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Prescribed Fire Opportunities in Grasslands Invaded by Douglas-fir: State-of-the-Art Guidelines

**George E. Gruell
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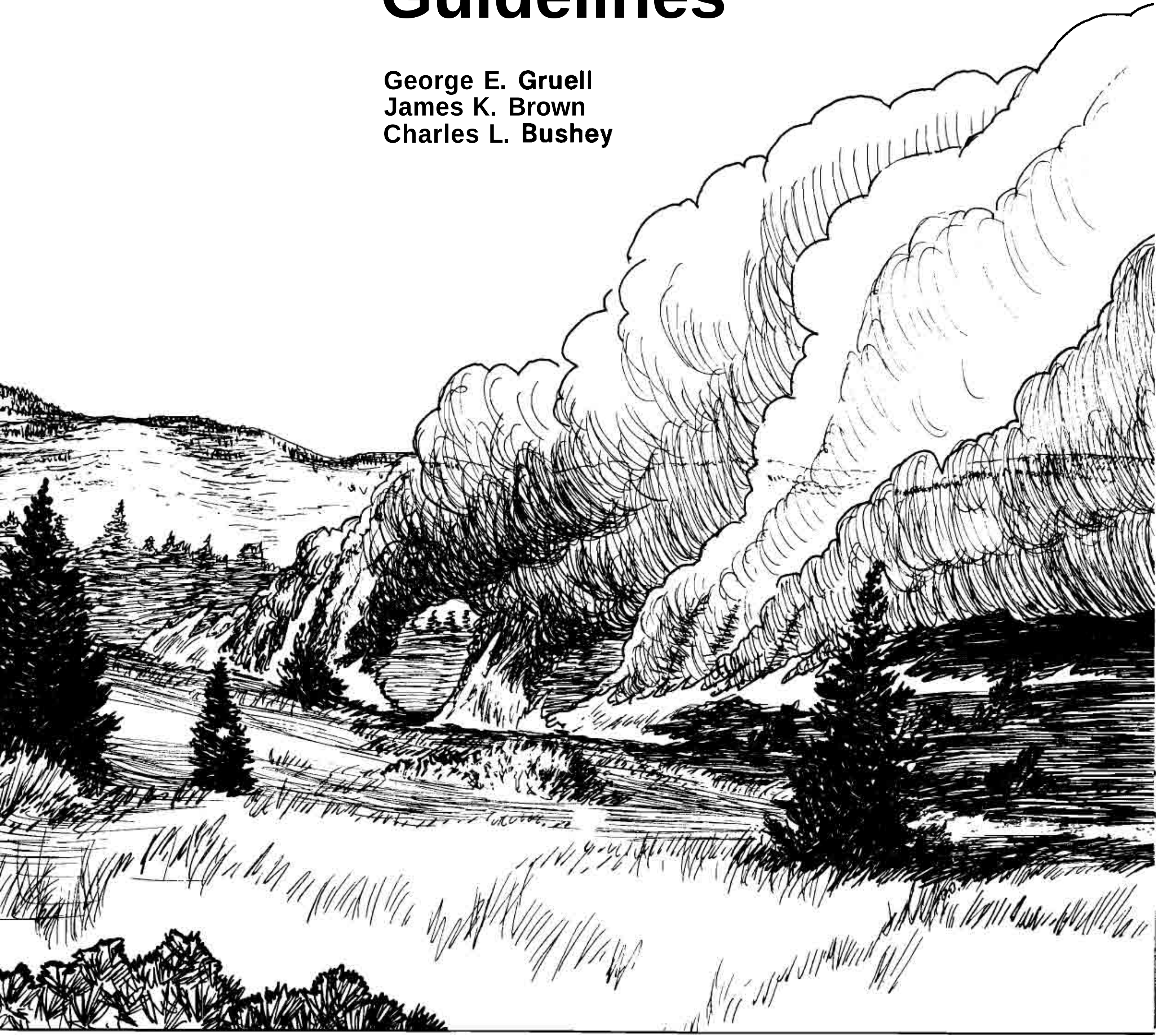

PREFACE

This report incorporates new data, existing research, and experience from fire specialists, foresters, silviculturists, range managers, and wildlife biologists who deal with prescribed fire. The situations suitable for treatment of prescribed fire were identified during the planning and implementation stages of a cooperative prescribed fire demonstration study between the Jefferson Ranger District, Deerlodge National Forest and the Intermountain Fire Sciences Laboratory. The interest and enthusiasm of personnel on the Deerlodge National Forest were instrumental in the development of this guide.

The authors acknowledge technical advice from several individuals having in-depth experience in prescribed burning. Particular thanks is due Sonny Stieger, zone fuel specialist, Helena National Forest (retired); Herald Wetzsteon, forest technician, Wisdom Ranger District, Beaverhead National Forest; Dan Bailey, supervisory forestry technician, Missoula Ranger District, Lolo National Forest; Larry Keown, fire management officer, Gallatin National Forest; and John "Oz" Osborn, fire management officer, Jefferson Ranger District, Deerlodge National Forest. The following also provided constructive suggestions: Wendell Hann, Northern Region, USDA Forest Service; Peter Stickney, Intermountain Research Station; Steven Bunting, University of Idaho; John Joy, Deerlodge National Forest; Bruce Kilgore and Steve Arno, Intermountain Fire Sciences Laboratory; and Edward Mathews, Montana Division of Forestry.

RESEARCH SUMMARY

This publication is a guideline on use of prescribed fire to enhance productivity of bunchgrass ranges that have been invaded by sagebrush and conifers. Six vegetative "situations" representative of treatment opportunities commonly encountered in the Douglas-firlgrassland ecotone include seedling, sapling, and pole invasions of Douglas-fir in grasslands, a saplinglpole stage in curlleaf mountain-mahogany, a pole stage in aspen, and a saplinglpole stage in pinegrass having commercial timber potential.

Photographs and descriptions of the situations cover vegetative characteristics, vegetative trend, role of fire, response potential of plants following fire, and fire prescription considerations.

Fire prescription considerations describe the determination of resource and fire objectives, the kind of fire needed to meet the fire objectives, fuel characteristics, and possibilities for fuel modification. Photographic examples of different grass quantities and flammability aid in determining whether fire will spread.

Suggestions for planning the prescribed burns cover choosing locations and developing appropriate prescriptions. An aid in developing prescriptions includes a range of prescription factors that allow fire to carry in grasslands invaded by conifers.

THE AUTHORS

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INTRODUCTION

Several million acres of seral grasslands in Montana under National Forest, National Resource (Bureau of Land Management), State, and private ownerships have been invaded by Douglas-fir or other conifers such as ponderosa pine, limber pine, lodgepole pine, or Rocky Mountain juniper. (See appendix I for scientific names of vegetation.) Before settlement, fire maintained these grasslands by impeding the invasion of conifers. The absence of fire has resulted in a marked reduction in the availability and palatability of forage, thus reducing the capability of these lands to support big game and livestock (Gruell 1983). In these situations, competition for forage between big game and livestock often becomes a significant management problem.

These guidelines focus on Douglas-fir invasion of seral grasslands on Douglas-fir bunchgrass habitat types (potential climax—Pfister and others 1977) in west-central and southwestern Montana. Focus is on Douglas-fir invasion of bunchgrass (habitat types) because of its widespread occurrence and great abundance. These habitat types have low potential for producing commercial timber, according to Pfister and others (1977). Mean yield capability is less than 30 ft^3/acre/yr. Generally, these trees are limby and of poor growth form. They are highly susceptible to damage from the western spruce budworm (*Choristoneura* occidentalis). Because of the low potential for growth of commercial timber, bunchgrass habitat types are particularly suited for management emphasis on wildlife and range values.

Interpretations of fire history and long-term succession by Arno and Gruell (1983), Gruell (1983), and Arno and Gruell (in press) demonstrate that presettlement wildfires restricted the growth of woody plants and promoted growth of bunchgrasses. Changes in environmental influences following settlement resulted in a shift toward dominance by woody plants. This shift seems to have occurred as suggested by Sindelar (1971). Livestock grazing reduced bunchgrasses and promoted soil disturbance that was favorable for establishment of sagebrush on seral grasslands. The sagebrush provided favorable microsites for regeneration of Douglas-fir seedlings. These trees became established because fire had been removed as an effective agent. Consumption of fine fuels by livestock, elimination of Indian fires, and fire suppression apparently acted independently to bring this about. Adjacent forested sites show marked increases in tree cover because of the absence of fire.

