it is sometimes difficult for the tractor driver to tell which plants have or have not been treated. Use of a dye or other marker might solve this problem.

Potential for Use

Initial evaluations suggest that the brush roller may provide more effective control of at least some species of brush and weeds than is currently possible. As a management tool, it should be useful in a variety of situations. Since the small tractor is highly maneuverable and inexpensive to operate, widely scattered shrubs and tree seedlings can be individually treated where new infestations are encountered. The machine can also be used to "clean up" regrowth after other brush control treatments are employed. In these situations, brush problems can be inexpensively controlled before they become dense enough to require more expensive, broadcast treatments, and the effective life of other kinds of brush management practices can be extended. The brush roller can also be used independently as a broadcast applicator in thick infestations, although swath width is narrow in comparison to those of either ground or aerial spray equipment, or pelleted herbicide applicators. Rough terrain may also limit its use in many situations.

Fire Hazard Reduction Practices for Annual-type Grassland

John V. Stechman

Prevention of grassland fire is widely sought by livestock owners to avoid economic losses of dry forage, damage or destruction of fences and other structures, and watershed disturbance. The attendant atmospheric and aesthetic "pollution" caused by a burn, although short-lived, is often construed as undesirable to an environmentally aware public. The visual impact of fire-blackened earth is intensified by associated, adverse psychological effects and persists until secondary growth obscures the aesthetic damage. Exclusion of natural grassland communities from livestock grazing and other kinds of domestic agriculture is desirable for hydrologic, ecologic, educational and recreational purposes, but, depending on one's viewpoint or land management objectives, may be detrimental. The resulting accumulation of excessive grass litter reduces soil temperatures and bacterial activity, depresses nutrient cycling and availability, lowers the yield and palatability of herbage for wildlife, and, of critical concern, represents a potential for conflagration.

The productive California annual grasslands of Mediterranean "savanna" climate, with alternating 6-month rainy and dry seasons, present a high fire hazard in the dry summer season. Maximum herbage yield of most annual species is reached at seed maturity in late May, and the bulk of the dry weight of tall grases is retained well into late August. Records of the California Division of Forestry indicate that over 80% of grassland fires occur during the period from May 1 to August 31 between 9 AM and 6 PM, caused mainly by equipment use and arson. The impact of fire and practices commonly utilized for its prevention and suppression were the center of interest of a study and demonstration on an annual grassland in San Luis Obispo County, California.

Study Area and Procedures

A 3-year study was initiated in the summer of 1977 on a 200-acre County School System Environmental Education Campus located in the Coast Range 6 miles west of San Luis Obispo. The site has been protected since 1968 for studies of natural and cultural history by children of primary and secondary school level. The effects of grazing, discing and mowing were investigated, along with controlled burning to evaluate the impact of wild fire. Climate of the area is characterized by average annual precipitation of 21.7 inches occurring primarily from November through April, and mean temperatures of 64.9° F for July, and 51.6° F in January. During the study, rainfall averaged 34.1 inches and temperatures were near-normal. Topography of the site selected for treatment is gently rolling and the soils are Los Osos-Diablo Clay loam varients 18 to 30 inches deep, developed over sandstone or shale. Forty-eight species of plants were identified in the cover. Dominant grasses are annual ryegrass *(Lolium multiflorum)*, softchess *(Bromus mollis)*, and wildoats *(Avena fatua, A. barbata)*. Secondary grasses include false brome *(Brachypodium distachyon)* and purple needlegrass *(Stipa pulchra)*. Principal forbs are filaree (*Erodium* spp.), burclover *(Medicago polymorpha)*, hog fennel *(Lomatium utriculatum)*, and hayfield tarweed *(Hemizonia luzulaefolia)*. All, excepting the needlegrass, are annuals.

