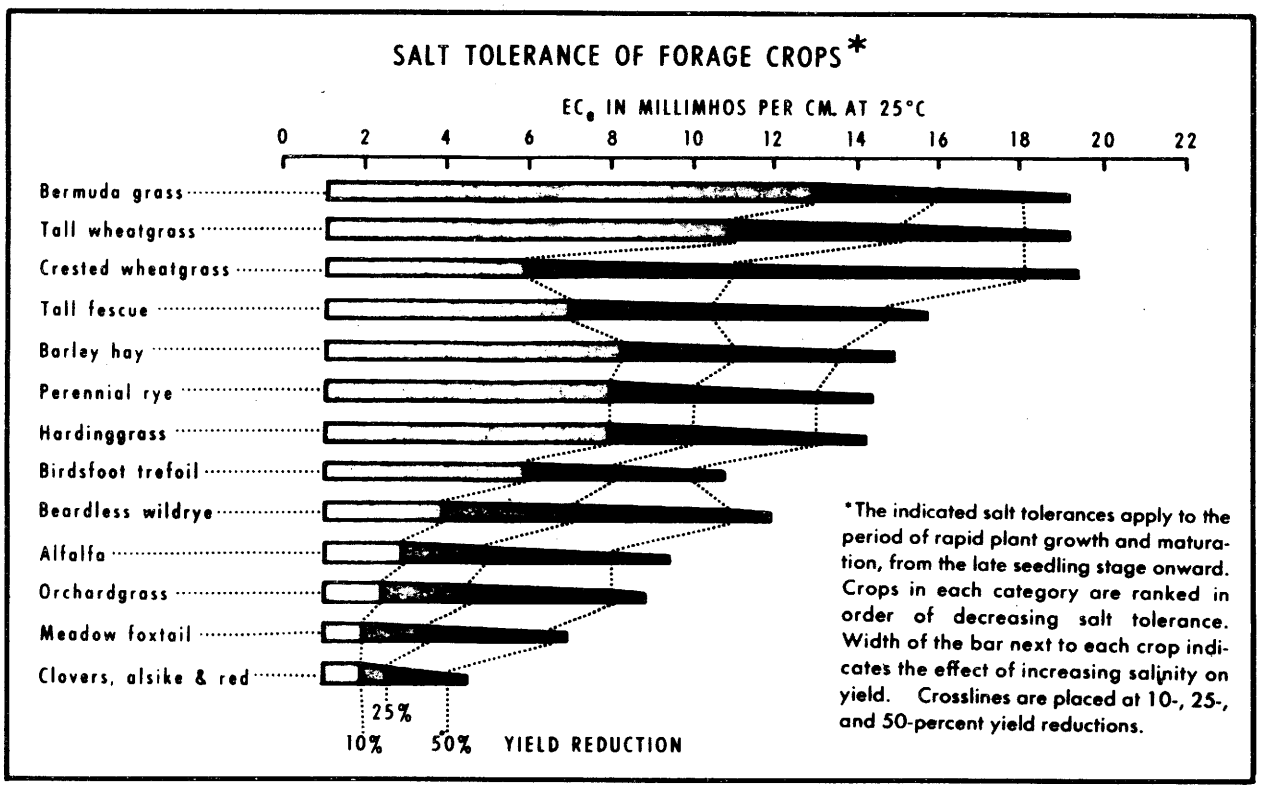
Soil tests for Phosphorous$^{(P)}$ and Potassium$^{(K)}$ and Zinc$^{(Zn)}$ give reliable estimates of these nutrients while the sulfur test is less reliable.

Range Soils

Grass with Adequate Nitrogen		P	K	S	Zn
		Levels are in parts per million (ppm)			
Response likely	less than	5	40	5	0.2
Response unlikely	more than	10	60	10	0.3
Legumes Adequately Inoculated					
Response likely	less than	5	50	5	
Response unlikely	more than	10	80	10	

Soil analysis is useful in diagnosing salt problems also. Soil samples for salinity should be composited only from within the suspected salty areas not from the entire field. The sample should be taken to a depth of two feet if possible.

Forage crops vary in their tolerance to salt as shown in the table below. This is important in deciding what species and variety to plant.



Salt tolerance of forage crops (Bernstein, 1964).

Range soils should be routinely checked for acidity because this affects not only the type of fertilizer to use but also the variety of seeded plants that have the best chance of establishment.

Acid soils are found on many range soils in this area. These soils may have developed acidity because of the nature of the parent material, or as a result of fertilizing. Continuous use of sulfur, or ammoniacal fertilizers such as ammonium sulfate or ammonium phosphate may make soils more acid.

Acidity is measured by pH. pH is neutral. Saline and calcareous soils are higher and acid soils are lower in pH value.

Yields of range forage are probably reduced at pH levels below 5.0.

Plant Tissue Tests

In using plant analysis to diagnose the nutrient status of annual grassland legumes, knowledge of environmental conditions under which the crop is growing is essential for proper evaluation of the test data. The following factors may influence test results: the plant itself (species, age and part analyzed), and environmental conditions (deficiencies or toxicities of elements not being tested, drought, high or low temperatures, disease and grazing). Any factor that limits plant growth more than the element being tested will likely increase the concentration of the tested element in the plant. The critical concentration is defined as that concentration of an element required to give a yield of 90 percent of maximum with all other growth factors present in ample supply.

Sampling.

In taking clover samples from grazed pastures, caution should be exercised to avoid urine and manure spots. Annual legumes are generally grown on extremely variable soils, and, therefore, samples should not be taken from rocky areas,

shallow spots, or swales unless knowledge of the nutrient status of these spots is desired.

Plant tissue samples should be taken in the spring after clover has commenced flowering. The plant part to be sampled depends on intensity of grazing. If the plants are extremely small, leaves or whole tops are used. Leaves should be taken from 20 plants. The sample should be taken immediately to the lab. If a few hours of storage are required allow the sample to dry being careful to avoid molding.

Critical Nutrient Concentrations

The critical concentrations of P, K and S in some annual clovers are listed below. Be sure to describe the factors which may affect the test values.

Note available P, as determined by soil test, is a more satisfactory evaluation of P needs than the plant tissue test.

TABLE 12. CRITICAL CONCENTRATIONS OF P, K AND S IN ANNUAL CLOVERS

Element	Species	Tissue sampled	Growth stage	Critical Level
P (total)	Subclover	Fully expanded leaves	2 leaves/runner	0.52% P
			6 leaves/runner	0.32% P
			1 flower/runner	0.15% P
			3 flowers/runner	0.11% P
	Rose clover	Leaves;	Flowering (May)	0.19%
		Tops	Flowering (May)	0.19-0.24% P
K (total)	Subclover	Leaves;	Flowering (May)	0.72-0.90% K
		Tops	Flowering (May)	0.80% K
	Rose clover	Leaves	Flowering (May)	0.87-0.95% K
S	Subclover	Leaf blades	Flowering	170 ppm SO_4-S 0.22% S
		Petioles		170 ppm SO_4-S 0.12% S
		Stems		170 ppm SO_4-S 0.11% S
		Tops	Flowering (May)	220 ppm SO_4-S[4]
	Rose clover	Tops	Flowering (May)	150 ppm SO_4-S[4]
	Native range clover	Tops	Flowering (May)	380 ppm SO_4-S[4]
	Bur clover	Fully expanded leaves	Flowering	140 ppm SO4-S 0.23% S
		Mid-stems	Flowering	100 ppm SP4-S 0.08% S
		Lower stems	Flowering	160 ppm SO4-S 0.08% S

Critical levels of S in subclover decrease as the plants develop, but appear to be relatively stable between the onset of flowering and wilting. Soil tests for available S give less precise estimates of the S status of pastures than do plant tissue analysis. With mixed annual grass-clover stands the S status of the plant community is best evaluated from analysis of the legume rather than of the grass component. Nitrogen-deficient grasses usually have S concentrations well above critical levels. Only when sufficient N has been applied to correct the N deficiency will S deficiency of grasses occur.

ACKNOWLEDGMENTS:

The fertilizer range land section was assembled and written by

Bill Richardson, Monte Bell and Ron Knight.

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Section III. MAJOR RANGE SOIL GROUPS

The following soil series are grouped according to their general potential for various range improvement techniques. For more detailed and complete descriptions and locations of the soil series, refer to the soil maps available in the Soil Conservation Service or Cooperation Extension offices.

In Section IV these soil groupings are further divided into range sites and the range improvement recommendations are outlined for specific objectives on these sites.

Soil Group A

Main soil series and complexes in this group include:

Soil Series-Complexes	Approximate Rangeland Acreage			
	Colusa	Glenn	Tehama	Total
Newville	-	38,000	194,000	232,000
Corning	7,000	15,000	70,000	92,000
Red Bluff	-	-	12,000	12,000
Dibble	-	-	12,000	12,000
Perkins	-	2,000	9,000	11,000
Redding	-	300	10,300	10,600
Pleasanton	-	1,700	700	2,400
Chamisal	1,700	-	-	1,700
Total	8,700	57,000	308,000	373,700

Associated soils include Hillgate and Kimball.

Most of the acreage in this group lies in the first foothills west of the Sacramento River in an 8 to 20 mile wide dissected terrace running from French Creek in Glenn County north to the Tehama-Shasta line.

In the south region these soils are located on small terraces in a broken belt along the foothills west of Arbuckle, Williams and Maxwell and another narrow broken strip runs from Stonyford to Newville in the Stony Creek Valley.

These are brown or red gravelly terrace soils, well drained on the surface but have a clay pan 8-22" deep. They are chiefly hilly to steep but are nearly level in a few places. Elevation ranges between 250 and 2000 feet and the rainfall from 17 to 30 inches.

The poor soil structure makes it extremely hard when dry and soft when wet (consistency of concrete wet or dry). Water may stand in low spots during the winter but the surface dries quickly with warm north winds during the spring.

Dry feed quality is poor because there are no effective legumes. The native vegetation consists of:

a. 5-10% desirable grass, soft chess, slender wild oats.

b. 10-20% less desirable grass, medusa-head, fescue, red brome ripgut.

c. 20-50% desirable forbs, broadleaf filaree, native lotus.

d. 25-55% undesirable forbs, plantain, lupine, tarweed.

e. Some sites have dense tree and brush cover, blue oak, manzanita, buck-brush, live oak and digger pine.

Feed production is low:

a. 800-1800 lbs. per acre dryland barley where farmable with 5-7 year rotation.

b. 300-1500 lbs. dry matter per acre of open land.

c. .4 - 1.9 animal unit months (AUM) per acre.

d. 2.7- .5 acres per AUM.

e. Ranchers figure 20 acres per head for a 4-6 month season running from November through May.

	Slope %	Permeability Inch/Hr	Available Water Capacity Inch/Inch Soil	Acid Base Reaction pH	Calcium Carbonate Lime %	Storie Index	Fertility N	P	K	S	Color
ım ıy ıdy clay loam	3-50%	.8-2.5 .05-.2 .8-2.5	.10-.14 .10-.14 .07-.11	5.6-6.5 5.6-6.0 6.1-6.5	0 0 0	14-31	Low	Med	High	Med	brown reddish-brown light yellowish-brown, light reddish-brown, brown
ım sandy clay loam	0-15%	.8-2.5 <.05 .2-.8	.12-.15 .14-.17 .07-.10	5.6-6.0 5.6-6.5 5.6-6.0	0 0 0	20-28	Low	V Low	High	Med	yellowish-red reddish-brown to yellowish-red mottled light yellowish-brown, yellowish-red, red
ım clay loam	0-3%			4.5-5.0 5.1-5.5	0 0	31-41	Low	Low	Low	Low	reddish-brown red
ım ı siltstone	10-50%			5.6-6.0 5.6-6.0	0 0	42	Med	Med	Med	Med	pale brown yellowish-brown yellow
ım ıy loam sandy clay loam	0-15%	.8-2.5 .2-.8 .8-2.5	.11-.14 .09-.11 0.7-.09	5.6-6.5 5.1-6.0 5.1-5.5	0 0 0	54-57					light brownish-gray light olive brown light yellowish-brown
ım	0.30%	.8-2.5 <.05 <.05	.12-.14 .12-.14	5.6-6.0 5.6-6.0	0 0 .1	17	Low	V Low	High	High	yellowish-red yellowish-red yellowish-red

Soil Group B

Main soil series and complexes in this group include:

Soil Series-Complex	Approximate Rangeland Acreage			
	Colusa	Glenn	Tehama	Total
Altamont	88,400	26,600	6,500	121,500
Nacimiento	-	25,400	42,300	67,700
Ayar	25,900	1,700	-	27,600
Myers	10,100	8,000	100	18,200
Total	124,400	61,700	48,900	235,000

Associated soils include Antone, Forgeus, Rumsey, Shedd, Yolo and Zamora.

The soils of this group comprise the bulk of the first foothills from the Yolo-Colusa line north to French Creek in Glenn County where they are interrupted by Group A soils. Group B starts again at the Glenn-Tehama line and runs in a wide belt just west of Group A soils north to Red Bank Creek.

This area known as the bald hills is among the best valley rangeland in California.

Other soils in this group lie in narrow flood plains along the many creeks that dissect the terraces.

These are heavy, deep, brown soils with mostly calcareous subsoils and are considered the best range except on the steep sites. Moisture-holding capacity is high; however, cracks to bedrock develop when dry.

These soils are rolling to very steep and lie between 150' to 2000' in elevation and rainfall ranges between 15 and 25 inches.

The alfalfa weevil has drastically reduced the traditionally excellent stand of bur clover on the soils.

Summer weeds such as star thistle, bull thistle and tarweed are often problems.

The native vegetation consists of:

a. 40-50% desirable grass, soft chess, common wild oats, annual rye.

b. 20-30% less desirable grass, ripgut, foxtail, medusa-head.

c. 15-50% desirable forbs, bur clover.

d. 10-20% undesirable forbs, yellow star thistle, bull thistle, fiddleneck.

Feed production is high:

a. 1600-2500 lbs. per acre dryland barley in 3-5 year rotation.

b. 1500-3500 lbs. dry matter per acre of open land.

c. 1.9 - 4.5 animal unit months (AUM) per acre.

d. .5 - .2 acres per AUM.

e. Ranchers figure 5 acres per head for a 6-7 month season.

Slope %	Permeability Inch/Hr	Available Water Capacity Inch/Inch Soil	Acid Base Reaction pH	Calcium Carbonate Lime %	Storie Index	Fertility N	P	K	S	Color
0-50%	.05-.2	.14-.17	6.1-7.8		18-46	Med	Low	High	Med	brown to light olive brown
mudstone & shale				1-8						whitish seams
3-50%	.05-.2	.14-.17	7.4-7.8	1-2	19-54	Med	Low	High	High	grayish to olive-brown
edrock										pale olive
0-30%	.05-.2	.16-.18	7.4-7.8	7-16	28-48	Med	V Low	High	Med	brown to reddish-brown
	<.05		7.9-8.4	40-70						white mixed with reddish-brown and pale yellow
0-10%	.05-.2	.14-.17	6.1-7.8	.1-.4	43-69	Low	V Low	High	Med	dark brown to yellowish-brown

Soil Group C

Main soil series and complexes in this group include:

Soil Series-Complexes	Approximate Rangeland Acreage			
	Colusa	Glenn	Tehama	Total
Millsholm	-	29,900	60,800	90,700
Sehorn	-	56,800	30,800	87,600
Contra Costa	56,900	9,100	-	66,000
Millsap	-	1,400	12,500	13,900
Total	56,900	97,200	104,100	258,200

Associated soils include Polebar.

Soils in this group are located on the taller foothills in a 2-10 mile wide band between the lower foothills (soil groups A and B) and the western valley trough running from Bear Valley north through Indian Valley, Stony Creek Valley and north to the Tehama-Shasta line.

These soils are brown in color, fine to medium textured, shallow to moderately deep, moderately steep and underlaid by hard sandstone and shale. Occasional soil slips occur on steep sites when the soil is saturated.

Elevation ranges from 300 to 2000 feet and the average annual rainfall is 20 to 35 inches.

These soils have an oak-grass cover. Millsholm is usually on south facing slopes; shallow (6-17") and free of brush and trees. Sehorn developed from the same parent material, but on north slopes, and deeper (12-27") and may have heavy tree cover.

They are mainly low in fertility and generally respond to fertilizers containing nitrogen, phosphorus and sulfur.

Major problems which cause low forage yields are low fertility and water-holding capacity. The alfalfa weevil has greatly reduced the bur clover stand in recent years.

Native vegetation consists of:

a. 10-25% desirable annual grass, mostly soft chess and slender wild oats.

b. 10-25% less desirable annual grass, mostly fescue and red brome with some ripgut and medusa-head.

c. 10-50% desirable forbs, mostly broadleaf filaree with some bur clover.

d. 15-30% undesirable forbs, mostly plantain.

Feed production is moderate:

a. 1200-1800 lbs. per acre dryland barley in 5-7 year rotation.

b. 1000-2500 lbs. dry matter per acre of open land.

c. 1.3 - 3.1 animal unit months (AUM) per acre.

d. .8 - .3 acres per AUM.

e. Ranchers figure 10 acres per head for a 6-7 month season.

	Slope %	Permeability Inch/Hr	Available Water Capacity Inch/Inch Soil	Acid Base Reaction pH	Calcium Carbonate Lime %	Storie Index	Fertility N	P	K	S	Color
am	30-65%	.8-2.5	.10-.14	6.1-7.3	0	5-9	Low	Med		Low	pale brown to light yellowish-brown
dstone, shale											
	10-65%	.8-2.5	.15-.19	5.6-6.5	0	5-26	Low	Med		Low	pale brown, brown brown, grayish-brown
shale											
dy											
	10-65%	2.5-5.0	.04-.06	5.6-6.5	0	4-23	Low	Med		Low	brown
e											
loam	3-65%	.05-.2	.14-.18	6.1-6.5	0	11-38	Low	Med		Low	brown
stone											
	30-65%	.05-.2	.14-.16	6.1-7.3	0	8-15					
		.05-.2	.14-.16	6.1-7.3	0						
		.05-.2	.13-.15	6.1-7.3	0						
	10-65%	.8-2.5	.15-.18	6.1-6.5	0	8-14					grayish-brown to brown
		.05-.2	.11-.14	5.6-6.0	0						brown

Soil Group D

Main soil series and complexes in this group include:

Soil Series-Complexes	Approximate Rangeland Acreage			
	Colusa	Glenn	Tehama	Total
Maymen	33,100	68,900	17,000	119,000
Parrish	-	4,900	36,200	41,100
Stonyford	7,400	3,800	10,400	21,600
Lodo	10,300	22,100	51,100	83,500
Los Gatos	-	5,300	14,900	20,200
Total	50,800	105,000	129,600	285,400

Associated soils include Hulls, Josephine, Tyson and Yorkville.