Management of forested wildlife habitat, and rangelands, largely involves maintaining desirable successional stages of vegetation. An appropriate mix of vegetation stages is usually necessary for producing a diversity of wildlife species and for maintaining high carrying capacities over long periods. Evidence of vegetation trend in Montana suggests that optimum habitat conditions for many wildlife species including mule deer (Odocoileus hemionus) and ruffed grouse (Bonasa *umbellus*) seem to have occurred during earlier successional stages when there was a good balance between forage and cover. Aspen and crown-sprouting shrubs had reached peak production, having responded favorably to pre-1900 fire disturbance followed by an extended fire-free period. Shrubs intolerant to fire damage including antelope bitterbrush, curlleaf cercocarpus (curlleaf mountain-mahogany), and mountain big sagebrush also reached peaks in production. As succession advanced in the absence of fire, forest openings were converted into tree cover, forests thickened, shrubs deteriorated, and bunchgrasses were reduced or eliminated. This vegetal transformation has resulted in heavy competition between wildlife and livestock for a diminishing supply of forage.

Prescribed burning has not been widely used to eliminate Douglas-fir that has invaded bunchgrass ranges. Consequently, little information is available to describe burning opportunities or assist in development of fire prescriptions. This guide identifies situations in Douglas-firlbunchgrass habitat types where habitat capability for wildlife and forage for livestock can be improved with prescribed fire. The more moist Douglas-firlpinegrass habitat types, frequently supporting harvestable timber, have also been included because of their shrub potential, widespread occurrence, and close association with Douglas-firlbunchgrass habitat types. Other habitat types such as Douglas-fir/snowberry have good potential to produce shrubs during early to mid-successional stages but are not illustrated in detail here. Where these mesic habitat types are associated with the more xeric Douglas-fir/bunchgrass habitat types, the forage resource can be enhanced by coordinating timber harvests with prescribed burning.

These guidelines are also applicable to other conifers capable of converting grassland sites. Contents should help bridge the gap between broad resource plans (such as National Forest plans and action plans) by identifying burning opportunities and approaches in application of prescribed fire.

This guide was developed around six "situations" that illustrate stages in Douglas-fir succession and associated fuels where application of prescribed fire would result in enhancement of the wildlife and range resources. The six situations described are representative of Douglas-fir succession in fire ecology groups four and five (Fischer and Clayton 1983). The situations include (1) seedling, (2) sapling, and (3) pole stages in Douglas-firlbunchgrass habitat types; (4) a sapling1 pole stage in curlleaf mountain-mahogany on a Douglas-fir/Idaho fescue habitat type; (5) a pole stage in aspen in a Douglas-firtrough fescue habitat type; and (6) a saplinglpole stage in a Douglas-firlpinegrass habitat type. Situations described occur from low to middle elevations from 4,000 to 7,000 feet. The extent of each situation depends on continuity of habitat type, time since fire, and past management.

PLANNING THE PRESCRIBED BURN

Planning for a prescribed burn is a twofold process: choosing good locations and developing a prescription.

Choosing Locations

Choosing good locations for applying prescribed fire is based upon an evaluation of benefits and costs. Selected burn units should have good potential for forage response, be located where big game and livestock will use them, and be treatable with reasonable costs. The situations described here can help in identifying sites with good forage response potential. Some other considerations are briefly discussed.

The objective of using prescribed fire in most instances is to increase the carrying capacity, thus reducing the level of competition between big game and livestock. Needs for security cover should also be assessed. Most areas that will be considered for prescribed burning are winter or spring-fall range. Generally, the retention of security cover for big game in this zone is not as important as on summer range where animals remain during most of the hunting season. Nonetheless, evaluation of security cover needs of big game should be made on a case-by-case basis.

On most livestock allotments, it is advisable to rest treated units prior to burning and during the first growing season. This can be followed by light to moderate late-season grazing. An important consideration in maintaining good postfire response is to treat a large enough area that use by livestock and wildlife will not be excessive. Where forage use is heavy, this may require treating a thousand acres or more.

We suggest that initial planning be focused on identification of treatment alternatives throughout a drainage basin. Opportunities to integrate timber harvests into the treatment alternatives can facilitate attainment of objectives, especially on sites having good potential for aspen and shrubs. For example, patch cuts followed by broadcast burning can be designed to reduce fuels and stimulate growth of forage plants. Cutting units may also serve as holding lines for subsequent prescribed burns in adjacent uncut areas.

A primary consideration in keeping costs down is size of burns. Costs per acre treated increase rapidly for units less than about 80 acres. Time of year also affects costs. For example, burning during late summer and early fall requires more effort to prepare and hold lines, which increases costs substantially.

Large burns make it easier to take advantage of natural fuel breaks and changes in vegetation to control fire. Use of natural fuel breaks will keep costs down, while eliminating damage that may occur from fire line construction. The size of the burn depends on complexity of the project. Factors to consider include the season of livestock use, travel restrictions, private property, mining activity, recreationists, and so forth. The manager should try to burn as large an area as possible. This can be accomplished by burning single units or several smaller units close together.

The situations described here often intermingle on the landscape (fig. 1). Therefore, more than one situation may be included in a single burn unit. After situations are identified, the most logical treatment sequence can be determined.

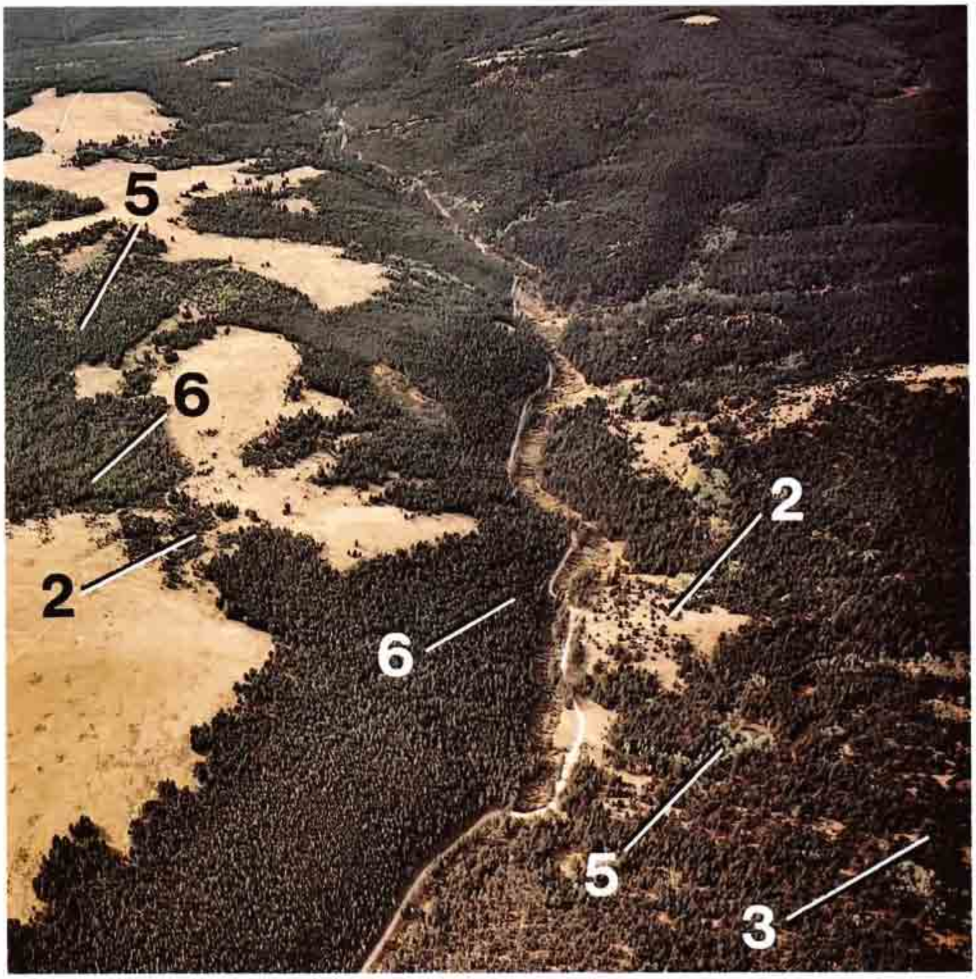


Figure 1.—Examples of situations on Galena Gulch study area. Numbers follow sequence in text.