Four treatments were repeated annually for 3 consecutive years. The treatments were: burning, discing, and mowing, applied on contiguous, 1-acre, rectangular plots during the dry herbage period each year, 1977 through 1979, and winter-spring grazing, 1978 through 1980. The latter plot was located within an adjacent 20-acre pasture. Two comparable plots were established as untreated controls bordering, but at opposite margins of the treated plots. Discing was done with an off-set disc and mowing with a rotary flail to about 2 to 4 inches stubble; both were applied in 2 directions at each treatment time with a wheel tractor. Burning was conducted in the late morning under temperatures between 75 and 90° F and relative humidities of 20 to 40%, a thin layer of uncharred herbaceous litter remained after burning, typical of fast, low temperature grass fires. Grazing by cattle was controlled at a

The author is professor, Range Management, California Poly State University, San Luis Obispo 93407.

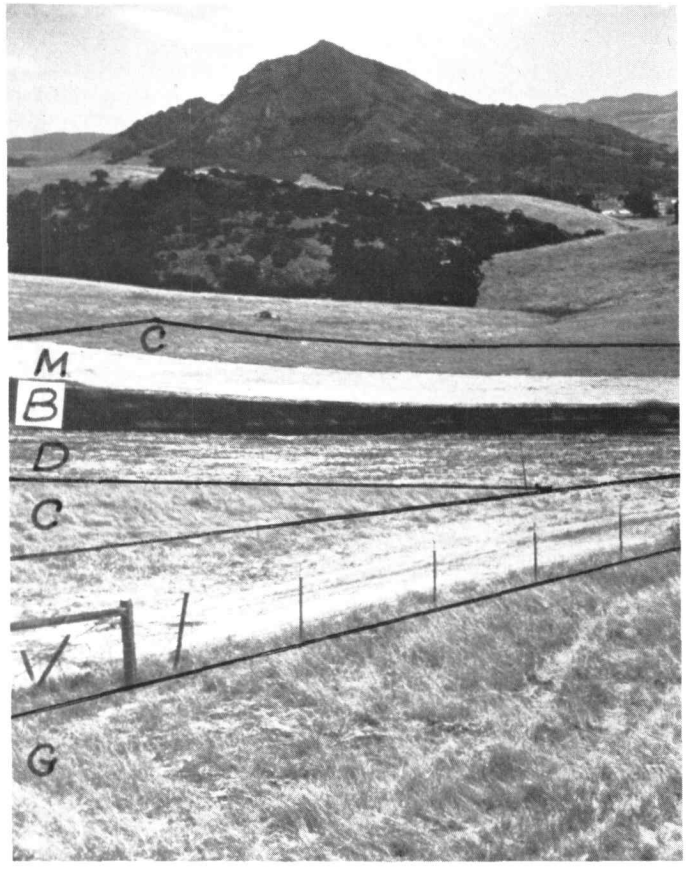
moderate rate (0.7 acres/AUM) to harvest 30 AUM's from the 20-acre pasture each year during the green forage period, February through May.

Data were collected for species composition and live plant density between flowering and seed cast of the dominant grasses using the step-point technique. Observations were also recorded concerning plant height, color, and development, rodent activity, and soil surface characteristics. Total dry herbage (fuel, including feces) was determined following plant maturity by clipping and plucking to soil surface, replicated 9.6 sq. ft. circular subplots located randomly at paced intervals within each treatment. Tests were made for rate of fuel combustion within the mowed, grazed and (one) control plots June 27, 1979, and July 10, 1980, under burning conditions described above. Time for combustion was recorded for duplicate 10 × 10-foot square subplots ignited at one corner so as to burn crosswind.