This group comprises the brushland soils in the first hills of the mountains that form the eastern edge of the Mendocino and Trinity National Forests.

These gravelly loam, slightly acid, foothill soils are generally steep to very steep and lie between 1,000 to 4,000 feet elevation. Precipitation ranges from 25 inches at the lower elevations to more than 40 inches on the higher ridges and peaks.

Natural fertility and water-holding capacity are low in contrast to the high erosion hazard.

Generally this site is covered with dense shrubs or brush such as chamise, ceanothus, manzanita and scrub oak. The higher elevations have stands of interior live oak, brewer oak and digger pine. The understory consists of sparse grasses and forbs like annual bromes, filaree, annual clovers, annual fescues and popcorn flower.

Range improvement practices such as clearing, reseeding and fertilizing should be restricted to only selected sites where soils are deep enough.

Feed production is very low:

a. 100-800 lbs. dry matter per acre of open land.

b. .1 - 1.0 animal unit months (AUM) per acre.

c. 8.0 - 1.0 acres per AUM.

d. If there is any grazing at all ranchers figure 35 acres per head for a 6-7 month season.

	Slope %	Permeability Inch/Hr	Available Water Capacity Inch/Inch Soil	Acid Base Reaction pH	Calcium Carbonate Lime %	Storie Index	Fertility N	P	K	S	Color
ım	10-65%	.8-2.5	.10-.4	5.6-6.0	0	3-16	Med	High	High	Med	pale brown to light yellowish-brown
ındstone											yellowish-brown
ıam	10-65%	.8-2.5	.12-.14	6.1-7.3	0	3-23					grayish-brown dark gray
ım ıy	10-65%	.8-2.5 .05-.2	.11-.14 .11-.14	5.6-6.5 5.1-5.5	0	7-29	Low	V Low	High	Med	brown reddish-brown to yellowish-brown
ıck											
ıy ' loam .salt	20-65%	.8-2.5	.12-.15	6.1-6.5	0	4-11	Low	V Low	High	Med	reddish-brown brown to yellowish-brown
ım	10-65%	.8-2.5	.12-.15	5.1-5.5	0	0-16	Med	Med	High	Low	brown to reddish-brown

Soil Group E

Main soil series and complexes in this group include:

Soil Series-Complexes	Approximate Rangeland Acreage			
	Colusa	Glenn	Tehama	Total
Maxwell (formerly Venado)	5,000	-	-	5,000
Leesville	2,500	-	-	2,500
East Park	1,300	500		1,800
Total	8,800	500		9,300

These are alluvial fans and basin fills developed largely from Serpentine rock sources. They are found in Bear Valley and the Stonyford area, Colusa County and west of Chrome and Gravelly Ridge, Glenn County. Elevation is 1000 to 1500 feet. Slopes range between 0 and 16 percent and the better soils are farmed to wheat or irrigated pasture.

The high magnesium to calcium ratio of 1:1 restricts plant growth and palatability while the predominately dense clay restricts root growth.

This site has sparse brush in some sites, digger pine and chamise. Vegetation is primarily annual grasses and forbs. Annual bromes and filaree are the most desirable vegetation. There are very few legumes; however, bur clover grows in some areas.

Feed production is low to moderate:

a. 1200-1800 lbs. per acre dryland wheat in 3-5 year rotation.

b. 200-2500 lbs. dry matter per acre of open land.

c. .3 - 3.1 animal unit months (AUM) per acre.

d. 4.0 - .3 acres per AUM.

e. Ranchers figure 15 acres per head for a 6-7 month season.

	Slope %	Permeability Inch/Hr	Available Water Capacity Inch/Inch Soil	Acid Base Reaction pH	Calcium Carbonate Lime %	Storie Index	Fertility N	P	K	S	Color
	0-2%		7.5-8.0 8.0 8.0	 ++ ++++	44						black dark gray light mottled gray
alluvium											
rp											
	0-2%		7.0-7.2	0 0	55						brownish-gray dull brownish-gray
ay loam											
ay, clay loam ntine alluvium			7.0-8.0	++							dark brownish-gray
lly											
	0-10%	.05-.2	.10-.12	6.6-7.3	16-41						
ly clay, , sandy clay ntine alluvium		.05-.2	.08-.10	7.4-7.8							

ACKNOWLEDGMENTS:

The major range soil groups section was assembled and written by Monte Bell, Mark Testerman, Bill Richardson, Barry Wallace and Don Greiner.

REFERENCES FOR SECTION III.

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SOIL SURVEY, GLENN COUNTY, CALIFORNIA, U.S. Department of Agriculture, Soil Conservation Service and Forest Service and University of California Agricultural Experiment Station, May 1968.

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Section IV. RANGE IMPROVEMENT RECOMMENDATIONS

The recommendations are given for each soil group and further divided within a soil group where there are distinct range sites and/or alternate objectives.

The recommendations are as specific and detailed as possible so that ranchers and range managers can figure costs, locate materials and equipment and evaluate the feasibility for his own situation.

Of course, on site inspection, consultation with public and private parties knowledgeable and experienced in range improvement and some clear thinking and planning are necessary before making investments in a range improvement practice.

RANGE SOIL GROUP A

Brown and red gravelly, terrace soils

RANGE SITE A1 - Entire soil group area except where brush is substantial or tree canopy is solid.

OBJECTIVE 1 - increase early production and palatability of native vegetation.

Recommendations - range fertilization

1. 40-60 lbs. nitrogen per acre broadcast on the surface will double feed; and if applied prior to fall rains will advance range growth six weeks ahead of unfertilized range with normal rainfall. There will be no carryover response the second year. Ammonium sulfate is recommended because of price, reduced leaching loss and sulfur content which improves grass and clover growth and quality.
2. Use the cheapest source of applied nitrogen. At present 300 lbs. per acre ammonium sulfate (63 lbs. actual N, 72 lbs. sulfate sulfur) costs about $18.00 per acre applied (1979 application costs - approximately $2.25 per acre ground and $4.00 by air). On land open and level enough ground rig application is usually cheaper than air.
3. Allow at least 4 inches growth before grazing to allow grass to utilize the nitrogen efficiently.
4. Apply fertilizer between October 1 and January 1.
5. 150 lbs. nitrogen per acre will increase feed 3 to 4 times the first year and 2 times the carryover year compared to unfertilized range. This may be economical under certain livestock - fertilizer - feed price relationships.

6. This range site usually has very little clover. Therefore, it is not economical to fertilize with sulfur and phosphorus.
7. Stocking level must be increased to utilize forage produced or no economical gain will result from fertilizing.

RANGE SITE A2 - level and free enough of rocks, brush and trees to farm with common dry farm equipment.

OBJECTIVE 1 - Establish annual legumes to increase quantity and quality of feed for seasonal or year-round grazing.

Recommendations:

1. Order seed early (June) because most comes from Australia. Seed must be pellet inoculated just before seeding.

Seed Varieties	Lbs./Acre (Raw Seed)
Sub clover	
Geraldton	2
Daliak	1
Yarloop	1
Seaton Park	2
Howard	1
Woogenellup	2
Mt. Barker	1
Rose clover	
Wilton	2
Hykon	2
Kondinin	2
	16

New sub clover varieties Northam, Nungarin, and Trikkala should be included if available. Hykon rose clover probably not available now. If not, use California Common.

2. If the field has been farmed to grain, harvest with a straw spreader.
3. Graze the stubble to remove most of the straw.
4. Take a soil sample of each field or major soil type. A minimum of 20 sub-samples 6 inches deep taken throughout the field are needed for each sample.
5. Fertilize based on soil test results

Test	Fertilizer or Equivalent
pH less than 5.5	2 tons/acre sugar beet lime

5.

Test	Fertilizer or Equivalent
Available phosphorus or sulfur	
less than 5 ppm	500 lbs. single superphosphate (100 lbs. P_2O_5; 60 lbs. sulfate sulfur)
5-10 ppm	250 lbs. single superphosphate (50 lbs. P_2O_5; 30 lbs. sulfate sulfur)
over 10 ppm	100 lbs. single superphosphate (20 lbs. P_2O_5; 12 lbs. sulfate sulfur)

6. Direct drill properly inoculated seed before or just after the beginning rain in October. If no rain by November 1st, plant dry.
7. If a drill is not available, lightly disc or harrow to loosen top 1" of soil, and broadcast seed. Ringroll immediately after broadcast seeding to cover seed and firm seedbed.

Management of new stands

1. Graze moderately during winter when field is dry enough.
2. Do not graze from March 15 to May 15 to allow flowering and seed set.
3. Must graze heavily during the dry season, allowing livestock to shatter and plant seed.

Management of established stands

1. Fertilize with 100 lbs. single superphosphate (20 lbs. P_2O_5; 12 lbs. sulfate sulfur) per acre each year unless soil test for phosphorus is high (over 10 ppm). If pH is below 5.5, apply 2 tons sugar beet lime per acre every 7 years, or when top 6" of soil drops below pH 6.
2. Close grazing during the entire season will favor sub clover. Grazing all year except April 15 to June 1 will favor rose clover. Undergrazing will depress sub clover production.

3. A dryland grain crop may be planted every 5-7 years in rotation with a good stand of clover and still allow the clover to reseed itself. It may be desirable to add new varieties after cropping.

Cost of establishment (1979)

Cost item	$/acre
Fertilize 2 tons/acre sugar beet lime applied	16
Drill rental	4
Inoculated seed 16 lbs/acre @ 1.70	27
	$47

Stands have been maintained for 25 years on this range site.

University of California research has shown a two to four-fold increase in production compared to unimproved range and increased grain yields in rotation.

RANGE SOIL GROUP B

Deep heavy textured, bur clover and "bottom land" soils

RANGE SITE B1 - Entire soil group area

OBJECTIVE 1 - Increase early growth quantity and quality of native feed.

Recommendations - range fertilization

1. 300 lbs. ammonium sulfate (63 lbs. actual nitrogen, 72 lbs. sulfate sulfur) per acre has increased the first years feed by 50% and the next 3 years by 20-30%. Cost applied is about $18.00 per acre.
2. Always add sulfur with the nitrogen. Many of these soils are very sulfur deficient.
3. Even though this soil group is usually adequate in phosphorus (over 10 ppm) the addition of P to the N and S will increase production by about 20%, especially in the carryover years, provided the bur clover stand is adequate.
4. Apply the fertilizer between October 1 and January 1.
5. Allow at least four inches of grass growth before grazing to utilize the nitrogen efficiently.
6. Graze heavily in the winter and early spring to prevent the grass from choking out the clover. Do not leave a heavy dry residue going into the fall.
7. Plan to increase the grazing use or there will be no economical benefit from fertilizing.

OBJECTIVE 2 - Increase production of native bur clover

Recommendations - range fertilization

1. 150 lbs. per acre elemental sulfur every five years. This material at $70 per ton costs about $8.00 per acre applied and should double the clover growth. This results in 20-30% more

total feed with a much higher quality. Even dry bur clover has adequate protein for stock (8%) compared to grass (4%) which is below the requirements.

2. Elemental sulfur will not leach and can be applied during any season without loss. However, elemental sulfur requires bacterial action to make it available to plants. It will take several months to a year depending on particle size, before a response is obtained.
3. Have soil and tissue tests run every other year. (See section on fertilizing range.) If the soil phosphorus level drops to 10 ppm, phosphorus should be added in amounts to equal 20 lbs. P_2O_5 per year. Values over 20 ppm indicate no phosphorus is needed.

Caution. Carefully inspect area to make sure bur clover stand will be adequate. The alfalfa weevil has greatly reduced bur clover stand in recent years. Also some sites on these soils have been undergrazed to the point where bur clover has been crowded out. This recommendation is good only if bur clover or other high producing annual legume is present.

Also in areas of solid bur clover, sulfur along with a good bur clover year can create a bloat and prolapse hazard to cattle and sheep.

RANGE SITE B2 - level and free enough of rocks, brush and trees to farm with common dry farm equipment. Moderately acid to moderately calcareous soils.

OBJECTIVE 1 - Increase native feed growth in order to cut hay.

Recommendations - range fertilization

1. 300 to 600 lbs. ammonium sulfate or equivalent per acre.
2. Apply fertilizer before January 1.

OBJECTIVE 2 - Establish a high producing annual legume for increased yield of high quality dry feed for grazing during the summer and fall in a 3 to 5 year rotation with dry farming.

Recommendations:

1. Order seed early. This variety is often in short supply. Seed must be pellet inoculated. Recommend 15 pounds Lana vetch (raw seed) per acre.
2. If the field has been farmed to grain, harvest with a straw spreader.
3. Graze the stubble to remove most of the straw.
4. Take a soil sample of each field or major soil type. A minimum of 20 sub-samples 6 inches deep taken throughout the field are needed for each sample. (See fertilizing range section.)
5. Fertilize based on soil test results.

Test	Fertilizer or equivalent
Available phosphorus or sulfur	
less than 5 ppm	500 lbs. single superphosphate (100 lbs. P_2O_5 - 60 lbs. sulfate sulfur)
5 - 10 ppm	250 lbs. single superphosphate (50 lbs. P_2O_5 - 30 lbs. sulfate sulfur)
over 10 ppm	100 lbs. single superphosphate (20 lbs. P_2O_5 - 12 lbs. sulfate sulfur)

6. Drill properly inoculated seed before or just after the beginning rain in October. If no rain by November 1, plant dry.

7. If a drill is not available, disc to loosen top 4" of soil, and broadcast seed. Ringroll immediately after broadcast seeding to cover the seed and firm seedbed.

Management of new stands

1. Graze moderately during early winter when field is dry enough.
2. Do not graze from March 1 to June 1 to allow flowering and seed set.
3. Must graze heavily during the dry season, allowing livestock to shatter and plant seed.

Management of established stands

1. Fertilize with 100 lbs. single superphosphate (20 lbs. P_2O_5, 12 lbs. sulfate sulfur) per acre each year unless soil test for phosphorus is high (over 10 ppm). If pH is below 5.5 apply 2 ton sugar beet lime per acre.
2. Do not graze from March 1 to June 1 to allow flowering and seed set.
3. Dryland grain should be planted every 3 - 5 years and vetch reseeded in stubble.

Cost of establishment

Cost item	$/acre
Fertilize 300 lbs. single superphosphate or equivalent	20
Drill rental	4
Inoculated seed 15 lbs./acre	9
	$33

Stands have produced well for 3 - 5 years on this range site.

University of California research has shown a two to four-fold increase in production compared to unimproved range and increased grain yields in rotation.

RANGE SITE B3 - level and free enough of rocks, brush and trees to farm with common dry farm equipment. Moderately acid to neutral medium textured soils with no free lime.

OBJECTIVE - establish new species of annual legumes to compliment bur clover in producing high quality feed over a greater range of environmental conditions. Grazing is not restricted to any particular season.

Recommendations

1. Order seed early (June) because most comes from Australia.

   Seed must be pellet inoculated just before seeding.

Seed Varieties	Lbs./Acre (Raw seed)
Sub clover	
Geraldton	1
Daliak	1
Yarloop	1
Seaton Park	1
Howard	1
Woogenellup	1
Clare	1
Mt. Barker	1
Rose clover	
Wilton	1
Hykon	1
Kondinin	1
Barrel Medic	
Jemalong	2
Cyprus	2
	15

   New sub clover varieties Northam, Nungarin, and Trikkala should be included if available. Hykon rose clover probably available now. If not use California Common.

2. If the field has been farmed to grain, harvest with a straw spreader.

3. Graze the stubble to remove most of the straw.

4. Take a soil sample of each field or major soil type. A minimum of 20 sub-samples 6 inches deep taken throughout the field are needed for each sample.

5. Fertilize based on soil test results.

Test	Fertilizer or equivalent
Available phosphorus or sulfur	
Less than 5 ppm	500 lbs. single superphosphate (100 lbs. P_2O_5, 60 lbs. sulfate sulfur)
5 - 10 ppm	250 lbs. single superphosphate (50 lbs. P_2O_5, 30 lbs. sulfate sulfur)
Over 10 ppm	100 lbs. single superphosphate (20 lbs. P_2O_5, 12 lbs. sulfate sulfur)

6. Drill properly inoculated seed before or just after the beginning rain in October. If no rain by November 1, plant dry.

7. If a drill is not available lightly disc or harrow to loosen top 1" of soil, and broadcast seed. Ringroll immediately after broadcast seeding to cover seed and firm seedbed.

Management of new stands

1. Graze moderately during winter when field is dry enough.
2. Do not graze from April 15 to June 1 to allow flowering and seed set.
3. Must graze heavily during the dry season allowing livestock to shatter and plant seed.

Management of established stands

1. Fertilize with 100 lbs. single superphosphate (20 lbs. P_2O_5, 12 lbs. sulfate sulfur) per acre each year unless soil test for phosphorus is high (over 10 ppm).
2. Close grazing during the entire season will favor sub clover. Grazing all except April 15 to June 1 will favor rose clover and the medics. Undergrazing will depress sub clover production. Allowing a heavy residue of old feed going into the fall is a frequent cause of clover stand loss.

3. A dryland grain crop may be planted every 5-7 years in rotation with a good stand of clover and still allow the clover to reseed itself. It may be desirable to plant improved varieties after cropping.

Cost of establishment (1979)

Cost item	$/acre
Fertilize 100 lbs./acre single superphosphate	6
Drill rental	4
Inoculated seed 15 lbs/acre	26
	$36

In the past livestock operators have relied on the resident legume bur clover (a medic) for high quality late feed. More recently the alfalfa weevil has reduced bur clover stands severely. The weevil preferentially damages medics, but will also attack true clovers.