Developing the Prescription

Although this publication provides some specific fire prescription suggestions, it is not intended to be a detailed guide for writing prescriptions. Because prescribed fire opportunities are often unique, they should be evaluated individually. To determine safe, effective fire prescriptions, the first step is to specify objectives for the fire and define constraints on using it. Next consult technical aids for evaluating fuels, weather, fire behavior, and fire effects. Then integrate relevant technical knowledge with experience to write the prescription. This process, along with considerations for choosing technical aids appropriate to defining prescription windows, are discussed by Brown (in 1985). References useful for planning prescribed fire, in addition to those cited earlier, are listed in the reference section.

A range in prescription factors used in prescribed burning grass invaded by sagebrush is shown in table 1. These values were determined by interviewing people experienced in prescribed burning of sagebrush. The values in table 1 do not constitute a prescription for any individual site but indicate the latitude within which prescriptions can be developed. Local fuel conditions and terrain will dictate whether individual prescriptions should promote or retard flammability. For example, on a steep slope with reasonably continuous fuels, windspeeds of 3 to 7 mi/h and relative humidities of 25 to 40 percent may constitute a desirable prescription for those factors. However, on an area with little slope and sparse fuels, windspeeds of 6 to 12 mi/h and relative humidities of 15 to 30 percent may constitute a desirable prescription.

To help find the answer on whether fire will spread in grass fuels, appendix II includes photographic examples of different grass quantities and associated flammability. Experience with prescribed fire on grazed range indicates that fine fuel loadings will not support fire spread unless accompanied by at least 15 to 20 percent sagebrush cover. The lightly grazed example may allow fire to burn in some localities, but the broken fuel continuity could interrupt fire spread unless sagebrush cover is at least 10 percent. The ungrazed example will support fire spread. Fire intensity is increased with the addition of sagebrush.

Table 1.—Range of prescription factors that allow fire to carry in grasslands invaded by big sagebrush and Douglas-fir. The range in prescription factors for individual burns may be smaller to satisfy local fuel and terrain conditions

Situation	Average windspeed	Cloud cover	Temp-erature	Relative humidity	Fuel moisture 1-hour timelag	Fuel moisture 10-hour timelag	Time of year
	Mi/h	*Percent*	*°F*	*Percent*	*Percent*	*Percent*	
1. Sagebrush, grass, Douglas-fir seedlings	3 to 12	0 to 10	50 to 80	15 to 40	6 to 12	8 to 15	spring, fall
2. Sagebrush, grass, Douglas-fir saplings	3 to 12	0 to 10	55 to 80	15 to 40	6 to 12	8 to 15	spring, fall
3. Mountain-mahogany, sagebrush, grass, Douglas-fir seedlings and saplings	5 to 12	0 to 10	55 to 80	15 to 40	6 to 12	8 to 15	spring, fall
4. Douglas-fir pole stage in sagebrush and grass	3 to 8	0 to 20	50 to 75	25 to 60	6 to 15	8 to 18	fall
5. Douglas-fir pole stage in aspen	4 to 10	0 to 10	55 to 80	20 to 40	6 to 12	8 to 15	fall (preferred) spring
6. Douglas-fir saplings and poles, pinegrass and shrub understory	3 to 8	0 to 20	50 to 80	25 to 60	6 to 15	8 to 18	fall

Two aspects of the prescription—season of burning and the combined influence of fine fuel moisture and windspeed on flammability—merit additional comment. A tradeoff between windspeed and fine fuel moisture or relative humidity is sometimes possible in achieving sustained fire spread. For example, increased windspeed can overcome the damping effect of slightly high relative humidity. Conversely, low relative humidities can sometimes overcome lack of wind. Experience is needed to recognize when the tradeoffs are effective in maintaining fire spread. Caution is advised in basing prescriptions on the flammable and nonflammable limits of relative humidity and windspeed shown in table 1. When windspeeds are high and relative humidities low, for example, control of fire may be difficult. Conversely, when windspeeds are low and relative humidities high, fire may not spread. The season when prescribed fires are scheduled affects the attainment of objectives and cost effectiveness.

Spring Fires.—These fires are conducted as soon as dead fine fuel moistures are low enough to support fire spread but before green up of herbaceous vegetation. New green growth should be less than 2 inches in height to favor sustained fire spread with minimal damage. Fine fuel moisture contents as low as 5 percent may be acceptable in the spring but present control difficulties during other seasons, depending on other burning conditions. In large burns where differences in elevation and aspect affect flammability, stage burning may be needed to meet objectives. This requires on-site monitoring of fuel moisture to know when different sections of the burn are in prescription. Spring burns tend to produce a mosaic of burned and unburned areas, which is usually desirable for meeting wildlife habitat objectives in sagebrush. Small burns as well as large ones that create a mosaic can be cost effective. But obtaining large burned-over areas may be difficult and costly. Some advantages and disadvantages of spring burning are:

Advantages
- Small Douglas-fir are easily scorched and killed
- Soil moisture content is high and damage to sensitive bunchgrasses such as Idaho fescue is minimal unless fires are set too late in the spring
- Burns are less complex and less expensive than at other seasons
- Smoke dispersion is good

Disadvantages
- The prescription window or time in prescription is short and even absent in some years
- Access can be a problem
- Poor site preparation results where forest floor duff (02 horizon) has accumulated
- Moist fuels beneath conifers prevent spread of fire

Fall Fires.—Fall burning period is usually considered the time after late summer rains have broken the normal fire season. Many plants have ceased growth and are dormant. A wide latitude in fuel moisture content, fuel consumption, soil moisture content, and fire effects is possible. This adds to the complexity of fall burning. Objectives of prescribed fires must be evaluated carefully to determine proper scheduling during the fall. Late summer burning may be appropriate to meet objectives for substantial exposure of mineral soil. Large areas of sagebrush can often be inexpensively burned. Some advantages and disadvantages of fall burning are:

Advantages
- Good site preparation can be obtained
- The time in prescription is longer than at other seasons
- There is better access than in the spring
- Fire spreads more readily on wetter sites
- Ceanothus regenerates well where dormant seeds are present

Disadvantages

- Burns may be more complex and expensive than at other seasons
- Wind erosion is possible in areas susceptible to strong sustained wind
- Smoke dispersion may constrain opportunities

SITUATIONS

Each situation is illustrated by a photograph accompanied by a description of vegetation and fuels found in the scene. The quantitative information was obtained by sampling within the scene areas. Because vegetation and fuels vary from site to site within a situation, the photographs must be considered as examples only.

Vegetation and fuels were measured as described in appendix III. Fine fuel and litter measurements closely follow procedures developed by Brown and others (1982). Herb and shrub composition (presencelabsence) was determined by reconnaissance within the field of view.

Following each scene are discussions of vegetal characteristics and trend, response potential, and fire prescription considerations.

SITUATION 1: Douglas-fir Seedling Stage in a Douglas-fir/Idaho Fescue h.t.

SITE CHARACTERISTICS

Density

Trees[1]		Seedling and sapling[2]
(No./acre)	Basal area *(Ft²/acre)*	*(No./acre)*
10	1	35,000

Cover *(percent)*

Trees	Shrubs
8	*27*

Fuel loading *(lb/acre)*

Grass and litter	2,980
Live shrub	1,940

Herb and shrub composition

Rough fescue, Idaho fescue, bluebunch wheatgrass, western yarrow, western puccoon, heartleaf arnica, fernleaf fleabane, fringed sagebrush, rubber rabbitbrush, mountain big sagebrush

[1]Trees over 10 feet high.
[2]Trees less than 10 feet high.