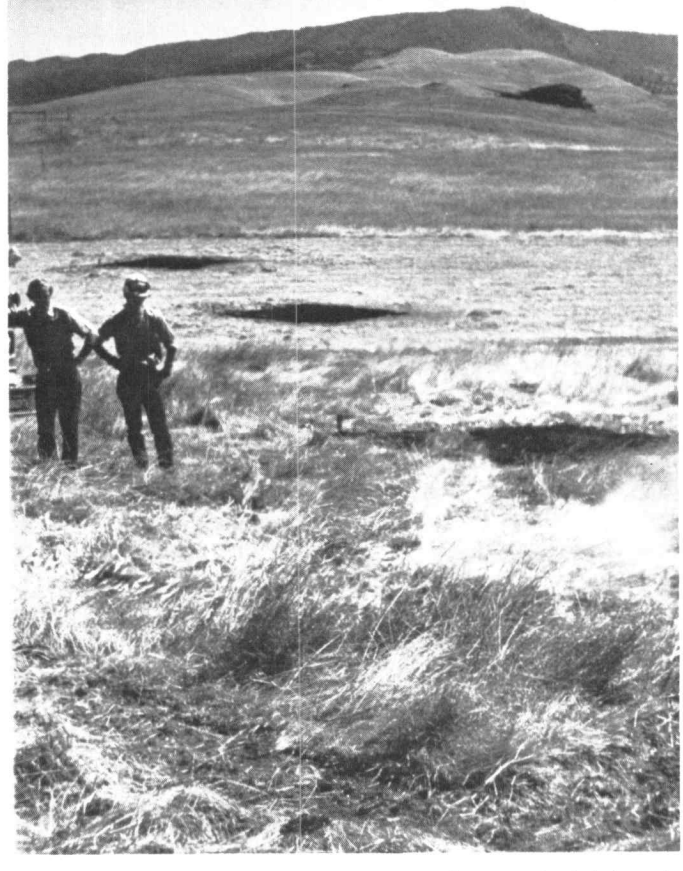
Results and Discussion

Average effects of three years of repeated treatments on species composition, live plant density, residual dry matter, and combustion time are presented in Table 1. The grass-forb (G:F) ratio was highest (30:1) on protected plots and lowest (4:5:1) following repeated burning which favored tarweed, filaree, hog fennel, and other broad-leaved herbs. Apparently the residual litter, greater density, and more rapid development of annual grasses early in the growing season under protection reduced light and temperatures near the soil surface to levels below those required by forbs. Annual ryegrass dominated all plots, was somewhat favored by mowing, but was reduced in abundance by grazing. Wild-oats benefited from all treatments, especially discing which produced a two-fold increase. Perhaps burial of its large seed by the disc promoted establishment and consequent competitive advantage. Soft chess was diminished by all treatments, particularly on disced and burned plots where it contributed only about one-third the abundance it displayed on undisturbed areas. A corresponding decrease of soft chess and G:F ratio (to 7:1) occurred with discing. Excepting for a slight shift from soft chess to ryegrass under mowing, this practice appears to have had little influence on cover composition in this study. Spring mowing during the major grass growing season may encourage later-maturing summer-annual forbs, while summer mowing is deleterious to summer-annuals such as tarweed which may be cut while flowering. Grazing appears to have favored forbs since, like burning and discing, it reduces the litter or mulch layer. This corroborates the well-documented principle that forbs increase in abundance with decreasing mulch on annual grassland and is evident in the relationship between dry matter and G:F ratio depicted in Table 1. Grazing also favored false brome at the expense of ryegrass which was selectively grazed.

Protection produced the greatest dry matter residual due to the combined effects of a favorable environment for production of grass and maximum accumulation of both current year's growth and partially decomposed residue of 2 previous years. The abundance of residual matter provided feed and cover for rodent activity (runs, mounds, etc.) observed to be greatest under this practice. A depression of average annual dry matter occurred under discing and burning as a result of both its destruction and the decreased grass yield.



Study area in October, 1977, depicting plot layout for study of four traments: G-grazed, D-disced, B-burned, M-mowed and C-controls.



A test of combustion rate being conducted on a control plots; note completed tests on the mowed plot in the background.

Table 1. Average composition, density, residual and combustion time for three years of treatment.