In mixed stands we have observed only moderate damage to clovers; whereas, the medics were completely destroyed. Field releases of parasites for biological control of the alfalfa weevil on these ranges started in 1974. Seeding is advised on a small scale until biological control of the alfalfa weevil has developed.

RANGE SITE B4 - Level and free enough of rocks, brush and trees to farm with common dry farm equipment. Heavy textured, moderately calcareous soils containing free surface lime (Nacimiento, Ayar). Areas with limited bur clover.

OBJECTIVE - Establish new species of annual legumes to compliment California bur clover in producing high quality feed over a greater range of environmental conditions. Grazing is not restricted to any particular season.

Recommendations:

1. Order seed early (June) because most comes from Australia and are often in very short supply. Seed must be pellet inoculated just before seeding.

Seed Varieties	Lbs/Acre (Raw Seed)
Clare sub clover	2
Barrel Medic	
Jemalong	2
Cyprus	2
California bur clover	2
	8

2. If the field has been farmed to grain, harvest with a straw spreader.
3. Graze the stubble to remove most of the straw.
4. Take a soil sample of each field or major soil type. A minimum of 20 sub-samples 6 inches deep taken throughout the field are needed for each sample.
5. Fertilize based on soil test results

Test	Fertilizer or equivalent
Available phosphorus or sulfur	
Less than 5 ppm	500 lbs. single superphosphate (100 lbs. P_2O_5, 60 lbs. sulfate sulfur)
5 - 10 ppm	250 lbs. single superphosphate (50 lbs. P_2O_5, 30 lbs. sulfate sulfur)
Over 10 ppm	100 lbs. single superphosphate (20 lbs. P_2O_5, 12 lbs. sulfate sulfur)

6. Direct drill properly inoculated seed before or just after the beginning rain in October. If no rain by November 1, plant dry.

7. If a drill is not available lightly disc or harrow to loosen top 1" of soil and broadcast seed. Ringroll immediately after broadcast seeding to cover seed and firm seedbed.

Management of new stands

1. Graze moderately during winter when field is dry enough.
2. Do not graze from April 15 to June 1 to allow flowering and seed set.

Management of established stands

1. Fertilize with 100 lbs. single superphosphate (20 lbs. P_2O_5, 12 lbs. sulfate sulfur) per acre each year or 200 lbs. single superphosphate (40 lbs. P_2O_5, 24 lbs. sulfate sulfur) per acre every other year if soil test for phosphorus is high (over 20 ppm). If single superphosphate is not available, apply 100 - 200 lbs. elemental sulfur per acre every 5 - 10 years.
2. Close grazing during the entire season will favor legumes. Undergrazing will depress sub clover production.
3. A grain crop may be planted every 5 - 7 years in rotation with a good stand of legume and still allow the clover to reseed itself. It may be desirable to plant improved varieties after cropping.

Cost of establishment

Cost Item	$/Acre
Fertilize 100 lbs/acre single superphosphate	6
Drill rental	4
Inoculated seed 8 lbs/acre broadcast	13
	$23

Caution. These soils include some of the best bur clover range. More recently the alfalfa weevil has reduced bur clover stands severely. The weevil preferentially damages medics, but will also attack true clovers.

In mixed stands we have observed only moderate damage to clovers; whereas, the medics were completely destroyed. Field releases of parasites for biological control of the alfalfa weevil on these ranges started in 1974. Seeding is advised on a small scale until biological control of the alfalfa weevil has developed.

RANGE SITE B5 - Level enough to farm with conventional dry farm equipment. Moderately acid to moderately calcareous deep loamy textured soils. Special conditions where sub-surface moisture is present during early summer. May be small swale areas uneconomical to farm.

OBJECTIVE 1 - Establish permanent improved species of perennial grass to extend the grazing season and where operator does not want to dry farm to annual crops.

Recommendation Calendar for Mechanical Seedbed Preparation

1. 1979 early spring before moisture is lost and vegetation heads out plow to a depth of at least 8".
2. 1979 Summer - maintain a clean fallow field.

Grass seeding fall 1979

1. Reducing competition is most important. Harrow out seedling weeds if any after opening fall rains. Plant perennial grass about mid December.
2. Drill 5 lbs/acre perennial grass or grass mix and 100 lbs./acre 16 - 20 fertilizer in 12-16" rows not more than 1/2" deep.
3. Commercial drills are now available or if a grain drill is used, mix 5 lbs. Perlagrass seed with 16 lbs. rice hulls. Calibrate the seeder to seed 16 lbs. rice hulls per acre. (Similar setting to 100 lbs. barley per acre).
4. Do not include any annuals in the seed mix. The following perennial grasses should be considered.

   Hardinggrass - several stands on good soil sites have been producing for over 25 years.

   Perlagrass - a selection out of Hardinggrass. Makes more rapid seedling growth.

   Palestine Orchardgrass - one of the more palatable grasses, and more susceptible to being selectively grazed out.

4.

Tall Wheatgrass - easiest to establish. Not as palatable as the other grasses.

Management of new stand

1. Spray as necessary for broadleaf weeds.
2. Mow as necessary for annual grass control in May.
3. Do not graze until July 1.

OBJECTIVE 1A - establish legumes in perennial grass stand for winter and spring grazing on acid to neutral sites.

1. Fall 1980 - Drill legume seed in the perennial grass stand that was established in 1979.
2. Drill no deeper than 1/2".
3. Properly pellet inoculate seed just before seeding.

Seed Varieties	Lbs/Acre Drilled (raw pure live seed)
Sub clover	
Daliak	1
Yarloop	1
Seaton Park	2
Woogenellup	2
Clare	1
Mt. Barker	1
Barrel Medic	
Jemalong	1
Rose Clover	
Wilton	2
	11

New sub clover varieties Northam, Nungarin, and Trikkala should be included if available. If Wilton rose clover not available, use California Common.

4. Fertilize based upon soil test results.

Test	Fertilizer or equivalent
Available phosphorus or sulfur	
Less than 5 ppm	500 lbs. single superphosphate (100 lbs. P_2O_5, 60 lbs. sulfate sulfur)
5 - 10 ppm	250 lbs. single superphosphate (50 lbs. P_2O_5, 30 lbs. sulfate sulfur)
Over 10 ppm	100 lbs. single superphosphate (20 lbs. P_2O_5, 12 lbs. sulfate sulfur)

OBJECTIVE 1B - Establish legumes in perennial grass stand for winter and spring grazing on neutral to moderately alkaline soils containing free lime.

Seed Varieties	Lbs/Acre (Raw Seed)
Sub clover	
Clare	3
Barrel Medic	
Jemalong	2
Cyprus	2
California bur clover	2
Rose clover	
Wilton	2
	11

OBJECTIVE 1C - Establish legumes in perennial grass stand, for summer and fall grazing only.

1. In fall, 1980 drill 10 lbs. Lana vetch per acre (raw seed)

Management of established stand

1. For maintenance of Perlagrass, it should be allowed to grow to a height of 18" at least once each year.
2. Sub, rose and the medics will be favored by close grazing and sub may not persist if undergrazed. Vetch is favored by no grazing during flower and seed set (spring). Vetch tends to go out of the stand over time especially if soil compacts.

3. Fertilize with 100 lbs. single superphosphate (20 lbs. P_2O_5, 12 lbs. sulfate sulfur) per acre each year or 200 lbs. single superphosphate (40 lbs P_2O_5, 24 lbs. sulfate sulfur) per acre every other year if soil test for phosphorus is high (over 20 ppm). If high, apply 100 - 200 lbs. elemental sulfur per acre every 5 - 10 years.

RANGE SOIL GROUP C

Brown clay loam foothill soils.

RANGE SITE C1 - entire soil group area except where brush or tree canopy is greater than 60 per cent.

OBJECTIVE 1 - increase early growth, quantity and quality of native feed.

Recommendation - range fertilization

1. 300 lbs. ammonium sulfate (63 lbs. actual nitrogen, 72 lbs. sulfate sulfur) per acre will double production the first year and give a 20-30% increase for two carryover years providing bur clover is present. Cost applied is about $18.00 per acre.
2. Always add sulfur with the nitrogen. Many of these soils are very sulfur deficient.
3. Phosphorus level in these soils is usually borderline (10 ppm). However, a soil test for P should be made. Unless there is abundant bur clover, the additional phosphorus does not pay.
4. Apply the fertilizer prior to the fall rains.
5. Allow at least 4 inches of grass growth before grazing.
6. Increase grazing use in proportion to the increased growth to obtain a return.
7. Fertilize every three to five years or 20 to 30% of the field annually.

OBJECTIVE 2 - increase production of native bur clover

Recommendation - range fertilization

1. 150 lbs. per acre elemental sulfur every five years. This material at $70.00 per ton costs about $8.00 per acre applied and should double the clover growth. This results in 20-30% more total feed production with a much higher quality.

Dry bur clover has adequate protein for stock (8%) compared to grass (4%) which is below the requirements.

2. Elemental sulfur will not leach and can be applied during any season without loss. However, elemental sulfur requires bacterial action to make it available to plants. It will take several months to a year, depending on particle size, before a response is obtained.

3. Have soil and tissue tests run every other year (See section on fertilizing range.) If the soil phosphorus level drops to 10 ppm, phosphorus should be added in amounts to equal 20 lbs. P_2O_5 per year. Values over 20 ppm indicate no phosphorus is needed.

Caution. Carefully inspect area to make sure bur clover stand will be adequate. The alfalfa weevil has greatly reduced bur clover stands in recent years. Also some sites on these soils have been undergrazed to the point where bur clover has been crowded out; other sites are too shallow to support bur clover.

RANGE SITE C2 - level and free enough of rocks, brush and trees to farm with common dry farm equipment.

OBJECTIVE 1 - increase native feed growth in order to cut hay.

Recommendation - range fertilization

1. 300 to 600 lbs. ammonium sulfate or equivalent per acre.
2. Apply fertilizer before January 1.

OBJECTIVE 2 - establish a high producing annual legume for increased yield of high quality dry feed for grazing during the summer and fall in 3 to 5 year rotation with dry farming.

Recommendations:

1. Order seed early. This variety is often in short supply. Seed must be pellet inoculated. Recommend seeding 15 lbs. (raw seed) of Lana vetch per acre.
2. If the field has been farmed to grain, harvest with a straw spreader.
3. Graze the stubble to remove most of the straw.
4. Take a soil sample of each field or major soil type. A minimum of 20 sub-samples 6 inches deep taken throughout the field are needed for each sample.
5. Fertilize based on soil test results.

Test	Fertilizer or Equivalent
Available phosphorus or sulfur	
less than 5 ppm	500 lbs. single superphosphate (100 lbs. P_2O_5, 60 lbs. sulfate sulfur)
5 - 10 ppm	250 lbs. single superphosphate (50 lbs. P_2O_5, 30 lbs. sulfate sulfur)

6. Drill properly inoculated seed before or just after the beginning rain in October. If no rain by November 1, plant dry.

7. If a drill is not available, disc to loosen top 4" of soil and broadcast seed. Ringroll immediately after broadcast seeding to cover seed and firm seedbed.

OBJECTIVE 3 - establish new species of annual legumes to compliment California bur clover in producing high quality feed over a greater range of environmental conditions. Grazing is not restricted to any particular season.

Recommendations:

1. Order seed early (June) because most comes from Australia. Seed must be pellet inoculated just before seeding.

Seed Varieties	Lbs./Acre (Raw Seed)
Sub clover	
Geraldton	1
Daliak	1
Yarloop	1
Seaton Park	1
Howard	1
Woogenellup	1
Clare	1
Mt. Barker	1
Rose clover	
Wilton	1
Hykon	1
Kondinin	1
Barrel Medic	
Jemalong	2
Cyprus	2
	15

New sub clover varieties Northam, Nungarin, and Trikkala should be used if available. If any of above rose clovers are not available, use California Common.

2. If the field has been farmed to grain, harvest with a straw spreader.
3. Graze the stubble to remove most of the straw.

4. Take a soil sample of each field or major soil type. A minimum of 20 sub-samples 6 inches deep taken throughout the field are needed for each sample.

5. Fertilize based on soil test results.

Test	Fertilizer or Equivalent
Available phosphorus or sulfur	
Less than 5 ppm	500 lbs. single superphosphate (100 lbs. P_2O_5, 60 lbs. sulfate sulfur)
5 - 10 ppm	250 lbs. single superphosphate (50 lbs. P_2O_5, 30 lbs. sulfate sulfur)
Over 10 ppm	100 lbs. single superphosphate (20 lbs. P_2O_5, 12 lbs. sulfate sulfur)

6. Drill properly inoculated seed before or just after the beginning rain in October. If no rain by November 1, plant dry.

7. If a drill is not available, lightly disc or harrow to loosen top 1" of soil and broadcast seed. Ringroll immediately after broadcast seeding to cover seed and firm seedbed.

Management of new stands

1. Graze moderately during winter when field is dry enough.

2. Do not graze from April 15 to June 1 to allow flowering and seed set.

3. Must graze heavily during the dry season allowing livestock to shatter and plant seed.

Management of established stands

1. Fertilize with 100 lbs. single superphosphate (20 lbs. P_2O_5, 12 lbs. sulfate sulfur) per acre each year or 200 lbs. single superphosphate (40 lbs. P_2O_5, 24 lbs. sulfate sulfur) per acre every other year if soil test for phosphorus is high (over 20 ppm). If high, apply 100 - 200 lbs. elemental sulfur per acre every 5 - 10 years. If pH is below 5.5, apply 2 tons sugar beet lime per acre every 7 years.

2. Close grazing during the entire season will favor sub clover. Grazing all year except April 15 to June 1 will favor rose clover. Undergrazing will depress sub clover production.

3. A grain crop may be planted every 5 - 7 years in rotation with a good stand of clover and still allow the clover to reseed itself. It may be desirable to add new varieties after cropping.

Cost of establishment (1979)

Cost item	$/Acre
Fertilize 2 tons/acre sugar beet lime applied	16
Drill rental	4
Inoculated seed 16 lbs/acre @ 1.70 per lb.	27
	47

Stands have been maintained for 25 years on this range site. University of California research has shown a two to four-fold increase in production compared to unimproved range and increased grain yields in rotation.

RANGE SITE C3 - relatively dense brush and trees have been removed resulting in considerable bare ground. (See brush management section).

OBJECTIVE 1 - establish a high producing annual legume for increased yield of high quality dry feed for grazing during the summer and fall in 3 to 5 year rotation with dry farming.

Recommendations:

1. Order seed early. This variety is often in short supply. Seed must be pellet inoculated. Recommend seeding 15 lbs. (raw seed) of Lana vetch per acre.
2. If the field has been farmed to grain, harvest with a straw spreader.
3. Graze the stubble to remove most of the straw.
4. Take a soil sample of each field or major soil type. A minimum of 20 sub-samples 6 inches deep taken throughout the field are needed for each sample.
5. Fertilize based on soil test results.

Test	Fertilizer or Equivalent
Available phosphorus or sulfur	
less than 5 ppm	500 lbs. single superphosphate (100 lbs. P_2O_5, 60 lbs. sulfate sulfur)
5 - 10 ppm	250 lbs. single superphosphate (50 lbs. P_2O_5, 30 lbs. sulfate sulfur)

6. Drill properly inoculated seed before or just after the beginning rain in October. If no rain by November 1, plant dry.
7. If a drill is not available, disc to loosen top 4" of soil and broadcast seed. Ringroll immediately after broadcast seeding to cover seed and firm seedbed.

OBJECTIVE 2 - establish new species of annual legumes to compliment California bur clover in producing high quality feed over a greater range of environmental conditions. Grazing is not restricted to any particular season.

Recommendations:

1. Order seed early (June) because most comes from Australia.

   Seed must be pellet inoculated just before seeding.

Seed Varieties	Lbs/Acre (Raw Seed)
Sub clover	
Geraldton	2
Daliak	1
Yarloop	1
Seaton Park	2
Howard	1
Woogenellup	2
Mt. Barker	1
Rose clover	
Wilton	1
Hykon	1
Kondinin	1
Medic	
Jemalong	1
Cyprus	1
California bur	1
Blando brome(or annual ryegrass)	1/2
	16 1/2

   New sub clover varieties Northam, Nungarin, and Trikkala should be used if available. If any of above rose clovers are not available, use California Common.

2. Take soil sample of each field or major soil type.

3. Fertilize based on soil test results.

Test	Fertilizer or Equivalent
Available phosphorus or sulfur	
Less than 5 ppm	500 lbs. single superphosphate (100 lbs. P_2O_5, 60 lbs. sulfate sulfur)
5 - 10 ppm	250 lbs. single superphosphate (50 lbs. P_2O_5, 30 lbs. sulfate sulfur)
Over 10 ppm	100 lbs. single superphosphate (20 lbs. P_2O_5, 12 lbs. sulfate sulfur)

4. Drill properly inoculated seed before or just after the beginning rain in October. If a drill is not available, broadcast seed. If no rain by November 1, plant dry.

5. Ringroll or lightly drag where possible immediately after broadcase seeding.

Management of established stands

1. Fertilize with 100 lbs. single superphosphate (20 lbs. P_2O_5, 12 lbs. sulfate sulfur) per acre each year or 200 lbs. single superphosphate (40 lbs. P_2O_5, 24 lbs. sulfate sulfur) per acre every other year if soil test for phosphorus is high (over 20 ppm). If high, apply 100 - 200 lbs. elemental sulfur per acre every 5 - 10 years.
2. Fairly close grazing during the entire season will favor sub clover. Grazing all year except April 15 to June 1 will favor rose clover and the medics. Undergrazing will depress sub clover production.

Cost of establishment

Cost Item	$/Acre
Fertilize 100 lbs/acre single superphosphate	6
Inoculated seed, 16 1/2 lbs/acre @ 1.70 per lb.	28
	34

Caution. Seeding can be done selectively on where there were dense stands of brush and very little competition is expected from resident annuals. Establishment success has been poor where first-year dense resident annuals cannot be controlled by farming.

RANGE SOIL GROUP D

Gravelly brushland soils.

RANGE SITE D1 - relatively dense brush and trees have been removed resulting in considerable bare ground. (See brush management section).

OBJECTIVE 1 - increase early growth and total production of native feed.

Range fertilization

1. At $10-15 per acre for 40-60 lbs. of nitrogen, it is doubtful the increase in feed will be economical.
2. The soils in this group vary greatly in phosphorus level and must be checked before fertilizing.
3. Legumes must be present in order to obtain a response from phosphorus applications alone.