VEGETATION CHARACTERISTICS

Situation 1 is an example of Douglas-fir seedlings invading a seral sagebrushlbunchgrass community on a Douglas-fir/Idaho fescue habitat type. This situation is generally restricted to openings of less than 2 acres. Adjacent conifer stands vary in age and structure. In our example, the Douglas-firs in the background are sapling and pole sizes while conifer seedlings are abundant (35,000per acre). The high number of seedlings reflects dense patches less than 2 feet high that are screened by sagebrush. Sagebrush has a canopy cover of about 27 percent. Bunchgrasses include Idaho fescue, rough fescue, and bluebunch wheatgrass, while forbs form a minor part of the plant cover on this semiarid site.

VEGETATION TREND

Examination of fire scars in the vicinity suggests that the absence of fire for about 100 years allowed Douglas-fir to invade this park, which was formerly dominated by grass. Douglas-fir was preceded by establishment of sagebrush that provided shaded microsites conducive to regeneration of Douglas-fir seedlings. If fire is excluded, Douglas-fir seedlings will reach sapling size within the next 20 years.

Antelope bitterbrush may be an important component of the vegetation, but it is often senescent, showing little evidence of seedling regeneration. Continued protection from disturbance, particularly where conifer competition is intense, will result in extensive long-term decline and eventual loss of bitterbrush from the community (Bunting and others 1985).

RESPONSE POTENTIAL

Use of prescribed fire reduces or eliminates Douglas-fir seedlings and sagebrush and improves growing conditions for a variety of forage plants by increasing available soil moisture, nutrients, and sunlight. The response potential of grasses and forbs will vary depending on preburn composition and density. Herbage production may be less than preburn levels the first growing season, but can be expected to increase threefold or more by the fifth growing season (fig. 2). Curves on figure 2 are generalized to show average responses. The level of production will vary by site depending on several variables, particularly soil moisture during the growing season. A decline in forage production to preburn levels after 20 years is based on the assumption that sagebrush competition will be intense.

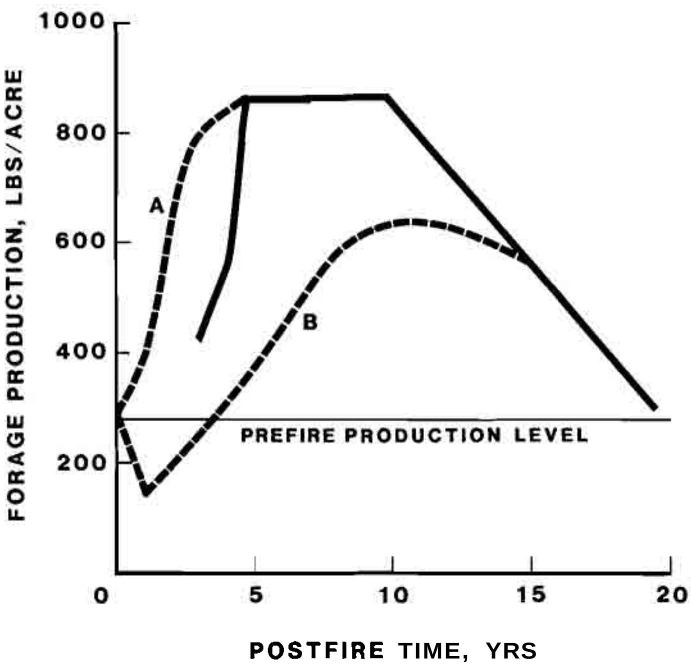


Figure 2.—Forage production after disturbance by fire. Solid line is for grasslands largely based on data from Idaho and Oregon (Peterson and Flowers 1985). Dashed curves show rapid increase in production recorded in central Montana (A) and slower, less productive situations where conifer competition was severe (B).

Wheatgrasses.—Wheatgrasses recover quickly because reproductive buds are located below the soil surface where they are protected from heat. Bluebunch wheatgrass usually returns to preburn conditions in 1 to 3 years (Wright and others 1979). Rhizomatous species in particular have the capability of recovering quickly. Nimir and Payne (1978) reported a 42 percent increase in the basal area of slender wheatgrass at the end of the first growing season after a light spring burn in southwest Montana. Production may remain above preburn levels for a decade or longer. A twofold increase in bluebunch and thickspike wheatgrasses was measured in southeastern Idaho 12 years after an intense late summer prescribed fire (Blaisdell 1953).

Needlegrasses.—Production of most needlegrasses is initially reduced by fire. The degree of reduction seems to depend upon species and season of burning (Wright and others 1979). Needle-and-thread grass showed high mortality to June and July burns, but no mortality was recorded in response to August treatments (Wright and others 1979). First-year production of western needlegrass was reduced by an August wildfire in northeastern California, but by the third year its basal area had almost doubled in comparison to an adjacent unburned area (Countryman and Cornelius 1957). An apparent extreme in needlegrass response was measured in southwestern Montana where Richardson needlegrass in a rough fescue habitat type increased from 4 lblacre to 306 lblacre 2 years after a spring prescribed fire. This site had a heavy preburn canopy of mountain big sagebrush (Bushey 1984). In west-central Montana Hann (1984) found a marked increase in production of western needlegrass over the preburn level on a Douglas-firlrough fescue habitat type.

Idaho Fescue.—Fescues usually respond more slowly to fire than do other grasses. Idaho fescue, one of the most widespread grass species in Montana, is particularly sensitive to fire. Susceptibility to damage is apparently due to the compact root crown with the budding zone confined to a small area at or above the soil surface (Conrad and Poulton 1966).

Idaho fescue took 30 years to approach preburn levels in southeastern Idaho (Harniss and Murray 1973). Slow recovery was apparently influenced by marginal site conditions (Wright and others 1979) and a high-intensity late summer fire fueled by dense sagebrush.

Observations in Montana suggest that the susceptibility of Idaho fescue to loss from fire increases proportionately to the amount of dead fescue. Bunchgrass clumps with accumulated biomass may smolder for long periods. This permits lethal temperatures to develop around meristematic tissue. Idaho fescue in association with sagebrush is also influenced by fire severity. Sites with heavy sagebrush cover can generate severe fires, thus damaging or killing Idaho fescue. In northeastern Oregon measurements 11 months following a summer wildfire showed 27 percent mortality of Idaho fescue (Conrad and Poulton 1966), whereas fall burning in eastern Oregon when plants were dormant resulted in no mortality (Wright and others 1979). In western Montana, Antos and others (1983) report recovery of Idaho fescue to preburn levels 3 years after a summer wildfire.

The effects of fire on Idaho fescue vary greatly depending on timing of the burn, plant condition, and fuel loading. Damage to Idaho fescue can be minimized by burning in the spring or fall when plants are dormant.

Losses of Idaho fescue to prescribed fire should be kept in management perspective. Few areas exist in western Montana where the productivity potential of Idaho fescue justifies management for this species (Hann 1985). Generally, management should be for bluebunch wheatgrass, mountain brome, western needlegrass, and other productive and palatable species.

Where such grasses predominate, high mortality of Idaho fescue from an intense fire need not be a critical management concern.

Rough Fescue.—Many seral grasslands invaded by Douglas-fir contain rough fescue. This species generally responds favorably to prescribed fire in the long run. Productivities of 800 to 1,600 lblacre have been reported on unburned sagebrushlrough fescue habitat types (Mueggler and Stewart 1980). Rough fescue is considered fire sensitive because the budding zone is at or above the soil surface. According to Antos and others (1983), burning of the dense stubble of old culms materially contributes to plant losses. These investigators report that at the end of the first growing season following a summer wildfire in western Montana, rough fescue cover was 35 percent of that in unburned control stands. By the third year, rough fescue production had reached 65 percent of that in unburned stands. On spring prescribed burns in west-central Montana, no loss of rough fescue plants was reported 1 year following the fire (Bushey 1984; Hann 1984).

Application of prescribed fire in seral grasslands invaded by Douglas-fir may entail acceptance of short-term reductions in perennial grasses in order to achieve long-term gains. Most grasses show a twofold or more increase in production by the third year after treatment with prescribed fire. Initial reductions in fescues are usually compensated by the rapid response of other grasses.