Treatment	Composition-% Grass	Forbs	% Live Density	Residual dry matter, lbs/acre	Combustion time min. per 100 sq. ft.
Control	96.8	3.2	56.3	7,709	2.58
Grazed	93.8	6.2	47.6	4,917	3.95
Mowed	95.8	4.2	67.0	4,679	5.38
Disced	87.3	12.7	51.3	4,226	—
Burned	81.8	18.2	38.6	3,157	—

The incorporation of litter by discing may have increased soil Carbon-Nitrogen ratio and microbial activity, leading to a decrease of available nitrogen as evidenced by yellowing of the live herbage on disced plots. The potential increase in soil fertility provided by ash was reflected in deeper green herbage on burn plots. However, this did not apparently compensate for detrimental effects of fire on productive grasses, live plant density, and thus total herbage growth. Although a depression of yield the first year after a fire is often followed by superior production, reburning appears to further reduce and sustain yield depression. This decrease and associated reduction of live plant density led to little observable rodent activity on the burned plot.

Residual dry matter was diminished by grazing due to forage consumption and the reduced amount and perhaps increased rate of winter decomposition of carry-over from the previous year. The reduction was greater than expected, however, and an explanation is confounded among many effects of grazing. The reduction of dry matter due to mowing is also difficult to rationalize. However, the chopping and packing action condensed the dry herbage to a tight, insolating blanket. This resulted in a cool, moist environment favorable for germination and growth of a dense, fine-stemmed, highly-competitive stand of ryegrass, and the enhancement of decomposition as temperature warmed in the late winter. As a consequence, lower total plant residual occurred in the late spring, in spite of an increase in live plant density.

Total time required for combustion proved to be inversely related to the amount of residual under control, grazed and mowed treatments. However, mowing resulted in a disproportionate reduction in this measure of flammability. A 39% reduction of residual dry matter from the control due to mowing slowed combustion time 108% (protected grassland burned more than twice as fast as mowed). However, 36% less residual due to grazing resulted in only a 53% extension in the duration of the fire. (About the same, but less pronounced relationship existed when the rate of combustion in pounds per second is computed; mowing decreased the combustion rate 71%, and grazing, 58%.) Mowing is a widely used practice to deter the progress of a grass fire, but the reasons for its effectiveness are not clear. It is believed that by concentrating fuel, retention of any acquired moisture is enhanced and the rate of oxygenation during combustion is much reduced. While grazing favorably alters the behavior of fire (i.e. slows rate of spread) when compared to ungrazed grasslands, it does not, in the opinion of this author, reduce fire *hazard*. Moderately grazed ranges have enough residual litter to constitute a fuel as readily ignitable as an ungrazed range; only by abusively overgrazing can the chance of a fire be reduced.

Conclusions

Burning of grassland represents an undesirable event to certain segments of our population. Three years of repeated summer burning of annual grassland significantly reduced grass-forb ratios, live plant density and dry matter residual. Fire appears detrimental to rodent activity, soil protection, aesthetics, and usefulness of this grassland for studies of natural communities.

Discing following maturity of winter annual plants for 3 consecutive years resulted in an appreciable shift from grasses to forbs, slight reduction of plant density, and a large decrease of dry matter residual. Annual, peripheral, early summer discing, although constituting a considerable cost, erosion hazard, and disturbance of the natural scene, would maintain acceptable regeneration of the plant cover and soil protection. And, incorporation of the plant cover with soil precludes spread of ground fire from external sources.

Large reductions of combustible residue were achieved both by annual summer mowing and winter-spring grazing treatments over a 3-year period. Small decreases of grass-forb ratios resulted from both; density increased somewhat with mowing and decreased slightly under grazing. Both practices produced remarkable decreases in combustion rate. Strip-mowing of the perimeter would provide an effective method for reducing the spread of ground fire into a grassland area and while cost is a factor, environmental disturbance is minimal. Proper grazing would not protect an area per se, but would favorably alter wildlife behavior and provide a source of income. The minor increase in forbs with grazing benefits floral diversity and wildflower values. Pasture stock may be considered an asset to the aesthetics and provide an added dimension to education of young people concerning the place of domestic ruminants in grassland ecosystems.