OBJECTIVE 2 - establish annual legumes for production of high quality feed.

Recommendations:

1. Order seed early (June) because most comes from Australia.

   Seed must be pellet inoculated just before seeding.

Seed Varieties	Lbs/Acre (Raw Seed)
Sub clover	
Geraldton	2
Daliak	1
Yarloop	1
Seaton Park	2
Howard	1
Woogenellup	2
Mt. Barker	1
Rose clover	
Wilton	1
Hykon	1
Kondinin	1
Medic	
Jemalong	1
Cyprus	1
California bur	1
	16

New sub clover varieties Northam, Nungarin, and Trikkala should be used if available. If any of above rose clovers are not available, use California Common.

2. Take soil sample. See fertility range section.

3. Fertilize based on soil test results.

Test	Fertilizer or Equivalent
Available phosphorus or sulfur	
Less than 5 ppm	500 lbs. single superphosphate (100 lbs. P_2O_5, 60 lbs. sulfate sulfur)
5 - 10 ppm	250 lbs. single superphosphate (50 lbs. P_2O_5, 30 lbs. sulfate sulfur)
Over 10 ppm	100 lbs. single superphosphate (20 lbs. P_2O_5, 12 lbs. sulfate sulfur)

4. Drill properly inoculated seed before or just after the beginning rain in October. If a drill is not available, broadcase seed. If no rain by November 1, plant dry.

5. Ringroll or lightly drag where possible immediately after broadcast seeding; however, it is better to leave seed uncovered than to bury too deeply (over 1/2 inch).

Management of established stands

1. Fertilize with 100 lbs. single superphosphate (20 lbs. P_2O_5, 12 lbs. sulfate sulfur) per acre each year or 200 lbs. single superphosphate (40 lbs. P_2O_5, 24 lbs. sulfate sulfur) per acre every other year if soil test for phosphorus is high (over 20 ppm). If high, apply 100 - 200 lbs. elemental sulfur per acre every 5 - 10 years.

2. Fairly close grazing during the entire season will favor sub clover. Grazing all year except April 15 to June 1 will favor rose clover and the medics. Undergrazing will depress sub clover production.

Cost of establishment

Cost Item	$/Acre
Fertilize 100 lbs/acre single superphosphate	6
Drill Rental	4
Inoculated seed, 16 lbs/acre @ $1.70 per lb.	27
	$37

Caution. Seeding can be done selectively only where there were dense stands of brush and there is very little competition expected from resident annuals. Establishment success has been poor where first-year dense resident annuals cannot be controlled by farming.

RANGE SITE D2 - elevation above 1500', level enough for range drill operation where dense brush and trees have been removed.

OBJECTIVE - establish perennial grass where follow-up spray is required for brush seedling and sprout control.

Recommendations:

1. Seed Varieties — Lbs/Acre

Perlagrass	3
Intermediate wheatgrass	1
Tall fescue	1
	5

2. Do not fertilize.

3. Drill seed on contour with range drill by November 1 (or by mid-December if weather will permit).

Management of established stands

1. Spray for brush seedling and sprout control in June.

2. Do not graze until July.

Management of established stands

1. Allow perennial grass to grow to a height of 18" at least once each year.

2. On lower elevation sites after perennial grass has established itself and the brush controlled, annual legumes may be drilled in with the range drill.

Seed Varieties	Lbs/Acre
Sub clover	
Seaton Park	1
Woogenellup	2
Mt. Barker	2
Rose clover	
Wilton	1
Hykon	1
Kondinin	1
	8

2.

New sub clover varieties Northam, Nungarin, and Trikkala should be included if available. If above rose clovers are not available, use California Common.

Cost of establishment

Cost Item	$/Acre
Drill 5 lbs. grass seed @ $2.50 per lb.	13
Follow-up spray	35
	$48
Drill annual legume and fertilize	$40

Caution. Establishing annual legumes in the Mendocino revegetation areas has not been successful except for rose clover in some areas; however, the new varieties and inoculation techniques have not been fully tested in this area.

RANGE SOIL GROUP E

Gray and black serpentine soils.

Range site E - individual sites must be assessed.

Establishment of improved species is difficult on these soils. Some scattered stands of tall wheatgrass have been successful. Recent work at the Hopland Field Station has shown that with proper pellet inoculation and fertilization, annual legumes can be established on some serpentine soils. Phosphorus, sulfur and calcium deficiencies must be corrected, however.

ACKNOWLEDGEMENTS:

The Range Improvement Recommendations Section was assembled and written by the entire development committee, with revisions by R. Knight and M. Bell.

REFERENCES FOR SECTION IV.

THE CERTIFIED STRAINS OF SUBTERRANEAN CLOVER, B.J. Quinlivan, C.M. Francis, and M. L. Poole, 1968.

MENDOCINO NATIONAL FOREST TYPE CONVERSION, Joe Ely, Mendocino National Forest, 1967.

MANAGEMENT OF CLOVERS ON CALIFORNIA ANNUAL GRASSLANDS, A.H. Murphy, M.B. Jones, J.W. Clawson and J.E. Street, December, 1973.

CLOVER-BARLEY ROTATION FOR DRYLAND, Monte Bell and Jim Street, Range Roundup, 1967.

SECTION V. BRUSH MANAGEMENT

Brush management is the management and manipulation of stands of brush by mechanical, chemical, or biological means or by prescribed burning. Included is the reduction of excess brush to restore plant community balance and the manipulation of brush stands through selective and patterned control methods.

Objectives of brush management include, but are not limited to, range improvement, wildlife habitat improvement, forest management, fuel management, watershed protection and maintenance, and prevention of accelerated soil erosion. The first three objectives usually are pursued for basic economic reasons; concentrations of brush are reduced or modified to encourage growth of other species of greater economic value or to establish a successional stage that represents improved wildlife habitat. Fuel management includes fire protection and reduction of the threat of wildfire, and as a result, it affects sources of water and water quality and erosion. Successful fuel management means reduction of fire suppression costs, protection of valuable resources, and reduction of problems associated with accelerated erosion, e.g. flooding, sedimentation, and destruction of aquatic habitat. The value of these objectives is more difficult to assess in terms of simple cost/benefit measurements, but the incentive is no less economic than that represented by the first three objectives.

Management for any one objective or value has an influence on all other values. For example, brush range improvement, short of total type conversion, generally improves wildlife habitat. Reduction of brush concentrations definitely reduces the threat of wildfire holocausts. In addition, any reduction in brush canopy increases the amount of water reaching the soil surface by reducing interception losses (evaporation of rainfall from leaf surfaces). This improves the potential for greater water yield from watersheds (see Figure 1).

Feasibility of brush management ~~and manipulation~~ is determined by topography, soil erodibility, soil productivity, and the amount and rate of economic return on management investments. Management is generally limited to slopes of 60 percent or less and to soils 18 inches or more in depth with a capacity for water storage of at least 2 inches.

PRESCRIBED BURNING.

Use of prescribed fire ~~under controlled conditions~~ is one of the most effective and economical means of reducing brush fuels and opening brushlands for livestock grazing. Such use often is preceded by treatment of the brush to desiccate it and permit a more effective burn. This desiccation can be accomplished with herbicides, but crushing with mechanical equipment is more effective and permits more complete combustion. Crushing is encouraged where physical and economic conditions permit.

Local air pollution control districts require brush to be treated at least six months prior to the burn if economically and technically feasible. Districts may designate a period between January 1 and May 31, during which time range improvement burning may be conducted by permit on a no-burn day, providing that more than 50 percent of the land has been brush treated.

After the initial burn, follow-up work is generally required in subsequent years to control sprouting brush and seedlings. Control can be accomplished with herbicides, ~~or~~ fire, ~~The latter technique~~ requires the range operator to leave adequate forage residues to carry a light fire that will kill seedlings and injure or kill sprout~~ing~~ p~~lants~~. Two or more light fires or applications of herbicides at intervals of no more than three years may be required if complete conversion to a grass cover is desired.

With a permit, burning can be accomplished any time meteorological conditions insure smoke dispersal and danger of wildfire is minimal. The safe period for burning is generally from late fall through late spring. Most burns of crushed brush are accomplished after mid-May but before the hot, dry summer months. During this period, fuel moisture and weather conditions permit efficient burning of treated brush before surrounding untreated brush becomes dry and presents a wildfire hazard. In addition, intense heat at this time destroys or damages new growth when root reserves are low and plants are physiologically weak. The result is more effective control of brush seedlings and sprouts on the treated area.

Anyone planning brush range improvement burn will require a permit issued by the California Division of Forestry. This permit is a joint authorization by the CDF and local Air Pollution Control Districts.

Effective and safe use of prescribed fire requires experience. Individuals who want to use this tool should consult with the local Farm Advisor, the local office of the Soil Conservation Service, and with the local Range Improvement Association or members of the local Cattlemen's Association. In addition, a copy of the following publication should be obtained: Organize, Plan, Prepare for Control Brush Burning, 2402, University of California Agricultural Extension.

TREE MANAGEMENT ON WOODLAND-GRASS RANGE.

Over 7 million acres of rangeland in the foothills surrounding California's great valleys are covered with stands of trees that have aesthetic appeal but limit production of animal protein that is a staple in human diets. On more than half of this area dense stands of oak trees severely limit grazing. These stands often number more than 100 trees per acre, and 200 trees per acre are not uncommon. The most common species are black oak, blue oak, and interior live oak, (dominant above an elevation of 2000 feet) (common throughout the area in dense stands).

~~The former dominates above an elevation of 2000 feet, and the latter is common throughout the area in dense stands.~~ Live oak presents a particular problem because second growth sprouts may create extremely dense thickets that are difficult for man and animals to penetrate.

Selective control of oaks and other common trees ~~using the cut-surface treatment and chemical injection~~ can greatly improve the grazing potential. Studies conducted in the Sierra foothills showed that annual forage production could be increased over 500 percent by chemically controlling oaks in stands that averaged 120 trees per acre. ~~(Reference~~ (1). During the first season following treatment, forage production increased from 270 pounds per acre dry matter to 1,409 pounds per acre dry matter. This increased production was sustained for the three year period of the study.

More than 15 percent tree canopy cover can reduce ~~potential~~ forage production. Canopy cover not exceeding 15 percent will insure adequate shade for livestock in summer, enhance aesthetics of the range scene, and provide a source of acorns for wildlife food if healthy, productive trees are selected for retention. A minimum of 4 to 5 trees per acre should be maintained. In exceptionally dry seasons, such as 1975-76 and 1976-77, forage production is greater beneath scattered trees than in open range areas. This supplemental feed can be very important and suggests an additional reason for retention of a 15 percent canopy cover.

~~Where~~ numbers of trees are to be treated, costs per acre are important. The cut-surface treatment is an economical method of control. A small hand ax or hatchet is used to make a series of closely spaced frills or cuts circling the base of the tree near the ground (on vigorous sprouting species such as live oak a complete girdle is necessary). These cuts are made ~~straight into the trunk or~~ at a slightly descending angle ~~to~~ a depth ~~of one inch beneath~~ the bark layer.

Into each frill or cut is injected undiluted 2,4-D amine from a pump-type oil can. A 7-inch diameter oak requires about one-half fluid ounce of chemical. (Reference 1).

Using the cut-surface method, cost ~~per acre~~ for treating 120 oak trees of 7-inch diameter is about ~~$10.40~~. The cost of labor is assumed to be $3 per hour. One gallon 2,4-D amine costs about ~~$11.22~~. For cut-surface treatment, materials account for about one-half of the cost and labor one-half. (Reference 1).

Studies at the University of California Hopland Field Station have shown that at current labor and material costs 2,4-D amine applied by tree injector will cost between $8 and $11 per acre when stands average 120 trees per acre and individual trees average 7 inches in diameter. (Reference 2). ~~These estimated costs are~~ based on the following conditions: labor at $3 per hour; 2,4-D ~~applied~~ at a rate of one-half fluid ounce per 7-inch tree (~~one-half gallon per acre);~~ $11.22 per gallon of chemical; treatment time of 19.6 to 43.3 seconds per ~~tree;~~ 9 minutes total moving time per acre to treat 120 trees.

Treatment of blue oak is the least expensive, about $8 per acre. Costs for treatment of black oak and madrone are about $9.20 and $10 per acre, respectively. At ~~$10.40~~ per acre, live oak ~~and manzanita are~~ the most expensive to treat. Live oak and manzanita grow in clumps with many stems coming from one base. During the treatment of any one stem, other stems in the group interfere with and prolong application. Treatment of manzanita is prolonged because the shrub often grows low and parallel to the ground. The thick, spongy bark of black oak impedes penetration to the cambium layer and clogs the chemical ports of the injection tool.

Tests in the northern Sacramento Valley comparing the tree-injector with cut-surface treatment showed the former to be less expensive. (Reference 1).

Once use of the tree injector is mastered, labor costs usually are less. However, crew experience will influence the cost differential.

Oak trees killed by injection or cut-surface application of 2,4-D amine begin to decompose within one year of treatment. Small branches will begin to fall after one year. Entire trees usually begin to fall five to seven years after treatment. Trees can be mechanically grounded two to three years after treatment when the soil is moist.

Accumulations of dead wood interfere with grazing. They should be burned to permit access to forage. To prevent spread of fire individual piles of dead wood can be burned during the green-feed period in the spring. If a great deal of debris has accumulated a broadcast burn may be necessary. Dry grass in late spring will provide sufficient fuel to ignite the wood. Conduct of such a burn should follow the recommendations and procedures for a brush range improvement burn.

Stump treatment is the third technique that can be employed to selectively treat individual trees. This method is usually employed when trees are being cut or cleared for firewood.

This treatment employs undiluted 2,4-D amine applied by paintbrush to the entire cut-surface of small stumps or in a strip 2-4 inches wide around the circumference of the cut-surface of large stumps. It is important that the chemical be applied immediately after cutting. Any delay will permit the surface of the cut stump to dry and seal. This prevents penetration of the chemical and subsequent translocation to the roots that is necessary to insure control.

The effectiveness of stump treatment depends on how carefully the necessary procedures are conducted. If trees are cut at an angle or inadequate chemical is applied, sprouting may occur.

About one fluid ounce of chemical is required for each inch of stump diameter. The cost of 2,4-D amine required is the same as that for treatments previously described. Labor costs depend on whether the treatment is a separate operation or carried out by woodcutters as each tree is felled.

Stump treatment is effective for controlling sprouts. However, cutting and hauling wood, treating stumps and cleanup operations are expensive. Stump treatment is economical only if the returns from the wood are sufficient to cover costs. This method of control is considered practical when combined with woodcutting operations.

SEEDING RECOMMENDATIONS:

Soils on many of the brushland sites suitable for conversion may be too shallow to support thrifty stands of perennial grass that are sufficiently productive. Annual grasses and annual legumes often are more suitable. However, seeding of legumes must be qualified; above 3000 feet elevation annual legumes are difficult to establish and maintain due to low temperatures in winter and occasional frost heaving on finer textured soils.

The general recommendations for reseeding rangeland with mixtures of improved annuals are applicable to brushland range improvement projects. However, soils and site may require more specific recommendations. Always check with the farm advisor or local office of the Soil Conservation Service to determine site potential before starting a brush management program.

Where possible, seed should be drilled with a rangeland drill to insure placement of seed at the proper depth of the soil. If equipment availability, natural obstacles, or terrain prevent drilling the seed, it can be broadcast by ground rig or aircraft. This approach usually requires increasing the seed rate for drilled seedings by at least 50 percent. When seed is broadcast, it should

be covered whenever possible by harrowing lightly or by dragging chains, floats, or other suitable objects over the seeded area. This practice is essential for success when perennials are used.

Broadcasting seed in the fall following a late spring control burn can produce excellent results. The ash seedbed that results from the fire is an excellent medium in which to place the seed. When the fall rains occur, the ash forms a crust that protects and covers the seed.

In general, fertilizer recommendations suggested for other range sites described in this publication are suitable for brush range improvement projects. However, soil variability, the general low level of fertility in rangeland soils, the cost of fertilizer, and the expense of application all suggest the value of soil analyses on selected sites within a project area. The economics of livestock operations demand efficiency. This includes determining optimum fertilizer formulations and rates of application.

Brush Treatment Techniques Summary

Manual and Mechanical Control or Preparation[1/]	Brush Density[2/]	Maximum Slope - %	Equipment	Time
Grubbing and hand cutting[3/]	All	No Restriction	Hand tools	Year-long.
Straight dozer blade or brush rake	All but large trees	30-35	Crawler tractor and straight dozer blade or brush rake	Year-long.
Brushland disk	Light to medium	30-35	Crawler tractor and brush disk.	Spring and fall.
Ball and chain	All but large trees	60	One crawler tractor, anchor chain and submarine net float.	Year-long but fall, winter, early spring (before mid-May) is usual period.
Modified or smooth chain	All but large trees	30-35	Two crawler tractors and modified or smooth anchor chain.	Year-long but fall, winter, early spring (before mid-May) is usual period.

1/ Direct cost comparisons among mechanical alternatives are difficult because terrain, soil productivity and brush density influence equipment choice, However, the modified or smooth chain or the ball and chain combined with prescribed burning are used extensively where large areas are involved. See Table 2 for mechanical brush treatment production rates.

2/ See Table 1 for a classification of brush by type and volume. Medium brush is 15-30 tons per acre (dry weight). Less than this is light brush, and more is heavy brush.

3/ Appropriate for difficult terrain, for small areas, for removing scattered trees or shrubs and for removal of scattered representatives of a particular species in solid stands of brush. This technique is probably the most costly of all.

Tree Treatment Techniques Summary

Chemical Control	Species	Chemical	Equipment	Time
Injection	Tree types	2,4-D amine	Tree injector.	Year-long but January-May is best.
Frilling			Hand ax, pouring can or hand spray.	Year-long but January-May is best.
Stump treatment			Saw, hand spray, or paint brush and bucket.	Year-long but January-May is best.
Basal spray			Hand spray or power sprayer.	Year-long but January-May is best.
Foliar	1/		Aerial application, ground rig with boom or wand, backpack.	After initiation of vigorous spring growth.