Shrubs.—Use of prescribed fire on situation 1 sites should result in marked reduction in nonsprouting sagebrush. Postfire establishment of sagebrush seedlings may occur the first year or be delayed several decades depending on sagebrush species or subspecies, seed availability, soil disturbance, and competition from herbaceous plants. Sprouting sagebrush such as three-tip sagebrush and silver sagebrush may be present on adjacent moist sites.

Burning of sagebrush and Douglas-fir will kill bitterbrush on sites where the fire is severe. However, because bitterbrush is disturbance dependent, use of prescribed fire is ecologically sound when viewed on a long-term basis (Bunting and others 1985). A light to moderate severity prescription usually produces a mosaic of burned and unburned areas. Burning results in crown sprouting of surviving bitterbrush plants and exposure of mineral soil necessary for seedling establishment. Bitterbrush plants in unburned areas serve as seed sources for new plants, while surviving plants that crown sprout ultimately produce seed for establishment of new stands of bitterbrush.

PRESCRIPTION CONSIDERATIONS

Resource Objective.—Increase productivity of herbaceous vegetation, particularly grasses (fig. 2), and improve palatability.

Fire Objectives.—Kill 60 to 80 percent of the sagebrush and 60 to 80 percent or more of the Douglas-fir. Lack of continuous fuels usually results in patchy burns, so complete removal of sagebrush and Douglas-fir seedlings is not a realistic goal. Retention of some sagebrush may be desirable especially for wildlife needs such as winter range for mule deer.

Kind of Fire.—A heading fire with 2-foot or greater flame lengths is needed to kill the sagebrush and Douglas-fir seedlings. A fire with smaller flames probably would not sustain itself. Strip head fires with large distances between strips usually work well. However, narrow strips with fast ignition may be more effective where fuels are marginally sparse. A wide latitude exists for individual prescriptions (table 1). To satisfy local fuel and terrain conditions, the range in prescription factors determined as appropriate for individual burns will normally be smaller than in table 1. For large burns the more flammable end of the prescription spectrum should be sought. For example, seek windspeeds of 8 to 12 or 14 milh at 20 feet above vegetation, relative humidity near 20 percent, and temperatures above 65 degrees. Windspeeds can be too high, causing fires to skip through vegetation without killing it. Windspeeds greater than 15 milh can cause fires to burn in a finger pattern and even go out. The resulting disruption in fuel continuity makes it difficult to complete the burn at a later time.

Fall burning should be done after grasses have become dormant. Although it has been commonly believed that soil should be moist during fall burning, recent evidence indicates that moist soil offers no advantage to survival of Idaho fescue (Britton and others 1983). Caution seems advised, however, in applying this finding to bunchgrasses having large basal clumps containing accumulated dead material. When dry, these clumps are susceptible to crown kill from smoldering fire. Midsummer burning is not recommended because some herbaceous plants such as Idaho fescue are very susceptible to mortality. Spring burning should be done while desirable, sensitive perennial species are still dormant and before green-up reduces flammability. This applies to all situations where desirable fire-sensitive perennial species occur.

Fuels.—Successful spread of fire requires adequate grass fuel (see appendix II). Exclusion of livestock for one season is frequently necessary to develop adequate grass fuel. Where coverage of sagebrush is less than about 15 percent, a grass loading of about 600 lblacre is needed to support fire (Britton and Ralphs 1979). For sagebrush coverage greater than about 20 percent, 300 lblacre of grass may be adequate. Ample grass fuel is particularly needed at lower windspeeds to sustain fire spread, ignite sagebrush, and scorch seedlings. These marginal fuel loadings may be reduced on slopes exceeding about 40 percent. Steep slopes can increase windspeed (Rothermel 1983). Thus, to some extent steep slopes can overcome lack of wind to attain sustained fire spread.

SITUATION 2: Douglas-fir Sapling Stage in a Douglas-fir/Idaho Fescue h.t.

SITE CHARACTERISTICS

Density

Trees[1]		Seedling and sapling[2]
(No./acre)	Basal area *(Ft²/acre)*	*(No./acre)*
60	13	8,700

Cover *(percent)*

Trees	Shrubs
8	12

Fuel loading *(lb/acre)*

Grass and litter	5,060
Live shrub	840

Herb and shrub composition

Bluebunch wheatgrass, Idaho fescue, needle-and-thread, junegrass, Richardson needlegrass, carex, western yarrow, aster, fringed sagebrush, Missouri goldenrod, bitterbrush, mountain big sagebrush, rubber rabbitbrush

[1]Trees over 10 feet high.
[2]Trees less than 10 feet high.

VEGETATION CHARACTERISTICS

Situation 2 illustrates the sapling stage of Douglas-fir invasion in sagebrush/bunchgrass on a Douglas-fir/Idaho fescue habitat type. This stage is typified by trees 30 to 50 years old. Pole-size Douglas-fir can be seen in the background of the accompanying photo. Note the Douglas-fir seedlings in foreground and midground. The Douglas-fir saplings in our example number 8,700 per acre. On this site, shrub cover is 15 percent and is composed of sagebrush, bitterbrush, and rubber rabbitbrush. In general, both sagebrush and bitterbrush are in a declining condition because of competition from trees, insect defoliation, and other biotic factors. The herbaceous vegetation includes five bunchgrasses, a sedge, and several forbs. The potential for herbaceous plants generally is good on sites occupied by saplings because soils are deep and have a relatively high capacity to retain moisture.

VEGETATION TREND

Aging of Douglas-fir on Douglas-fir/bunchgrass habitat types indicates that before settlement these lands were occupied by bunchgrass (Arno and Gruell in press). Small clumps of trees were often found on restricted rocky microsites or thin soils where fuels were sparse. Grasslands were perpetuated by fires burning at intervals of about 5 to 40 years. In the absence of fire, shrubs increased greatly. Recently, however, productivity of shrubs has declined due to senescence of individual plants and conifer competition. Herbaceous plants have also declined. In the absence of fire or insect attack, these stands will reach the pole or sawlog stage in another 40 to 50 years. At this point, little herbaceous forage or live shrubs will remain beneath the tree canopies.

RESPONSE POTENTIAL

The potential for herbaceous plant response on situation 2 sites is higher than on situation 1 sites because soils are deeper and thus have a greater productivity potential. This favorable condition has coincidentally promoted invasion of Douglas-fir. Generally, sufficient numbers of forage plants are present to respond to fire treatment, but recovery potential may be low in Douglas-fir thickets where shading has reduced the herbaceous layer. These sites may recover slowly, particularly if the fire treatment is severe. However, if the fire treatment is light and desired tree mortality is not achieved, a followup treatment within 10 years could produce satisfactory results.

Although prescribed fire may result in reduced production of perennial grasses temporarily, increased productivity will occur in a few years and can be expected to continue for about 20 years, providing enough area is burned to absorb grazing impacts. Use of prescribed fire on situation 2 sites supporting bitterbrush is especially important. At the sapling stage, many bitterbrush plants have been lost to Douglas-fir competition, but there are sufficient numbers of living plants to assure regeneration of the stand. A no-treatment alternative would eventually result in a wildfire. Recovery of bitterbrush following wildfire would be extremely slow.

PRESCRIPTION CONSIDERATIONS

Resource Objective.—Increase productivity of herbaceous vegetation—same as situation 1.

Fire Objective.—Kill 60 to 80 percent of the sagebrush and 60 to 80 percent or more of Douglas-fir—same as situation 1.

Kind of Fire.—A heading fire with 3-foot and greater flame lengths is needed to kill the sagebrush and small saplings. Larger flames will be needed to kill saplings 4 to 5 inches diameter at breast height (d.b.h.). The primary difference between situations 1 and 2 is the requirement for greater fire intensity to kill the larger Douglas-fir. Dense sapling thickets with sparse understories are difficult to burn. Strip head fires are usually the most appropriate ignition method. Aerial ignition of strip head fires offers a method of generating a lot of heat quickly and creating indrafts that could help in burning out thickets. The latitude for development of prescriptions is nearly the same as for situation 1, table 1, except that temperatures and humidities prescribed for individual units should be selected to support greater flame development.

Fuels.—The need for grass fuels discussed in situation 1 applies here as well. Treatment of the conifer fuels should usually be unnecessary. However, cutting of some saplings in large thickets will add to the fuel load and increase drying of fuels. This will enhance burnout of thickets and should be considered where it will help sustain fire spread and maintain adequate fire intensities.

SITUATION 3: Douglas-fir Pole Stage in a Douglas-fir/Rough Fescue h.t.

SITE CHARACTERISTICS

Density		
Trees[1]		Seedling and sapling[2]
(No./acre)	Basal area *(Ft²/acre)*	*(No./acre)*
160	135	

Cover *(percent)*	
Trees	Shrubs
49	2

Fuel loading *(lb/acre)*	
Grass and litter	3,450
Live shrub	120

Herb and shrub composition

Rough fescue, Idaho fescue, junegrass, carex, bluebunch wheatgrass, Richardson needlegrass, sulfur eriogonum, common dandelion, prairiesmoke, strawberry, western yarrow, squaw currant, mountain big sagebrush, rose, chokecherry

[1]Trees over 10 feet high.
[2]Trees less than 10 feet high.

VEGETATION CHARACTERISTICS

Situation 3 illustrates a pole or small sawlog stage of Douglas-fir invasion that began 70 to 100 years ago. This stage of Douglas-fir succession is widespread on former grasslands but varies in stocking density. Stands may be even-aged, such as shown in the illustration, or be intermixed with varying densities of saplings and seedlings. Shrub cover is usually minimal, with only a few remnant crown-sprouting species such as squaw currant, rose, or snowberry present. The low-density herbaceous cover is mostly perennial bunchgrasses with a few forbs.

VEGETATION TREND

In the absence of fire after the mid-1800's, sagebrush invaded grasslands and eventually these shrubs provided shaded microsites for establishment of Douglas-fir seedlings. Sagebrush remnants at the base of trees attest to a sagebrushlgrass community in the past (fig. 3). Establishment of trees on former grasslands such as illustrated in our example has resulted in significant reduction of the bunchgrass cover. Shading and accumulation of litter beneath tree crowns (fig. 4) have suppressed the growth of grasses and prevented establishment of grass seedlings. In some stands, near total loss of the grass cover has occurred.

Figure 3.—Sagebrush remnants at base of Douglas-fir provided shaded microslte for establlshment of Douglas-fir seedlings.

RESPONSE POTENTIAL

Pole stands generally occupy deep soils that have good potential for producing herbaceous plants. However, herb response to disturbance will vary depending on recovery potential, which is related to tree density and herb presence. The response of herbs will depend on the amount of tree mortality caused by treatment. Felling (cutting)and broadcast burning is likely to result in a

Figure 4.— Douglas-fir needle litter accumulation limits growth of grassland understory plants.

better forage response than burning alone. Only a severe fire will kill pole-sized Douglas-fir, and considerable mortality is necessary to induce a major forage response. Delayed response of herbs may result where fuels are concentrated. From observations of burns in heavv conifer, we speculate that production will be delayed and will not reach production levels comparable to sagebrush sites (fig. 2).

PRESCRIPTION CONSIDERATIONS

Resource Objective.—Increase productivity of herbaceous vegetation. Retain tree cover for big game animals and birds.

Fire Objectives.—Remove at least 70 percent of litter layer and expose 30 to 60 percent mineral soil to favor establishment of grass seedlings. Retain 20 to 30 live pole-sized Douglas-fir per acre in an irregular spacing for wildlife and esthetic values (this objective may vary according to needs on individual sites).

Kind of Fie.—A strip head fire with flame lengths regulated to save 20 to 30 trees per acre is desirable. Flame lengths should be kept less than 2 feet around the trees to be saved. Backing fires are acceptable where fuel continuity is adequate to sustain fire spread. Lower duff moisture content should average less than 100 percent and moisture content of the entire duff layer should average less than 75 percent to achieve adequate mineral soil exposure (Brown and others 1985). If duff moisture content at time of burning is less than 100 percent, the desired mineral soil objective can be met with a low-intensity fire. Flame lengths of 1 to 2 feet are adequate. A late summer or early fall burn normally will be required to meet the duff moisture prescription. Once duff becomes wet in early fall from rainfall of about 1 inch or more, it is unlikely that the duff will dry sufficiently to meet the prescription.

Fine fuel moistures can be higher than in the other situations if slash is present (table 1). If slash is not present, fine fuel moisture contents should be at the low end of the range in table 1.

Fuels.—Surface fuels in this situation are commonly sparse. Fires typically leave many trees alive because the sparse fuels generate insufficient heat to cause mortality. Treatment objectives can be accomplished more effectively by harvesting and using trees for **fuelwood** or other products. Slash from harvesting increases fuel loading and improves fuel continuity. Slash should be scattered away from leave trees. Opportunities for harvesting should be sought to provide both wood products and improved wildlife habitat.

SITUATION 4: Douglas-fir Sapling/Pole Stage in Curlleaf Mountain-mahogany on a Douglas-fir/Idaho Fescue h.t.

SITE CHARACTERISTICS

Density

Trees[1]		Seedling and sapling[2]
(No./acre)	Basal area ***(Ft²/acre)***	***(No./acre)***
40	1	1,500

Cover ***(percent)***

Trees	Shrubs
7	14

Fuel loading ***(lb/acre)***

Grass and litter	2,370
Live shrub	190

Herb and shrub composition

Bluebunch wheatgrass, Idaho fescue, needle-and-thread, junegrass, western yarrow, prairie smoke, fringed sagebrush, Missouri goldenrod, strawberry, mountain big sagebrush, snowbrush ceanothus, curlleaf mountain-mahogany, chokecherry, green rabbitbrush, squaw currant, rose

[1]Trees over 10 feet high.
[2]Trees less than 10 feet high.

VEGETATION CHARACTERISTICS

Situation **4** illustrates a saplinglpole stage of Douglas-fir in a **Douglas-fir/Idaho** fescue habitat type that is growing in association with **curlleaf** mountain-mahogany, sagebrush, and other woody plants and herbs. Shrub cover, not including the mountain-mahogany, is **14** percent in our example. Sagebrush, or bitterbrush, may be present. Localized inclusions of crown-sprouting shrubs including chokecherry, snowbrush ceanothus, and squaw currant may also occur. Production of herbaceous plants varies considerably.

VEGETATION TREND

Historically, mountain-mahogany was restricted to rock outcrops or sites where sparse fuels afforded protection from frequent surface fires (Gruell and others **1985).** Frequent fires prevented conifers and **curlleaf** mountain-mahogany from becoming established wherever fuel accumulated. In the absence of fire, mountain-mahogany, conifers, and various shrubs invaded. On sites such as that pictured, conifers are becoming highly competitive. As a consequence, mountain-mahogany are being displaced where they are in direct competition with conifers (fig. 5). Some mountain-mahogany are also dying from effects of insects (fig. 6). Without fire or cutting, mountain-mahagony and associated shrubs will continue to decline as Douglas-fir increases dominance of the site. Productivity of herbaceous vegetation will also decline. The continued absence of fire will increase the chances of hot wildfires that have the potential of killing mountain-mahogany over wide areas.

Figure 5.—Displacement of mountain-mahogany by Douglas-fir.

Figure 6.—Loss of mountain-mahogany to insects.

RESPONSE POTENTIAL

Where Douglas-fir are competitive, **curlleaf** mountain-mahogany can be regenerated by cutting or use of prescribed fire (Gruell and others **1985). Mountain-**mahogany is likely to regenerate if conifer competition is substantially reduced and mineral soil is exposed. Because **curlleaf** mountain-mahogany is a weak sprouter, its reestablishment depends upon seed dispersal from adjacent sites or **surviving** plants within the burn that were not killed. Where ungulate browsing is heavy, the area treated should include hundreds or thousands of acres in order to minimize impacts on new seedlings.

PRESCRIPTION CONSIDERATIONS

Resource Objective.—Increase productivity of herbaceous vegetation and promote regeneration of **curlleaf** mountain-mahogany by establishment of seedlings.