1/ Recommendations for control of specific plants are contained in "Chemical Control of Woody Plants", Bulletin 812, University of California Agricultural Experiment Station.

Table 1. Brush classification by type and volume.

Vegetation Type[1/]	Vegetation loading[2/] Tons/acre (estimated) Low	Moderate	Heavy
Light to medium chamise (2.5'-4' high)	<7	7-15	16-25
Low brush mixtures including combinations of big sagebrush, California sagebrush, California buckwheat, white sage, black sage, coyote brush, chamise, and sumac (2'-5' high).	<7	7-15	16-25
Mixed brush (4'-6' high) and scrub oak.	<10	10-25	--
Heavy pure chamise, manzanita or buckbrush (4'-6' high).	---	20-30	31-40
Heavy mixed brush (6'-7'	---	20-35	36-55
Heaviest mixed brush with toyon, oaks, big manzanita and madrone on north slopes at higher elevations and latitudes (8'-12' high)	---	30-45	46-60

1/ Adapted from Forest Service Region 5 Fire Control Handbook by Clive Countryman and Lisle Green (U.S. Forest Service) and T.E. Adams.

2/ Prepared by Clive Countryman and Lisle Green, U.S. Forest Service.

Table 2. Mechanical Brush Treatment Production Rates [1/] [2/]

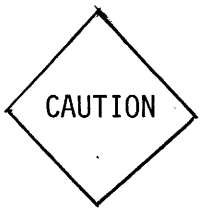
Method [3/]	Acres per Hour [4/]		
	Light Brush	Medium Brush	Heavy Brush
Straight Dozer Blade-crushing (180-275 flywheel H.P.)	--	2.5-3.0	2.0
Brush Rake-piling/windrowing (180-275 flywheel H.P.)	1.0-1.4	0.5-0.7	0.5-0.7
Brushland Disk (9'6" Towner Disk, Model No. 801-144 with 36" blades, requiring 150-180 flywheel H.P.)	0.7-1.5	0.7-0.9	0.3-0.5 (crushing & some incorporation)
Modified Chain (180' of 60-90 lb. chain requiring two 270 flywheel H.P. crawler tractors)	3.5-4.2	2.0-3.0	2.3-2.9
Ball and Chain (120-150' of 20-35 lb. chain with 5' water-filled marine net float requiring 270 flywheel H.P.)	1.2-1.5	0.6-1.2	0.5-0.7

1/ Summarized from data in: Roby, George A. and Lisle R. Green. 1975. Mechanical Methods of Chaparral Modification. USDA, Forest Service, Agr. Handbook No. 487, U.S. Government Printing Office.

2/ Costs of tractor operation can be calculated from data in "Farm Machinery Costs", Leaflet 2263, Division of Agricultural Sciences, University of California. To these costs should be added transporation, support equipment costs and pay for the operator and swamper. Computation of current costs will require consideration of the effect of inflation.

3/ All methods employ crawler tractors. Drawbar H.P. is 75-81 percent of flywheel H.P.

4/ With two exceptions, lower figures represent 25-35 percent slopes and higher figures represent 0-25 percent slopes. The ball and chain is more efficient on steep slopes. For this method, the lower figures represent slopes of less than 50 percent, and the higher figures are for slopes greater than 50 percent. Figures for the straight dozer blade represent rates on slopes of less than 30 percent.



March 1976

PESTICIDE USE WARNING

READ THE LABEL

Pesticides are poisonous and must be used with caution. Read the label carefully before opening a container. Precautions and directions must be followed exactly. Special protective equipment as indicated must be used.

Storage: Keep all pesticides in original containers only. Store separately in a locked shed or area. Keep all pesticides out of the reach of children, unauthorized personnel, pets and livestock. Do not store with foods, feeds or fertilizers. Post warning signs on pesticide storage areas.

Use: The suggestions given in this publication are based upon best current information. Follow directions: measure accurately to avoid residues exceeding tolerances, use exact amounts as indicated on the label or lesser amounts give in this publication. Use a pesticide only on crops, plants or animals shown on the label.

Container Disposal: Consult your County Agricultural Commissioner for correct procedures for rinsing and disposing of empty containers. Do not transport pesticides in vehicles with foods, feeds, clothing, or other materials, and never in a closed cab with vehicle driver.

Responsibility: The Grower is legally responsible for proper use of pesticides including drift to other crops or properties, and for excessive residues. Pesticides should not be applied over streams, rivers, ponds, lakes, run-off irrigation or other aquatic areas except where specific use for that purpose is intended.

Beneficial Insects: Many pesticides are highly toxic to honey bees and other beneficial insects. The farmer, the beekeeper and the pest control industry should cooperate closely to keep losses of beneficial species to a minimum.

Processed Crops: Some processors will not accept a crop treated with certain chemicals. If your crop is going to a processor, be sure to check with the processor before making a pesticide application.

Posting Treated Fields: When worker safety reentry intervals are established be sure to keep workers out and post the treated areas with signs when required indicating the safe reentry date.

Permit Requirements: Many pesticides require a permit from the County Agricultural Commissioner before possession or use. Such compounds mentioned in this publication are marked with an asterisk (*).

Plant Injury: Certain chemicals may cause injury or give less than optimum pest control if:

Used: at the wrong stage of plant development; in certain soil types; when temperatures are too high or too low; the wrong formulation is used; and excessive rates or incompatible materials are used.

Personal Safety: Follow label directions exactly. Avoid splashing, spilling, leaks, spray drift or clothing contamination. Do NOT eat, smoke, drink, or chew while using pesticides. Provide for emergency medical care in advance.

A -- BRUSH MANAGEMENT--MECHANICAL TREATMENT WITH THE BALL AND CHAIN TO IMPROVE THE EFFECTIVENESS OF PRESCRIBED FIRE[1/]

Brush range can be more effectively improved by combining mechanical treatment and prescribed fire.

An effective method of mechanical treatment on steep slopes employs the ball and chain. This equipment crushes and desiccates brush and creates a concentration of dry fuel that improves the effectiveness of prescribed fire.

Ranchers and land managers in California who have used the modified chain before burning report:

Better Burns . . .

because fuel is concentrated on the ground.

Safer Burns . . .

because the dry brush can be burned when wildfire hazard is minimal.

Cleaner Burns . . .

because most of the fuel is consumed and no blackened stems remain.

Ball and Chain

Mechanical brush treatments with disks, or with anchor chains between two tractors, or by crushing with a dozer is not feasible on steep side slopes. The "ball and chain" technique of crushing brush was developed to fill this gap.

Size of tractors used

A variety of tractors have been used for ball and chain operations. But the most efficient have been in the D-8 category (270 net HP at flywheel). Most operators agree that tractor weight is probably more important than horsepower and that tractor weight must be in proportion to weight of the ball and chain.

Equipment

The equipment used for a ball and chain operation is a light-to-heavy anchor chain (destroyer or cruiser) attached to a steel, 5 foot diameter marine net float (buoy). These are generally available only through Navy surplus. The anchor chains are usually "modified" like those pulled between two tractors. In operation the float or "ball" is generally filled with water. This adds needed weight for effective crushing and helps prevent denting and rupturing of the ball.

The working chain forms an arc, caused as the chain drags through brush, over rocks and on the ground. Swath width then becomes one-third or two-thirds the chain length, depending on size of brush, steepness of slope, and chain weight in relation to weight of the ball.

Various lengths of chain have been used, from 50 to 200 feet. Typical lengths in current use are 120 or 150 feet.

Chain weights usually range between 10 and 80 pounds per foot. The weight used is in proportion to ball weight and chain length. On some projects, chain weight has been so great that the ball could not drop on gentle slopes. For this reason, long chains are most effective when chain weights are kept light. With short chain lengths, heavy chains can be used.

Following is a sample chart that will help in determining the size and length of chain needed when using a 5 foot buoy filled with water:

Length of Chain	Recommended Weight of Chain in Lbs./Ft.*
60 - 90 feet	50 - 60
90 - 130 feet	35 - 50
130 - 180 feet	20 - 35

*Weights do not include the crossbars added to modify chains.

Steel cable 7/8" - 1 1/8" diameter has been used to drag the ball. Operation was not successful because the cable was easily damaged, and the cable did not do an adequate job of crushing and uprooting brush compared with the modified chain.

The buoy or ball is constructed of high tensile 3/16 inch steel plate and is 58 inches in diameter. Unmodified and filled only with water, buoys have developed leaks after some use. This problem is much reduced by cutting up one buoy and welding it over another as an armor plating. It is very important to check the buoys for leaks prior to use and prior to armor plating.

An empty ball weighs about 600 pounds. Filled with water, and armor plated, it weighs about 5,000 pounds.

Balls have been filled with gravel, or sand and a combination of the two, and a few have been filled with concrete. The gravel and/or sand filled buoy has more weight than one filled with water. Adding water increases the weight to about 6,700 pounds. When filled with concrete, a ball will weigh approximately 9 to 10,000 pounds depending on density of the filler.

Use of sand and gravel makes filling and emptying balls for transport more difficult, but leaks cease to be a problem. Concrete, too, eliminates leaks, but emptying is impossible and transport difficult.

Insuring that buoys are completely filled with water further helps to prevent severe denting that can lead to development of leaks. Since water will not compress, complete filling prolongs the life of a buoy considerably.

Techniques

There are a number of techniques for using the ball and chain, most of which appear effective. Choice generally depends on the individual's evaluation of the management problem.

There is some difference of opinion concerning the best way to attach the ball and chain to the tractor. Some operators believe the chain should be attached directly to the rear drawbar. Others feel safer attaching it to the cable winch. Hitches have been welded on the ripper bar and on both sides of the tractor.

When the chain is attached to the rear drawbar, the center of gravity is kept low, the operator has good control and the tractor can change direction without unhooking. However, there are disadvantages; when working from a road, the chain is very low and it can do considerable damage to berms, fill, revegetation on fills, and overside drains and aprons. Also, moving the ball up and down the slope can be done only by moving the tractor up and down the slope.

With the side hitches in use, the center of gravity also is low, but as with attachment to the rear drawbar, there are problems of damage to berms and movement of the ball up and down slope. With this attachment, there is the added problem of hooking and unhooking the chain when changing direction.

Attaching the chain to the cable winch allows "reach" of the ball and chain to be extended. Once some cable has been let out, the operator can adjust the ball up or down a slope simply by using the winch. When working from a road, the higher winch attachment point can keep the cable and chain above the berm and some overside drains. It does raise the center of gravity, but most operators do not consider this a serious problem. This method allows the tractor to change direction without unhooking, a definite advantage.

Attaching the ball and chain directly to the cable results in considerable wear on the sides of the winch drum case. This results because the weight of the ball and chain pulls the cable sideways off the drum. The problem might be remedied by attaching heavy roller guides to the sides of the drum. However, most operators have not been concerned about this wear.

By using a hitch welded to the hydraulic ripper crossbar, the operator can adjust the center of gravity. When working from a road, he can prevent some damage to berms and fills by raising the ripper bar. Also, he can change the tractor direction without unhooking. However, when using the ripper bar, it is impossible to use a winch. This is considered a serious sacrifice by most operators.

Use of a swivel increases the effectiveness of the ball and chain. The most effective arrangement appears to be a single swivel about 20 to 25 feet from the tractor. As the ball moves across the slopes, it rolls and turns the chain. The rolling chain effectively chops and breaks brush. When a second swivel is used at the ball, the ball rolls but the chain slides along and is less effective.

There should be 20 to 25 feet of smooth lead chain between the tractor and the swivel. This allows the tractor to back up and turn on the smooth chain without damage to the swivel and crossbars on the modified chain.

Regardless of the method of hookup used, there is a definite need for a cable winch. Often, the ball and/or chain gets caught. The winch frequently has proved the most effective method of freeing the ball and chain.

The ball and chain is used occasionally on flat ground and gentle slopes (less than 30 percent). The technique used employs the ball as an anchor while the tractor drives around it in a circular fashion. The best results are obtained in old chamise. Heavy brush with "tough" species does not crush well. Most operators believe this technique is inefficient, that the disk or modified chain between two tractors should be used on gentle slopes.

Capabilities of the ball and chain

Vegetative types[2/]. If the project objective is uprooting and mulching brush, the ball and chain is effective only in light brush (less than 15 tons per acre) or in desiccated brush. Even in light fuels, follow-up burning is usually considered necessary to reduce fuel concentrations to a safe level. In medium-to-heavy brush (15 to 45 tons per acre), the ball and chain has been very effective as a crushing technique used to prepare brush for prescribed burning.

Since prescribed burning usually is planned, or if not planned, usually is found necessary as a follow-up measure to ball and chain treatment, one pass or two passes in opposite directions will prove adequate. Additional passes increase the costs per acre and do not significantly improve burning conditions.

Ball and chain treatment is most effective when moisture content of the brush is low (summer through early winter). The brush is more brittle at this time and easily broken. A high percentage of dead and dry fuels results.

Slope. The optimum situation for a ball and chain operation is a long straight ridge with side slopes greater than 30 percent. Production tends to increase as the side slope gradient increases because the weight of the ball becomes more effective on steep slopes.

Ridges perpendicular to the ridge being worked present a problem. Frequent finger ridges, rocky points, draws, and small drainages cause the ball to trail back up the slope behind the tractor. When this occurs, large areas of brush are missed. The tractor proceeds until the ball can be pushed back down the slope and the operation continued.

Edging. In use the ball and chain tends to swing in a pendulum-like fashion; it "snakes" upslope due to brush drag or terrain, then swings down.

2/ See Table 1 for a classification of brush by type and volume.

This creates a desirable irregular or scalloped edge to the crushed strip. The scalloped edge is aesthetically pleasing and its shape enhances the transition from standing brush to treated area, a great benefit to wildlife.

Rocks and trees. Large boulders and large trees (greater than 12" DBH) create problems for the ball and chain. Since the ball will hang up, it is necessary to pull it up the slope until it is clear and can roll back down. Under conditions of many rocks and trees, a winch is very helpful.

Roads. Care must be taken when working from roads or working across them. Whenever possible, these situations should be avoided. The chain will damage berms, overside drains, and road fills. Well vegetated road fills have been stripped, the denuded slopes requiring application of erosion control techniques.

Production rate

In light brush (less than 15 tons per acre) production rates for the ball and chain have averaged from 1.2 acres per hour to 1.5 acres per hour. In heavier brush (15 to 30 tons per acre) production rate has averaged from 0.6 to 1.2 acres per hour. When brush volume has exceeded 30 tons per acre, production rate has averaged 0.5 to 0.7 acres per hour. All rates are for two or more passes. Lower rates in each case occurred on slopes of 50 percent or less. Higher figures reflect rates on slopes greater than 50 percent.

Costs

Cost of tractor operation can be calculated from data in "Farm Machinery Costs," Leaflet 2263, Division of Agricultural Sciences, University of California. To this cost should be added transportation, support equipment costs and pay for the driver and swamper.

On-site costs to the Forest Service had varied from $22 to $50 per acre in light brush and from $40 to $70 per acre in heavier brush for three to four

passes. These costs reflect experience through 1973. Computation of current costs will require consideration of the effect of inflation.

General comments and recommendations

Soil disturbance. In general, the ball and chain disturbs soil less than does any other method. Some important exceptions are: (1) near the tractor where the chain digs relatively deep, especially along road berms or wherever there are small knobs and outcroppings; and (2) ball tracks created where the ball is lowered down a slope and where it is pulled back up.

Where disturbance occurs, erosion control may be necessary. In the case of ball tracks, this can involve hand crews needed to construct water bars and plant seed.

Transportation problems. The ball and chain poses special handling problems due to its bulk and weight. The best equipment for transportation is a large flatbed truck with a high capacity hoist or "A"-frame. This allows one man to load, drive to the job site, and unload. However, the ball can be chained to a tractor blade for loading and unloading. As noted earlier, material used to fill the ball can make handling and transportation difficult.

For short hauls, it is possible to drag the ball and chain behind the tractor or pick the ball up with the tractor blade. However, when dragged, the ball and chain may cause damage that requires repair to prevent erosion.

Cutting each "shot" of chain (90 feet) in half and inserting a Navy master connector link makes it possible to lengthen or shorten the chain by 45-foot increments. This flexibility makes the chain easier to handle and use.

Swivels. Swivels are sometimes hard to acquire even though many equipment companies handle them. Commercially manufactured swivels are expensive ($300 to $1,000, depending on type and capacity), and they should be ordered well in advance of anticipated need.

For safety reasons, most operators recommend swivels with a 20- to 30-ton capacity, depending on the weight of the ball. Since most swivels have a built-in 40 percent safety factor, this appears to be a safe capacity range.

Special hazards. Several balls have been lost (down the canyon) over the past few years. In all known cases, loss was due to one of the following: broken swivel; clevis pin working loose or unscrewing; clevis spreading apart. All swivel pins and and clevis pins should be threaded and/or fastened in place with a heavy duty cotter key or heavy bolt and nut secured with a cotter key. All pins and cotter keys should be checked several times during a day's operation.

Because a loose ball presents a hazard, use of the ball and chain above heavily used roads, trails, campgrounds, and residential areas is not recommended.

There is a hazard to the swamper or observer if he gets below the ball and chain. This becomes especially serious when the ball is snagged in trees or rocks. It is not unusual for the ball to jerk free suddenly, dropping quickly down the slope along with dislodged rocks and trees.

There also may be a "whipping" action in a slack chain as the tractor moves forward. There have been some close calls under this condition, and those individuals at hazard described the action as occurring much faster than a man can move.

When the ball and chain are attached to a winch line, the cable will sometimes become twisted in spite of the presence of a swivel. This develops torque stress in the line. When the tractor moves the chain, even slightly, the cable may suddenly untwist and injure any one standing near. This does not happen often because swivels usually do their job.

Some advantages and disadvantages of ball and chain crushing are:

Advantages

1. Can be applied to steep slopes eliminating or reducing the need for more expensive hand labor.
2. Except near the tractor, disturbs soil very little.
3. Allows varying degrees of clean-up depending on number of passes and desired aesthetic effects.
4. Effective for creation of irregular edge effect--scalloping, etc.
5. Treated brush can be burned when surrounding brushfields do not burn readily.

Disadvantages

1. Not very maneuverable. It is difficult to leave specimen trees or clumps.
2. Can create ball tracks down slopes that may require erosion control treatment.
3. Removes few roots and root burls. Sprouts are numerous.
4. Prescribed burning is usually necessary.
5. May damage road berms, fills, and small hills and knobs.
6. Ball and chain are difficult to handle (loading and unloading).
7. Efficiency is limited by presence of boulders and large trees.
8. The remote chance of losing a ball must be considered, particularly above residential areas.
9. Little debris is incorporated into the soil.

Table 1. Brush classification by type and volume.

Vegetation Type[1/]	Vegetation loading[2/] Tons/acre (estimated) Low	Moderate	Heavy
Light to medium chamise (2.5'-4' high)	<7	7-15	16-25
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Heavy mixed brush (6'-8' high).	---	20-35	36-55
Heaviest mixed brush with toyon, oaks, big manzanita and madrone on north slopes at higher elevations and latitudes (8'-12' high)	---	30-45	46-60

1/ Adapted by Clive Countryman and Lisle Green (U.S. Forest Service) and T.E. Adams from Forest Service Region 5 Fire Control Handbook.

2/ Prepared by Clive Countryman and Lisle Green, U.S. Forest Service.

B -- BRUSH MANAGEMENT--MECHANICAL TREATMENT WITH THE MODIFIED CHAIN TO IMPROVE THE EFFECTIVENESS OF PRESCRIBED FIRE[1/]

Brush range can be more effectively improved by combining mechanical treatment and prescribed fire.

An effective method of mechanical treatment employs the modifed chain. This equipment crushes and desiccates brush and creates a concentration of dry fuel that improves the effectiveness of prescribed fire.

Ranchers and land managers in California who have used the modified chain before burning report:

Better Burns . . .

because fuel is concentrated on the ground.

Safer Burns . . .

because the dry brush can be burned when wildfire hazard is minimal.

Cleaner Burns . . .

because most of the fuel is consumed and no blackened stems remain.

Modified chain for use between two tractors

Fifteen or more years ago brush was prepared for burning by dragging anchor chains across brushfields between two tractors. This compacted and crushed the brush. Generally good results were obtained. The Bureau of Land Management "modified" the anchor chain and improved its effectiveness by welding steel crossbars across each link. Their "Ely chain", used in Nevada and New Mexico, was the model for modified chains now used in California.

[1/] Adapted from: Roby, George A. and Lisle R. Green. 1975. Mechanical methods of chaparral modification. USDA, Forest Service, Agr. Handbook No. 487, U.S. Government Printing Office.

Size of tractors used

Most Federal projects where the modified chain was employed used tractors in the D8-46A category (270 net HP at flywheel). A few smaller tractors were used in the 200 to 230 HP category, but most people recommended using higher horsepower. Since traction is very important when using the chain, a minimum grouser height of 2 inches is recommended.

Size and length of chain

The modified chains used between two tractors are made from heavy anchor chain, ranging from 40 to 90 pounds per linear foot. They are usually available only through Navy surplus in 90-foot lengths called "shots".

The lengths of modifed chains in current use vary from 90 feet (1 shot) to 270 feet (3 shots) depending on the size of tractors, terrain, and number of large trees and boulders. A 180-foot chain is a very practical length in mountainous terrain. The effective swath width averages about one-half the length of the chain, or about 90 feet for a 180-foot chain.

Cutting each shot of chain in half and inserting a Navy master connector link makes it possible to lengthen or shorten the chain by 45 foot increments. This makes the operation more flexible on some projects because the chain length and weight can be adjusted to fit terrain, obstacles, and tractor size. It also makes the chain physically easier to handle.

The heavier chains, from 60 to 90 pounds per foot, not including the weight of the crossbars, appear to be the most effective. However, smaller chains have been used with generally satisfactory results. An important advantage of the lighter chains is the greater ease with which they can be handled and loaded onto a truck. In addition, smaller trucks can be used to haul the chain.

Modifying the chain[2/]

Most operators believe the modified chain is more effective than smooth chain for tearing out and crushing brush. The best results with modified chain occur when the bars are welded on perpendicular (90°) to each other. This means the bars should be welded on every link or every third link. Bars are parallel if welded on alternate (every other) links. When the bars are at right angles with each other, the chain tends to "walk" and roll along, crushing, chopping, and sometimes pulling out the brush. When the bars are parallel, the chain tends to slide over the brush.

A variety of hard steels have been used for crossbars. The most wear resistant used is a material called Wearalloy "B". This steel wears as well, or better, than moldboard steel, the other type most often used to modify chains. Wearalloy "B" has the added advantage of being available in long bar lengths of the correct width and thickness. This eliminates much of the expensive cutting necessary when moldboard or other steel plate is used.

The recommended dimensions for crossbars are 1 inch thick, 3 to 4 inches wide, and up to 18 inches long--the length depending on the size of the chain. There should be an overlap of approximately 4 to 5 inches on both sides of the links.

When welding the crossbars to the chain, it is necessary to first weld a small strip of strap iron to one side of the web of each link to which a crossbar will be attached. This raises the level of the web almost to the height of the outside of the link. The bar can then be welded the entire width of the link with an arc welder. Without this reinforcement, bars have broken off in use.

[2/] Figures 1, 2, 3 and 4 show how chain links are modified.

Techniques

Most operators believe that pulling the chain in a broad "J" or "U" configuration with a swath width equal to about half the length of chain produces the best results. Numerous variations have been used, depending on tractor size, terrain, and other factors.

The tractors should be of about equal horsepower since this allows the tractors to switch the lead position if a return swath is needed. They merely turn around in place and the tail tractor becomes lead tractor.

Each tractor should have 20 to 25 feet of smooth lead chain with a swivel attached to the far end. The smooth lead chain is necessary to allow the tractors to back up and turn around without running over the swivel and modified chain. A swivel at each end of the modified chain allows it to rotate and do a more effective job of crushing and tearing out the brush.

A third swivel has been used. It was installed in the center of the chain. This allowed each half of the chain to turn independently of the other. Many people do not feel this center swivel is necessary. But they agree it does help keep the chain from occasionally becoming twisted.

Many large swivels are available commercially. However, swivels made from D-9 track rollers and 1 1/2 inch steel plate appear to be used almost exclusively and serve the purpose quite well. The roller, with cover plates attached to keep out dirt, can be drilled and tapped to take a Zerk grease fitting protected by a raised welded ring. This allows the swivels to be lubricated, and this should be done as often as the tractor is lubed. The swivels are usually attached to the modified chain with Navy master connector links and to the 20 to 25-foot smooth lead chain with a 2-inch diameter pin.

Two locations for connecting the smooth lead chain to the tractors are used. One is the drawbar on the rear of the tractor, and the other is the cable winch.

There appears to be some advantage to the cable winch connection. In heavy fuels or in steep terrain where the tractors sometimes bog down, the operators can winch out 50 to 100 feet, stop the tractor, and winch the chain up to them. Wherever the tractors have difficulty getting traction, this proves very effective. Safety is another reason tractor operators like the winch attachment. Sometimes, in extremely high brush or in rough terrain, the operators lose sight of each other. In this situation, one operator may be unaware when the other tractor gets hung up and will continue to pull. This can result in pulling or twisting the stalled tractor. With the chain hooked to the cable, the operator of the stalled tractor can let out cable until he or the swamper gets the other operator's attention.

Since the modified chain is not very maneuverable, it is hard to pioneer the perimeter of the area to be cleared. Often a tractor with a brush rake (usually one of the tractors used to pull the chain) can be used to pioneer the perimeter for the chain. This is very helpful, especially in difficult terrain. The brush rake also is helpful in defining the buffer strips along stream bottoms.

Capabilities of the modifed chain

Vegetative types.[3/] The modified chain is very effective in all mature types of chaparral. Most operators suggest that two passes with the chain, one in each direction, are needed to prepare brush for burning. However, in some

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3/ See Table 1 for a classification of brush by type and volume.

instances one pass may be enough. In mature chaparral on the Cleveland and Los Padres National Forests prescribed fire burned mature chaparral that had been crushed with one pass of the chain. Untreated brush outside project areas could not be ignited during the burns.

During chaining operations, particularly during the second pass, there is a tendency for a windrow of brush to build up near the bottom of the loop. The chain eventually rolls over the windrow, but it again starts to accumulate brush. These windrows and the smaller scattered piles are easily burned.

Large trees (scattered or in groves) create problems because the modified chain is not very maneuverable. Depending on species and topography, trees larger than 12 inches DBH may be difficult to remove. Trees that are to be saved require narrower swaths and extra maneuvering. This lowers the rate of production considerably. Leaving islands for landscaping and wildlife purposes creates the same problem.

Slope. The modified chain is very effective on uniform slopes up to 30-35 percent. In situations where the winch has been used to pull the chain, slopes up to 45 percent have been chained successfully. The more rugged and broken the terrain, the less effective the chain becomes.

Rocks. In most situations, rocks affect the modified chain very little. Smaller rocks are moved very easily and the chain tends to walk or roll over them. Very large boulders with perpendicular sides will catch the chain. This requires one of the tractors to back up and go around. Production is reduced considerably, but most users are impressed with how well the modified chain performs in very rocky country.

Roads. The modified chain can damage road berms, fills, and overside drain structures when roads are crossed by the chain.

When roadcuts are not too high, it is possible to work above some roads by walking one tractor (usually the lead tractor) along the road. This technique has been used quite successfully on slopes that would otherwise be considered too steep.

Production rate

In light brush (less than 15 tons per acre) the rate of production has averaged from 3.5 to 4.2 acres per hour. In heavier brush (15 to 30 tons per acre) production rate has averaged from 2 to 3 acres per hour. When brush volume has exceeded 30 tons per acre, production rate has averaged 2.3 to 2.9 acres per hour. These rates are for two passes, one in each direction. Lower rates in each case occurred on slopes of 25-35 percent. Higher figures reflect rates on slopes of less than 25 percent.

Costs

Costs of tractor operation can be calculated from data in "Farm Machinery Costs", Leaflet 2263, Division of Agricultural Sciences, University of California. To these costs should be added transportation, support equipment costs and pay for tractor drivers and swamper(s).

On site costs to the Forest Service have varied from $15 to $50 per acre in light brush and from $20 to $75 per acre in medium to heavy brush for two passes. These costs reflect experience through 1973. Computation of current costs will require consideration of the effect of inflation.

General comments and recommendations

Safety. On steep slopes, the lead tractor should be on the downhill side. This puts it ahead of rolling rocks knocked loose by the chain and tail tractor.

The swampers should be behind or above the tractors and chain, and they should not ride the tractors unless seats are provided.

Communications. Communications are very important for most operations where heavy equipment is being used. With one tractor, visible hand signals will generally suffice. However, when two tractors are working as a team with one swamper, hand signals are not adequate. Radio communications are strongly recommended for the modified chain, for both operators and the swamper. In heavy brush it is easy for tractors to wander from the intended course. If he has radio communication, the swamper can oversee and control the operation from vantage points. Radio communications also are very important when an operator and his tractor get in trouble.

Small citizen's band radios have been used to good advantage. The radios are mounted on the tractors and the operators are provided with headphones. This allows the swamper and both operators to be in constant contact even though they cannot see each other. However, operators have sometimes refused to wear headphones because of discomfort. Recent improvements such as the bone conducting microphone and smaller earphones, both of which can be worn under the hard hat, have made this equipment more comfortable to wear.

Another communications technique uses dune buggy whips, with high visibility flags attached. These are fastened to the top of tractor canopies. This allows each operator and the swamper to keep sight of the tractors in high vegetation and in broken terrain. The use of this inexpensive technique is recommended for all modified chain operations.

Use of contractor. Contracts should be written so that both tractors will be provided by the same contractor. Two separate contractors working with the same chain can generate several problems: one contractor may think the other

is not doing his share; if one breaks down the other will still want to work and, if unable to do so, may put in a claim against the project or the other contractor.

The following are some of the advantages and disadvantages of crushing with the modified chain:

Advantages

1. Costs per acre are relatively low compared to other alternatives.
2. High rate of production compared to other alternatives.
3. Minimum soil disturbance.
4. Leaves debris on surface. Helps reduce erosion potential.
5. Works relatively well in rocky areas.
6. Crushed brush can be burned when surrounding brushfields will not burn readily.

Disadvantages

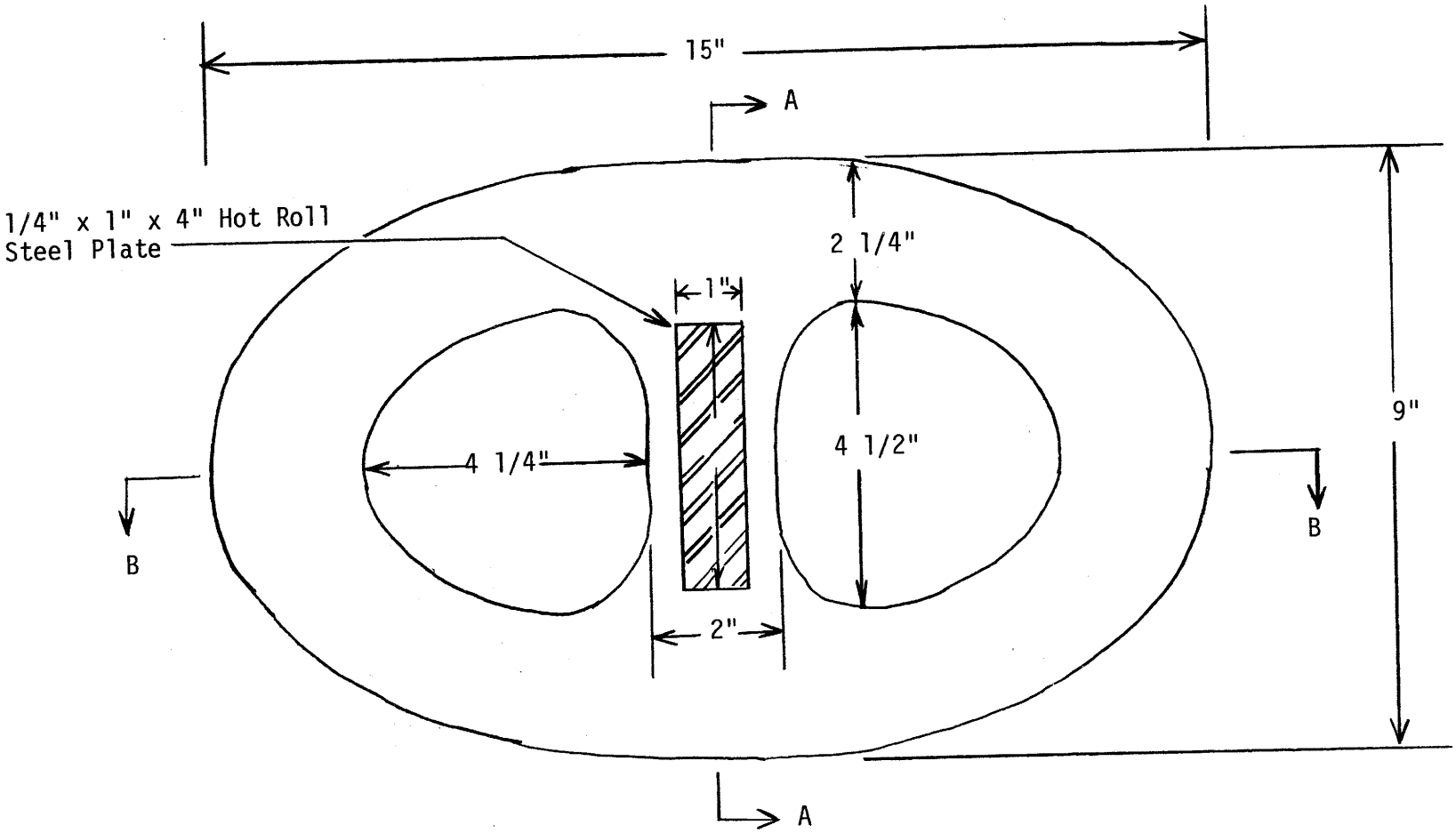
1. Not very maneuverable. It is difficult to leave specimen trees or clumps.
2. Needs radio communications.
3. Removes few roots and root burls. Sprouts are numerous.
4. Little or no debris is incorporated into the soil.
5. Application limited by slope and irregular terrain.

Table 1. Brush classification by type and volume.

Vegetation Type[1/]	Vegetation loading[2/] Tons/acre (estimated) Low	Moderate	Heavy
Light to medium chamise (2.5'-4' high).	<7	7-15	16-25
Low brush mixtures including combinations of big sagebrush, California sagebrush, California buckwheat, white sage, black sage, coyote brush, chamise, and sumac (2'-5' high).	<7	7-15	16-25
Mixed brush (4'-6' high) and scrub oak.	<10	10-25	--
Heavy pure chamise, manzanita or buckbrush (4'-6' high)	---	20-30	31-40
Heavy mixed brush (6'-8' high).	---	20-35	36-55
Heaviest mixed brush with toyon, oaks, big manzanita and madrone on north slopes at higher elevations and latitudes (8'-12' high)	---	30-45	46-60

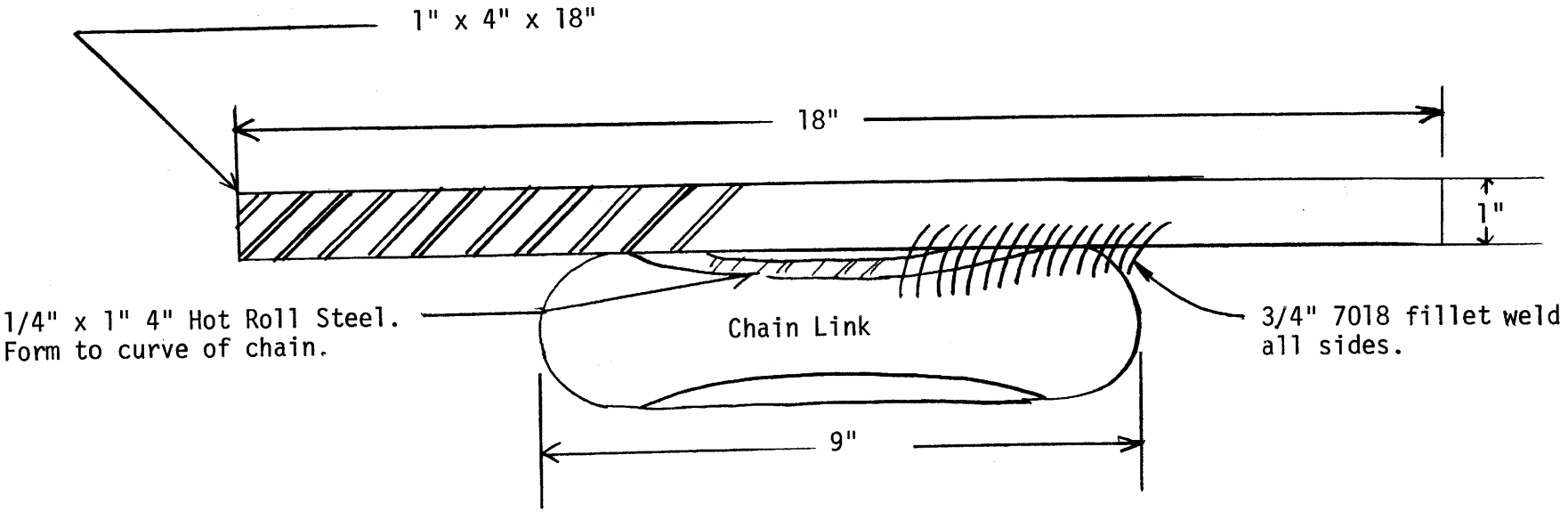
1/ Adapted by Clive Countryman and Lisle Green (U.S. Forest Service) and T.E. Adams from Forest Service Region 5 Fire Control Handbook.