F i e Objectives.—Kill **50** to **75** percent of the Douglas-fir and sagebrush to reduce competition. Remove litter and expose mineral soil to favor establishment of **curlleaf** mountain-mahogany seedlings.

Kind of Fire.—A mosaic of burned and unburned areas is desirable. Normally, this kind of mosaic results from fire in rocky, broken terrain occupied by mountain-mahogany because fuels are discontinuous. In the areas where fuels are continuous, a heading fire with **3-foot** and greater flame lengths is needed to kill the Douglas-fir and sagebrush. Where fuels are sparse and discontinuous, sustained fire spread is frequently difficult to achieve. Mountain-mahogany often exists in these areas and survives fire to supply seeds for establishment of new plants.

For the same fuels and terrain, higher windspeeds than needed in situations 1 and 2 may be desirable to help spread fire through sparse fuels. Otherwise, prescription conditions are the same as for situations 1 and 2 (table 1). Ignition effort should concentrate on the patches of continuous fuels to efficiently accomplish the mosaic of burned and unburned areas. Aerial ignition can be used to advantage where large burns, especially in remote areas, are planned. Spring and fall burning are both possible. However, fall burning may be necessary to achieve success where coverage of Douglas-fir and mountain-mahogany and topographic exposures cause fuels to dry slowly in the spring.

Fuels.—Control of grazing, as in situation 1, may be necessary to assure sufficient grass fuel to help carry the fire. Where possible, slash from harvesting would increase flammability and make it easier to accomplish the objectives of removing conifers.

SITUATION 5: Douglas-fir Pole Stage in Aspen in a Douglas-fir/Rough Fescue h.t.

SITE CHARACTERISTICS

Density

Trees[1] (*No./acre*)	Basal area (*Ft²/acre*)	Seedling and sapling[2] (*No./acre*)
230 (conifer)	89	38,000
210 (aspen)	38	10,000

Cover (*percent*)

Conifers	Aspen	Shrubs
45	20	1

	Fuel loading (*lb/acre*)
Grass and litter	4,250
Live shrub	20
Downed dead woody 0-3 inches	9,470
TOTAL	13,740
Downed dead woody 3+ inches	5,950

Herb and shrub composition

Rough fescue, Idaho fescue, pinegrass, Richardson needlegrass, junegrass, oatgrass, common dandelion, Missouri goldenrod, strawberry, western yarrow, lupine, violet, squaw currant, kinnikinnick

[1]Trees over 10 feet high.
[2]Trees less than 10 feet high.

VEGETATION CHARACTERISTICS

Situation 5 depicts a pole stage of Douglas-fir outcompeting aspen that apparently regenerated following an extensive fire in about 1846 (Arno and Gruell in press). Stands usually support a low density of crown-sprouting shrubs because of intense shading from conifers. Our example shows few shrubs on a site having good shrub potential.

VEGETATION TREND

In the absence of fire, aspen stands in the northern and middle Rocky Mountains have reached maturity and many have deteriorated (Gruell and Loope 1974; Gruell 1980, 1983; Krebill 1972; Schier 1975). Widespread evidence of remnant aspen beneath conifers shows that sites now dominated by conifers were once occupied by aspen. Historically, frequent fires stimulated aspen suckering and kept stands in the drier Douglas-fir community types in earlier stages of succession. As our example indicates, suckers may be present in deteriorated stands, but few will develop into trees. In stands where suckers are present, their growth is often suppressed because of browsing by livestock and wild ungulates.

Continued protection of aspen from disturbance will result in accelerated losses of clones. Wildfires can rejuvenate healthy clones, but the recovery potential of deteriorating clones will be markedly reduced in the coming decades. Fewer aspen will be alive to respond to disturbance, and the vigor of parent root systems will be reduced.

RESPONSE POTENTIAL

Aspen usually regenerate vegetatively by suckers that emerge from lateral roots after the aboveground stems are killed (Schier 1975). Sucker response varies depending upon the viability of the root system and severity of disturbance. Light burns produce marginal results because few parent stems are killed by the fire. Moderate-severity fires seem to produce the best results (Horton and Hopkins 1966). These fires kill nearly all of the parent stand, thereby stimulating sucker formation. Sucker densities 1 year after burning have ranged from 3,000 to 60,000 per acre (Brown 1985a; Bartos 1981). Cutting also stimulates sucker production and can be used alone or with fire to rejuvenate the aspen type.

Aspen can reproduce by seed (McDonough 1979), although establishment of new stands from seed has seldom been documented in the Western United States. Establishment requirements include a continuously moist seedbed of mineral soil. Mineral soil can be achieved by mechanical scarification or prescribed fire.

Most aspen stands have the potential of supporting a variety of herbs and shrubs. The use of prescribed fire enhances understory production by stimulating crown sprouting and providing mineral soil for seedling establishment.

Burned sites attract big game and livestock. Small burned areas concentrate animal use and tend to result in excessive damage to aspen sprouts and other forage plants. Areas of at least several hundred acres should be burned to minimize excessive damage. Burning a number of smaller units near each other within the same year might also disperse animal impacts. These can be planned to create a mosaic of fire-treated and unburned vegetation. Single large burns are the most cost-effective approach.

PRESCRIPTION CONSIDERATIONS

Resource Objective.—Maintain vigorous aspen clones and increase productivity of herbaceous vegetation and shrubs.

Fire Objectives.—Kill 80 percent or more of standing aspen to stimulate suckering and kill 80 percent or more of the conifers to minimize conifer competition during early succession. Expose 30 to 50 percent mineral soil to encourage establishment of shrub seedlings and herbaceous plants.

Kind of Fire.—A heading fire with 2-foot and greater flame lengths is needed to kill aspen and sustain fire spread in aspen fuels (Brown and Simmerman 1985). The only restriction required on fire intensity is to maintain control. Strip head fires will normally be necessary to obtain adequate spread of fire throughout the burn unit. Achieving sustained fire spread with sufficient intensity to meet objectives is often difficult in this situation because of light surface fuel quantities and high fuel moisture contents. Fuels adjacent to aspen stands are usually drier and more flammable. Sometimes this can be used to advantage by running fire into aspen stands with sufficient intensity to meet objectives. Aerial ignition may also be helpful in generating sufficient fire to kill aspen and small conifers.

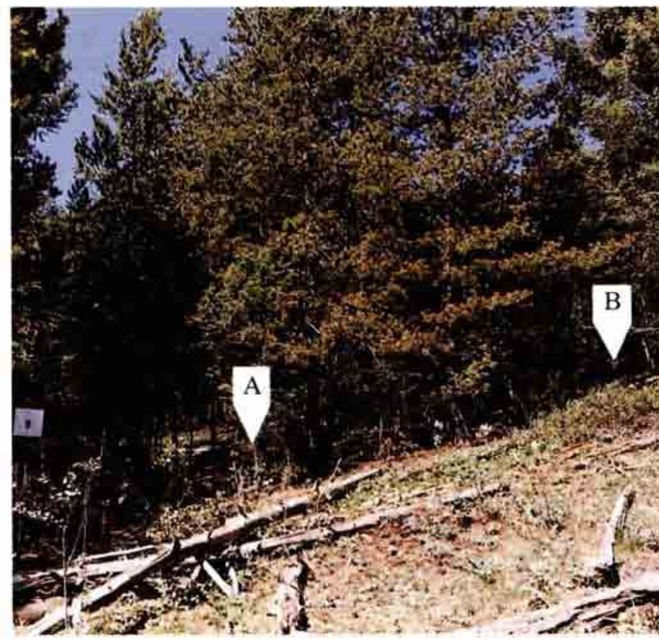
Fall is the best time to burn, especially where consumption of forest floor duff is necessary to expose mineral soil. Moisture content in the lower half of the duff should average less than 100 percent to remove adequate duff. If exposure of mineral soil is not needed or of secondary importance, spring burning may be possible. Spring burns should be scheduled when fine dead fuels are dry enough to burn but before live vegetation greens up. However, this period is short, making it difficult to achieve success.