2/ Prepared by Clive Countryman and Lisle Green, U.S. Forest Service.



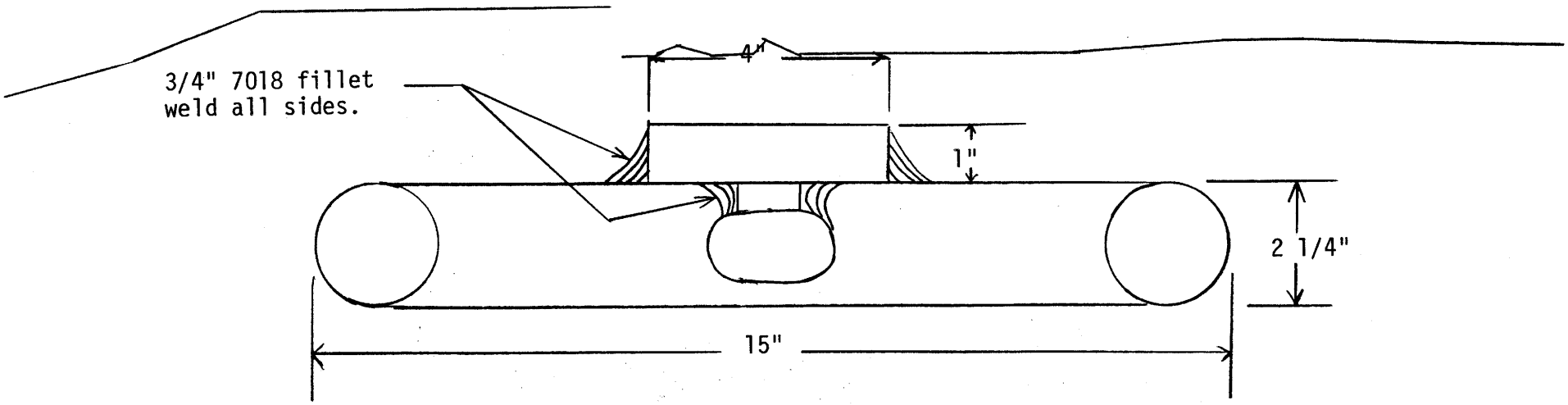
TYPICAL CHAIN LINK

FIGURE 1



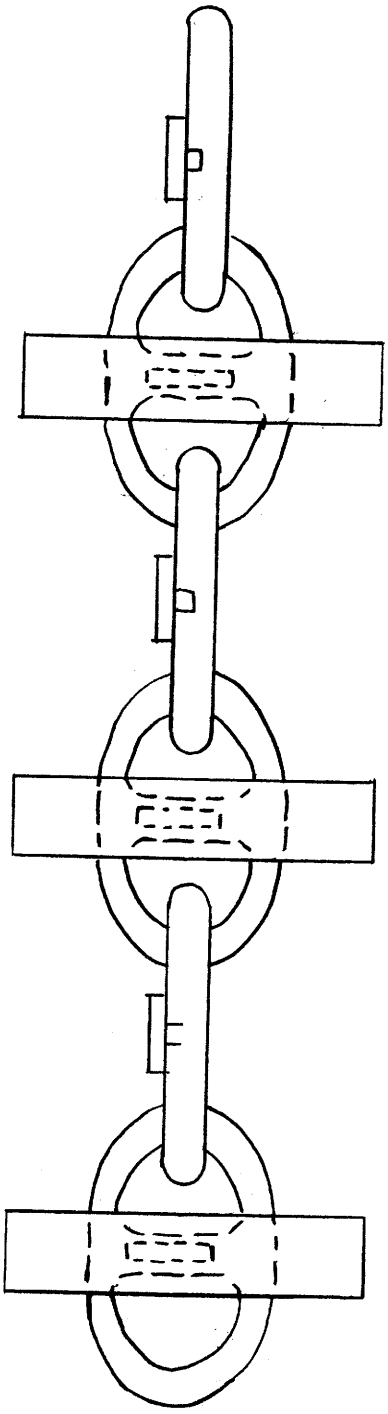
SECTION "AA"

FIGURE 2



SECTION "BB"

FIGURE 3



MULTIPLE CHAIN UNIT

FIGURE 4

C -- BRUSH MANAGEMENT--CLEARING WITH THE TRACTOR AND STRAIGHT DOZER BLADE OR BRUSH RAKE[1/]

A crawler tractor equipped with the straight dozer blade was one of the first means used to clear brush in range improvement and other programs. This technique continues to have value when used on relatively small projects, for supplementing other mechanical means of brush treatment, and for special purposes such as wildlife habitat improvement.

Limitations of the straight dozer blade stimulated modifcations that resulted in creation of the brush rake. This implement, that looks like a giant, reinforced garden rake, mounts in place of the straight blade. It displaces soil less than the straight blade and does not tend to incorporate as much soil with brush piled for burning. This is the principal advantage the brush rake possesses compared with its predecessor.

Tractor with straight dozer blade.

The straight dozer blade is of limited use for clearing and piling brush. Rate of production generally is low, and it often disturbs soil excessively. Loose soil frequently becomes mixed with the brush during piling. This makes burning of the piled brush difficult. If slopes are steep and the soil highly erodible, soil disturbed by the blade is subject to accelerated erosion.

One job for which the straight blade is sometimes used, and for which it is well suited, is compacting and crushing mature brush prior to prescribed

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1/ Adapted from: Roby, George A. and Lisle R. Green. 1975. Mechanical methods of chaparral modification. USDA, Forest Service, Agr. Handbook No. 487, U.S. Government Printing Office.

burning of the brush. When so used, the blade is raised one or two feet above the ground to knock down the brush and break it off at the soil surface. The tracks of the tractor add to the crushing effect.

Other jobs for which the straight blade is used include clearing and piling small, scattered stands of brush and removing unwanted, isolated trees not larger than 12 inches DBH. These jobs are not performed efficiently by the modified chain, ball and chain or brushland disk.

Often all the brush and trees above are not intended for disposal. When piled, this material provides good cover for small game including quail. On rangeland the piles may not reduce grazing significantly. The increase in wildlife that results is often compensation for a small reduction in livestock carrying capacity.

Size of tractors used

The tractors most commonly used with the straight dozer blade are of the D-7 or D-8 size (180-275 net HP at flywheel). Blades used with these tractors vary in widths from 12 to 14 feet. The wider blades are more efficient in moderate terrain, but they create transportation problems because of load width restrictions. Wide blades must be detached from tractors and hauled separately.

Capabilities of dozer crushing

On slopes not exceeding 35 percent the straight blade is very effective in crushing all vegetative types except young flexible brush.[2/] However, the effectiveness is affected by the presence of rocks.

Small rocks are not a problem during crushing operations. But rocks larger than a foot in diameter are a nuisance, can be dangerous, and decrease the

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2/ See Table 1 for a classification of brush by type and volume

amount of crushing possible. The operator must pay particular attention to large, scattered boulders and rock outcroppings. However, these usually do not create any special problems.

Production rates and costs

The following are estimated production rates and costs of crushing based on Forest Service experience on the Mendocino National Forest:

% slope	Fuel type	Acre/hr	On-site costs* $/acre
0-30	Heavy, pure manzanita, chamise or Ceanothus sp. (20-40 T/A; 4-6 feet high)	3.0	$12
0-30	Heavy, mixed brush (20-45 T/A; 6-8 feet high)	2.5	$14
0-30	Heaviest mixed brush (30-45+ T/A; 8-12 feet high)	2.0	$17

*The base year for costs is 1973. Current estimates must include the effect of inflation.

Cost estimates are based on the use of a D-8 tractor with operator. In 1973 this combination cost $35 per hour. Additional costs would include a swamper, support equipment and transportation.

Tractor with brush rake.

Many sizes of brush and root rakes for clearing and stacking brush are available. Most of these are produced by equipment manufacturers. However, many are homemade, and over the years, numerous modifications have been incorporated. Most designs produce similar results, but in general the ones with the least blade surface are the most efficient and do the cleanest job. (Figure 1).

Sizes and types in use

The size in width of most rakes varies from 12 to 14 feet and they are usually mounted on tractors of the D-7 to D-8 size. Wide rakes are more productive, but they present the same transportation problems as wide straight dozer blades.

Several types of rake attachments are available for straight dozer blades. These attachments are not as efficient as regular full-sized rakes, but they have some advantages over the straight dozer blades. (Figure 2).

Rake attachments are useful when road construction, ditching, or other activities requiring the straight dozer blade must be done with one tractor. When clearing and stacking of brush is completed the attachment can be removed in a short time. The straight blade then becomes available for other activities.

Capability of brush rakes

The brush rake is very effective in most types of brush[3/]. However, light sage, light chamise and other light brush tends to slip through the rake. A root grubber spanning the width of the blade and welded to the tines helps to overcome this problem. (Figure 3).

The rake is superior to the straight dozer blade in one important way; top soil that is often scalped by the straight blade is left in place by the rake. Also, the amount of soil that may become mixed with brush piles is reduced. However, the skill of the tractor driver will influence the degree of soil dislocation.

Brush can be piled in windrows or in isolated piles for burning. Slope, type and volume of brush, equipment available and operator experience will dictate how the brush will be piled for disposal.

3/ loc. cit.

When the brush rake is used, often there is a tendency to produce "too clean" a job. This results in too little debris on the soil surface for dissipation of raindrop energy and recycling of nutrients. Also, the cost of clearing becomes unnecessarily inflated.

The slope restrictions that affect operation of straight dozer blades apply to brush rakes.

Small rocks pose no special problems. Large rocks--those that will not pass between the tines--are a nuisance, especially when the operator is trying to keep them out of brush piles. They slow production and are hard on equipment. The brush rake can work around large boulders and trees. It is very selective compared to equipment designed to clear large, solid stands of brush.

When the ground is wet, excessive amounts of soil are incorporated with brush piles. For this reason, raking should not be done until soil is dry enough to fall freely from the brush as it is piled. Piles with excessive soil do not burn completely. In addition, burning time increases, and problems of clean-up result. These all add to costs.

Production rates

Rates of production reported by the Forest Service have varied. In light brush (less than 15 tons per acre) the rate of production has averaged from 1.0 to 1.4 acres per hour. In heavier brush (more than 15 tons per acre) production rate has averaged from 0.5 to 0.7 acres per hour. Lower rates in each case occurred on slopes of 25-35 percent. Higher figures reflect rates on slopes of less than 25 percent.

Costs

Cost of tractor operation can be calculated from data in "Farm Machinery Costs", Leaflet 2263, Division of Agricultural Sciences, University of California.

To this cost should be added transportation, support equipment costs and pay for the tractor driver and swamper.

On-site costs to the Forest Service have varied from $23 to $68 per acre in light brush and from $34 to $150 per acre in heavier brush (not including large oak trees). These costs reflect experience through 1973 and do not include any subsequent brush burning activities. Computation of current costs will require consideration of the effect of inflation.

The following are some of the advantages and disadvantages of crushing and clearing brush with the tractor and brush rake:

Advantages

1. Highly maneuverable.
2. Effective for creating an irregular edge effect--scalloping, feathering, etc.--that benefits wildlife.
3. Allows varying degrees of clean-up according to desired aesthetic effects.
4. Less dirt to burn piles or windrows than with the straight dozer blade.
5. Piles or windrows of brush can be burned when wildfire is not a hazard.
6. Some piles may be left for wildlife benefits.
7. Economical to transport compared with tractor and disk, tractors and modified chain or tractor with ball and chain.
8. Usually leaves a good seedbed.

Disadvantages

1. Application limited by slopes and soil conditions.
2. Can be expensive.
3. Unwanted brush piles must be burned.
4. Extra care necessary when brush mixed with soil is burned to insure no smoldering embers.
5. May increase erosion potential by compacting soil (reduces infiltration), disturbing surface unnecessarily or creating channels parallel to the slope.
6. In some cases, cleanup may be too thorough--not enough debris is left for dissipation of rainfall energy, erosion protection and recycling of nutrients.

Table 1. Brush classification by type and volume.

Vegetation Type[1/]	Vegetation loading[2/] Tons/acre (estimated) Low	Moderate	Heavy
Light to medium chamise (2.5'-4' high).	<7	7-15	16-25
Low brush mixtures including combinations of big sagebrush, California sagebrush, California buckwheat, white sage, black sage, coyote brush, chamise, and sumac (2'-5' high).	<7	7-15	16-25
Mixed brush (4'-6' high) and scrub oak.	<10	10-25	--
Heavy pure chamise, manzanita or buckbrush (4'-6' high).	---	20-30	31-40
Heavy mixed brush (6'-8' high).	---	20-35	36-55
Heaviest mixed brush with toyon, oaks, big manzanita and madrone on north slopes at higher elevations and latitudes (8'-12' high).	---	30-45	46-60

1/ Adapted by Clive Countryman and Lisle Green (U.S. Forest Service) and T.E. Adams from Forest Service Region 5 Fire Control Handbook.

2/ Prepared by Clive Countryman and Lisle Green, U.S. Forest Service.

Figure 1. Brush rakes with the least blade surface pick up a minimum of soil with the brush. Photo courtesy of the U.S. Forest Service.

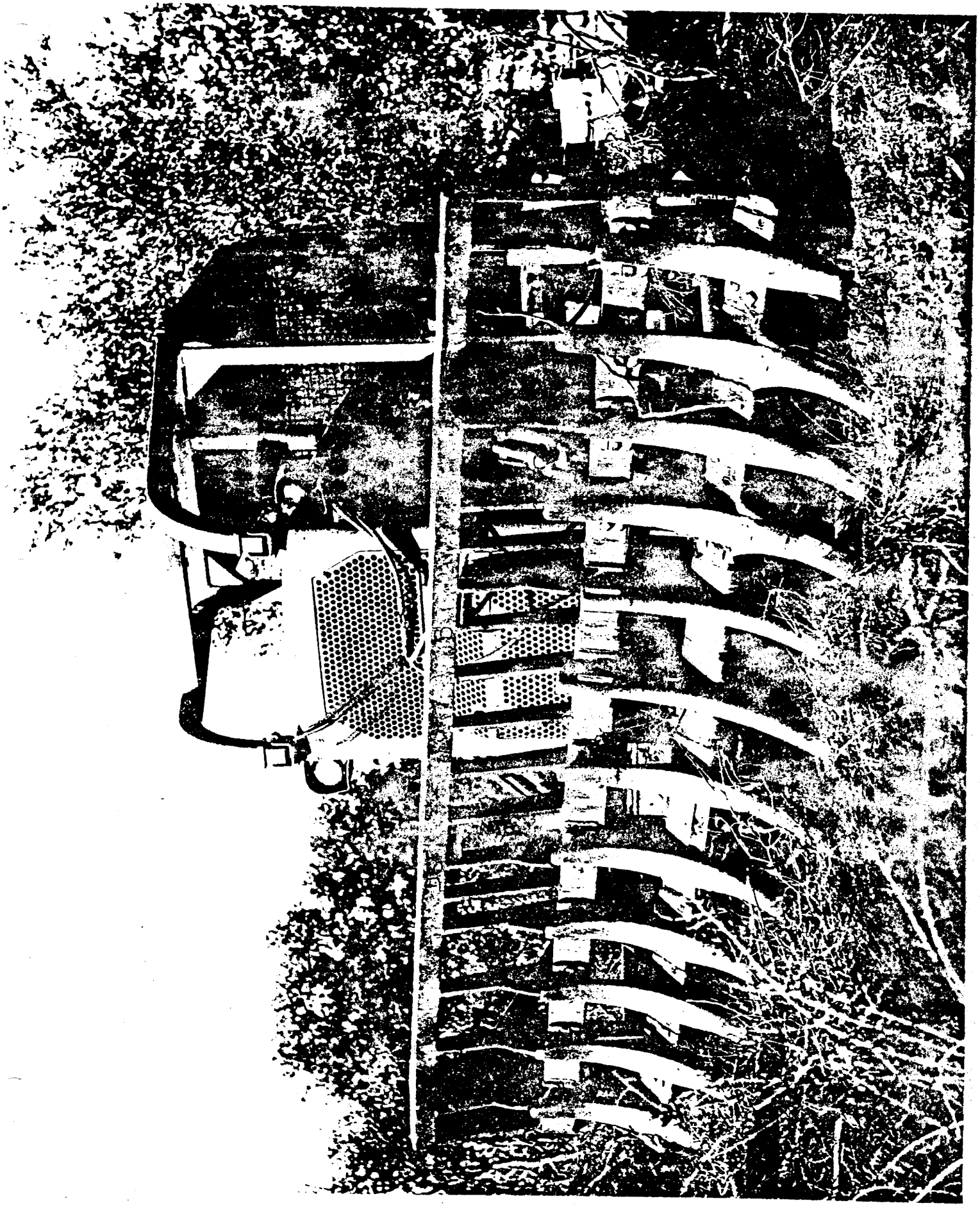


Figure 2. Brush rake attachments generally are less effective than brush rakes, but they can be removed permitting the straight dozer blade to be used for other work. Photo courtesy of Fleco Corporation.

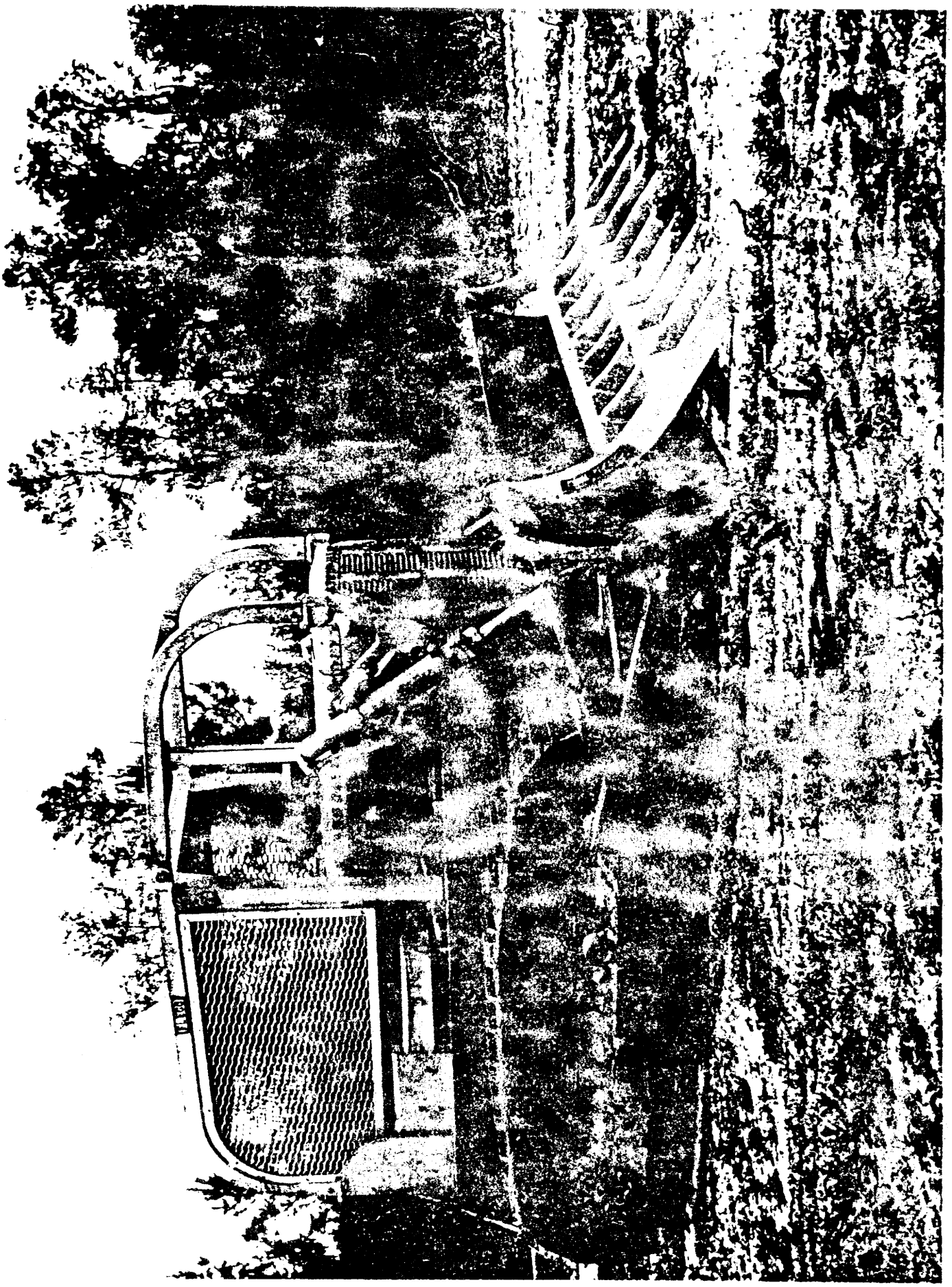
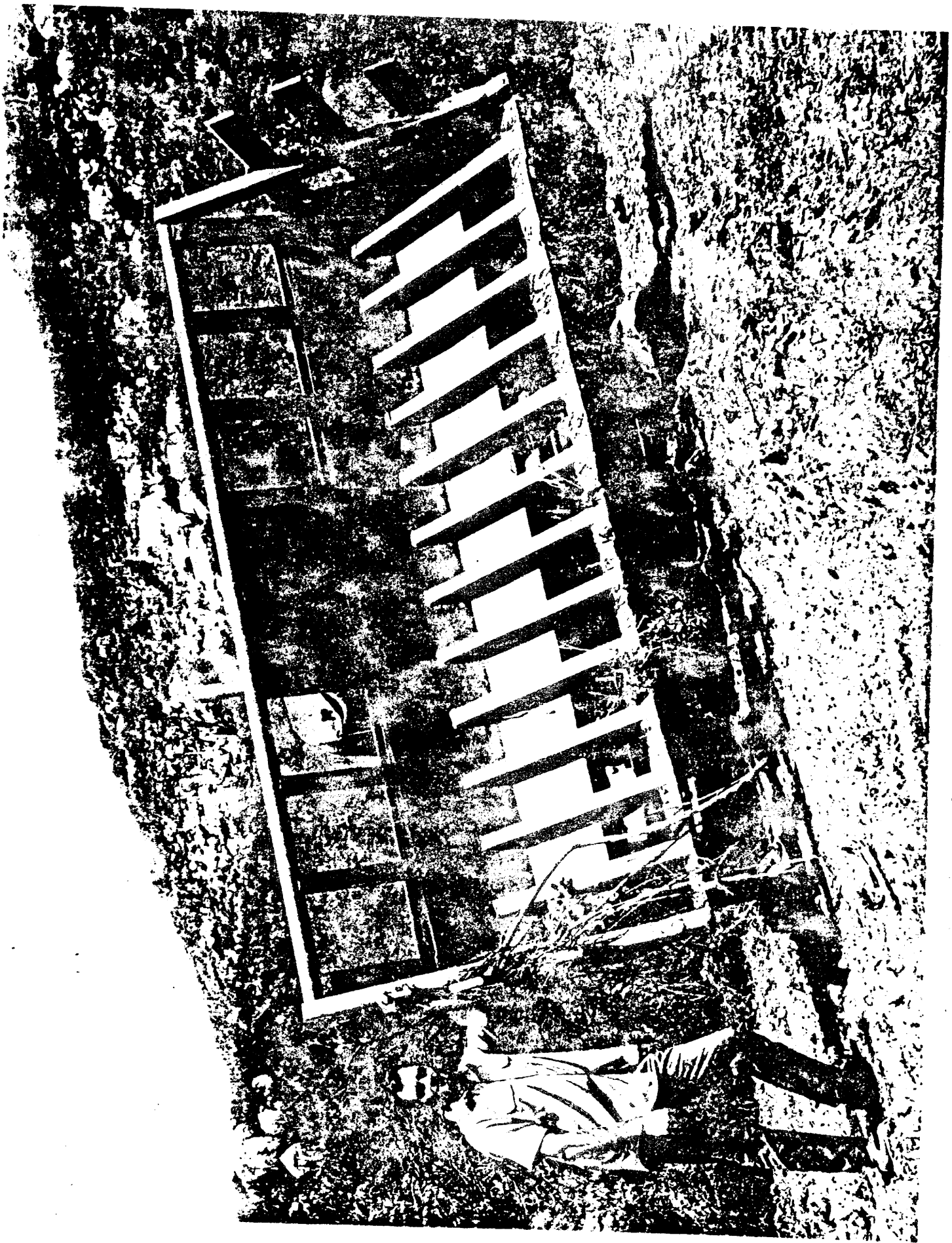


Figure 3. A brush rake with root grubber welded across rake tines. This modification uproots or cuts off small or flexible shrubs that tend to slip through the rake. Photo courtesy of the San Diego County Department of Agriculture, Weights and Measures.



D -- BRUSH MANAGEMENT--REDUCTION OF BRUSH WITH THE BRUSHLAND DISK[1/]

Several methods and tools are available for brush range improvement. One of the most effective is the brushland disk, an adaptation of a standard agricultural implement.

Where terrain is not steep, the brushland disk can be used alone to reduce brush stands. The tilling action of the disk crushes brush, incorporates it with the soil and prepares a rough seedbed.

Brushland Disks

Types and Sizes

Large disks pulled by crawler tractors have been developed to cut and crush brush and incorporate it with the soil. These brushland disks are available in a variety of sizes and weights from several manufacturers. Two manufacturing sources are Rome and Towner.

Disks currently in use range in weight from 6,000 to 12,000 pounds, and they are 8 to 12 feet in width. Blade size varies from 28 to 38 inches in diameter. The most commonly used disks at the present time are the 9 foot 6 inch Towner (Model No. 801-144) and the 12 foot 2 inch Towner (Model No. 801-184), both with 36 inch blades.

Brushland disks have two gangs of blades in tandem that can be opened in an offset manner. This creates a chopping and cutting action as the disk is

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[1/] Adapted from: Roby, George A. and Lisle R. Green. 1975. Mechanical methods of chaparral modification. USDA, Forest Service, Agr. Handbook No. 487, U.S. Government Printing Office.

pulled through the brush. The angle between the gangs can be adjusted while the disk is in operation if it is equipped with hydraulic or cable controls. To open or close mechanically operated disks, it is necessary to stop the tractor, remove some bolts, move the tractor forward or backward, and then replace the bolts. Hydraulic control is preferred because the cutting angle can be adjusted while in motion or stopped to adapt the equipment to changing soil and brush conditions.

Some disks are available with wheels and rubber tires that can be raised out of the way while working and then dropped (either manually or hydraulically) so the disk can be towed on the highway. Disks so equipped should employ multiple ply, puncture proof tires.

Large brushland disks are generally quite effective in uprooting, chopping, and mulching brush, even when concentrations are heavy. They are especially effective in uprooting root burls that can be a source of sprouts when brush is cut or broken at the surface and later burned. Sprout control has been particularly good in chamise-ceanothus chaparral.

Effectiveness of disks may be more closely related to weight than to blade diameter. Some project managers and equipment operators believe heavy disks, regardless of blade size, are required to control sprouting brush such as chamise.

The use of the disks does not remove the top soil, but it does stir and loosen it to a depth of 8 to 16 inches, depending on disk weight and blade size. As a result, infiltration and percolation rates of soil may increase temporarily. However, there has been little observed erosion on freshly disked land. But the erosion potential cannot be ignored.

Size of tractor necessary

Tractors with the horsepower indicated are recommended for disks in the following three weight categories:

Weight of disk	Net HP at flywheel
8,000 - 9,000 lbs.	125 - 145
9,000 - 10,000 lbs.	150 - 180
10,000 - 11,000 lbs.	185 - 270

Capability of brushland disks

Brushland disks have proven to be effective in light to moderate brush not exceeding 30 tons per acre.[2/] The effectiveness depends on a combination of disk weight and the number of passes through and over the brush. This combination is determined by density and composition of brush stands.

Brush should be disked on the contour and not parallel with the slope. Parallel disking can result in serious erosion. Efficient contour disking is limited to slopes of approximately 30 to 35 percent.

A few scattered rocks do not affect the disk. However, many scattered rocks will not allow the disk to adequately dig into the soil. This decreases the amount of brush cut and mixed with the soil and the number of root burls that can be brought to the surface.

In general, the disk is considered to be a tool that is very selective and maneuverable. When scattered large boulders or trees are present, the disk can be worked around the obstacles. Patches of brush and roost trees can be left to improve wildlife habitat. The perimeter of disked areas can be made irregular or scalloped to enhance "edge", the transition zone between vegetation types so important to wildlife.

2/ See Table 1 for a classification of brush by type and volume.

When the disk is in its open, working position, it should be turned only to the left. This is due to the angle of the gangs when open. If the disk is turned to the right while working, it causes increased strain on the tongue, drawbar and other parts. Drawbars and tongues have been bent or broken while turning to the right.

The disk appears to be equally effective in moist and dry soils. However, using the disk in wet weather when the soil is saturated is not recommended. The soil can be moist but not wet. If the tractor bogs down, it is generally too wet to disk.

There is one significant advantage to disking when soils are dry: roots and root burls brought to the surface or dislodged have less chance of survival. Also, the moisture content of brush in dry weather is lower then during winter and spring, and brush can be more readily broken and mulched.

Production rates

Rates of production in light brush (less than 15 tons per acre) have averaged from 0.7 to 1.5 acres per hour. In heavier brush (15 to 30 tons per acre) production rate has averaged from 0.7 to 0.9 acres per hour. When brush volume has exceeded 30 tons per acre, production rate has averaged from 0.3 to 0.5 acres per hour. Lower rates in each case occurred on slopes of 25-35 percent. Higher rates occurred on slopes of less than 25 percent.

These rates represent the two or more passes generally necessary to uproot brush, incorporate smaller stems with the soil and reduce fuel continuity so that fire cannot cross the treated area. The effect produced allows planting with the rangeland drill without additional preparation.

In chamise, one to two passes of the disk usually incorporates 85 to 95 percent of the brush. In the heaviest brush generally encountered, it takes

an average of four passes to do an adequate job. Rate of production for the first pass of the disk is about one acre per hour. Subsequent passes are much faster; rate of production may increase to 3 acres per hour. The ability to cover ground rapidly after the first pass may encourage unnecessary passes with the disk in an effort to leave the disked brushfield "clean".

The rates described represent the potential of the 9 foot 6 inch Towner disk with 36 inch blades (Model No. 801-144) pulled by a tractor with 150-180 net HP at flywheel. For smaller disks, production rates are slightly lower. Larger disks are slightly more productive.

Costs per acre

Cost of tractor operation can be calculated from data in "Farm Machinery Costs", Leaflet 2263, Division of Agricultural Sciences, University of California. To this cost should be added transportation, support equipment costs and pay for the tractor driver and swamper.

On-site costs to the Forest Service have varied from $26 to $70 per acre in light brush and from $60 to $175 per acre in heavier brush. These costs reflect experience through 1973. Computation of current costs will require consideration of the effect of inflation.

General comments and recommendations

Mechanical failures. On several projects, the tongues and drawbars of Towner disks failed. The most frequent failures were breaking of the main weld (near the back of the tongue) and bending of the tongue or swivel. Some of these failures were probably due to equipment abuse (turning the wrong direction, too much horsepower, etc.), however, there appears to be a definite weakness in the design of the tongue assembly. Until the manufacturer improves the tongue design, the Forest Service recommends that these points be inspected frequently during operation or reinforced before the equipment is used.

The hydraulic ram on Towner disks has failed. These failures were attributed to metal fatigue caused by "snapping" the ram open and closed. The ram bottomed-out and knocked out the end of the cylinder. This problem can be overcome by attaching a heavy safety chain between the ends of each gang. When the disk opens, the chain should take the load and not the hydraulic ram. An upright bracket and garage door spring can be used to keep chain slack out of the disk when it is closed.

Hydraulic hoses have been caught in brush or trees and broken. Usually this problem can be overcome by running the hydraulic lines through old cotton-jacket firehose that is threaded through the eye of a 3- to 4- foot-long rod welded vertically to the disk tongue. This keeps the hose up and out of the way while providing the necessary slack.

Safety precautions. The use of a canopy over and around the tractor operator is essential for all work in steep, irregular terrain. Work to be accomplished with the brushland disk is not excepted. Because the disk has a double action swivel hitch, it can tip forward as well as sideways. This has happened. On one project a 10,000 pound disk rode up onto "balled" brush, tipped forward and put a large dent in the tractor canopy at the level of the operator's head.

Disks have tipped over sideways. Generally such accidents occurred after the disks rode up on accumulations of balled brush beneath the disks. Disks that are 10 to 12 feet wide are more stable than narrower models. Swampers should be aware that these disks can roll over sideways suddenly. They must stay clear, especially of the downhill side.

Care also should be taken when performing maintenance on these large pieces of equipment. Disks should be on ground as level as possible, and they should be securely "chocked" in place while repairs are made.

Seeder attachment. A seeding attachment for brushland disks called the Holt Seeder has been used. The Forest Service attached this to several brushland disks. In every case they were considered unsatisfactory. This seeder could not be satisfactorily modified.

Some advantages and disadvantages of the brushland disk include:

Advantages

1. Considered to have good maneuverability--around trees, boulders, drainages, etc.
2. Effective for creating irregular edge effect--scalloping, feathering, etc.
3. Allows varying degrees of clean-up according to desired aesthetic effects.
4. Does a complete job--burning is not necessary.
5. Does not displace top soil.
6. Debris is incorporated into the soil. This enhances nutrient recycling.
7. Digs out many roots and root crowns. This reduces or eliminates the need for herbicides to control brush sprouts.

Disadvantages

1. Use is limited by slopes, soil, and rocky conditions.
2. Disturbs and loosens soil, making it more vulnerable to detachment and transport by high intensity and running water.
3. Costs are generally high and more fuel per acre treated is required compared with other mechanical treatments.

Table 1. Brush classification by type and volume.

Vegetation Type[1/]	Vegetation loading[2/] Tons/acre (estimated) Low	Moderate	Heavy
Light to medium chamise (2.5'-4' high).	<7	7-15	16-25
Low brush mixtures including combinations of big sagebrush, California sagebrush, California buckwheat, white sage, black sage, coyote brush, chamise, and sumac (2'-5' high).	<7	7-15	16-25
Mixed brush (4'-6' high) and scrub oak.	<10	10-25	--
Heavy pure chamise, manzanita or buckbrush (4'-6' high).	---	20-30	31-40
Heavy mixed brush (6'-8' high).	---	20-35	36-55
Heaviest mixed brush with toyon, oaks, big manzanita and madrone on north slopes at higher elevations and latitudes (8'-12' high)	---	30-45	46-60

1/ Adapted by Clive Countryman and Lisle Green (U.S. Forest Service) and T.E. Adams from Forest Service Region 5 Fire Control Handbook.

2/ Prepared by Clive Countryman and Lisle Green, U.S. Forest Service.

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