Prescription conditions are similar to those for other situations (table 1). The best time to burn, however, is in early fall after at least 50 percent of the herbaceous vegetation has cured and before rainfall has soaked the duff (Brown and Simmerman 1985). The chance of meeting all fire objectives is best at this time.

Fuels.—In open stands of aspen where shrubs, herbaceous vegetation, and downed woody fuels are adequate to sustain spread of fire with 2-foot or larger flames, fuel treatment is unnecessary. Where fuels are sparse, cutting of both aspen and conifers can improve effectiveness of the prescribed fire. Cutting adds surface fuels, which increases fire intensity. Both aspen and conifers should be cut at the same time to create fuel and help meet the objective of reducing conifers.

Sparse fuel, consisting primarily of live vegetation, presents the greatest difficulty to burning in the aspen situation. Aspen clones that are unlikely to support fire should be recognized (Brown and Simmerman 1985). If cutting is not an option to enhance flammability, effort to burn these clones is not worthwhile. Other opportunities should be sought.

SITUATION 6: Douglas-fir Sapling/Pole Stage in a Douglas-fir/Pinegrass h.t.



SITE CHARACTERISTICS

Density

Trees[1] (No./acre)	Trees[1] Basal area (Ft²/acre)	Seedling and sapling[2] (No./acre)
440	54	120

Cover (percent)

Conifers	Aspen	Shrubs
80	3	3

	Fuel loading (lb/acre)
Grass and litter	3,820
Live shrub	4,550
TOTAL	8,370
Downed dead woody 3+inches	31,030

Herb and shrub composition

Pinegrass, basin wildrye, Richardson needlegrass, Oregon-grape, violet, white spiraea, strawberry, western yarrow, aster, snowbrush ceanothus, mountain big sagebrush, rose, squaw currant

[1]Trees (conifers) over 10 feet high.
[2]Trees (conifers) less than 10 feet high.

VEGETATION CHARACTERISTICS

Situation 6 is illustrated here by a Douglas-firlpinegrass habitat type occupied by sapling and pole-sized Douglas-fir. Other moist Douglas-fir habitat types are similar. They characteristically occur on north aspects, along riparian zones, and in moist swales. Because wildlife values are high, management of these situations is of major importance. Because of intermixing bunchgrass and pinegrass habitat types, treatment of one may facilitate treatment of the other. Douglas-firlpinegrass habitat types have potential to support crown-sprouting shrubs. However, the understory on most sites is presently comprised of herbs such as pinegrass and heartleaf arnica.

Our example (fig. 7) is depictive of sites where deteriorated shrubs have been heavily browsed by wild ungulates because of limited availability. Squaw currant, snowbrush ceanothus, Scouler willow (fig. 8), aspen, rose, snowberry, white spiraea, and sagebrush are typically scattered through this vegetation type.

(A)

(B)

Figure 7.—Closeups of heavily browsed squaw currant (A) and snowbrush ceanothus (B). These shrubs appear at lower left (A) and upper right (B) of situation 6 photo.

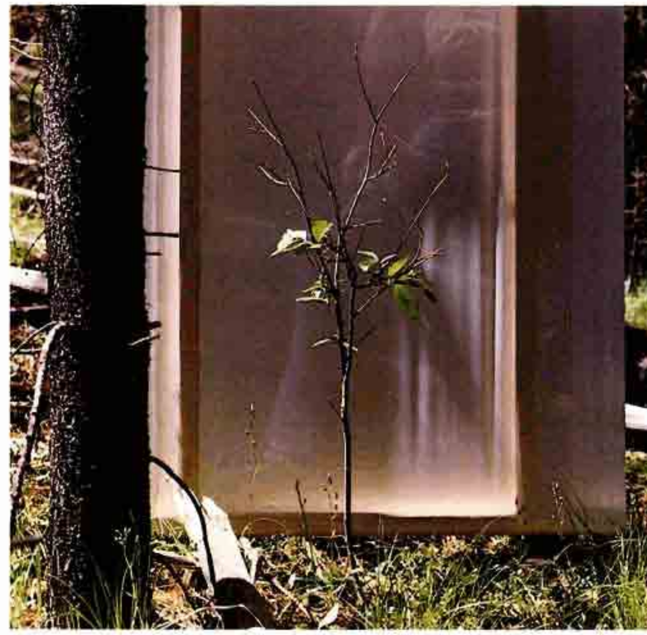


Figure 8.—Remnant Scouler willow that is losing a battle for survival.

VEGETATION TREND

Historically, these sites supported open stands of Douglas-fir and patches of lodgepole pine. In our example, logging and slash burning occurred around 1900. This stimulated regeneration of aspen, willow, ceanothus, and other shrubs and herbs. However, the absence of disturbance for 80 years or more has resulted in displacement of forage plants by conifers. Many shrubs have died and surviving shrubs are largely confined to small openings. They are heavily browsed and low in vigor.

The continued absence of disturbance on situation 6 sites will further reduce the ability of shrubs to respond to fie. Eventually, survivor species (sprouters) will disappear, and plant response will depend upon seed from both onsite and offsite sources.

RESPONSE POTENTIAL

The potential of plants to respond to disturbance depends on their reproductive characteristics. Most species are capable of reproducing from basal buds. Some also regenerate from seeds stored in the soil (onsite colonizers) or from wind-blown seed (offsite colonizers) (Stickney 1982). Onsite colonizers commonly occurring in moist Douglas-fir habitat types include snowbrush ceanothus, elderberry, buffaloberry, squaw currant, and blackberry. Offsite colonizers such as aspen and especially willow and cottonwood also have a potential to regenerate from seeds carried in from adjacent areas. In general, the more severe the fie treatment, the more favorable the site becomes for establishment of colonizers (Stickney 1982). Severe fires bare mineral soil essential for seedling establishment while activating onsite stored seed. Severe fires may kill some sprouters that arise from buds near the soil surface.

PRESCRIPTION CONSIDERATIONS

Resource Objective.—Increase coverage and productivity of shrubs. Increase diversity of plant species by recruitment of colonizer species.

Fire Objectives.—Kill shrubs above ground and expose 30 to 50 percent mineral soil. This will stimulate sprouting of existing shrubs and trees such as aspen. Create a favorable seedbed for establishment of colonizer species such as willow and cottonwood.

Kind of Fire.—A heading fire is the most practical. Wide strips should be ignited where the fuel continuity supports sustained fire spread. Otherwise narrow strips may be required to obtain the desired fire treatment. Flame lengths greater than 1 foot, which is near the lower limit for sustained fire spread, are suitable. Acceptable maximum flame lengths depend on requirements for control if the burn is in a clearcut. If the burn is beneath standing trees to be kept alive, flame lengths mostly less than 2 feet are desirable. Late summer or early fall is the best time to burn to expose 30 to 50 percent mineral soil. Moisture content of the lower half of the duff should average less than 100 percent to achieve adequate consumption of duff. A wide range in fine fuel moisture is acceptable if duff is adequately dry (table 1).

Fuels.—Some sites representing this situation will require addition of slash fuels to achieve effective spread of fire. Where this is the case, opportunities to harvest conifers should be sought. Other sites may contain adequate surface fuels to support fire without additional slash. However, opening up the canopy is desirable for shrub growth. The success of fire treatments is greatly improved by cutting.

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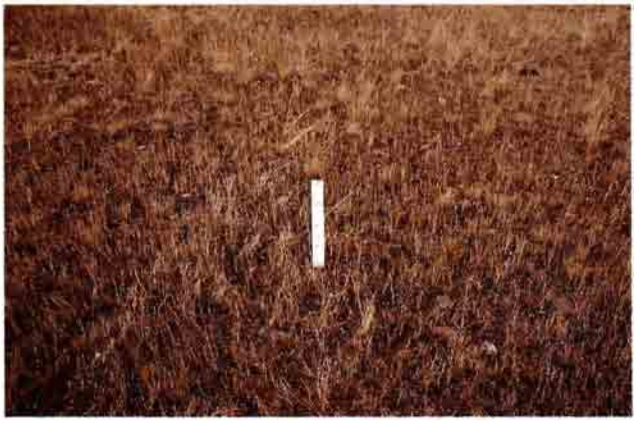
APPENDIX I: PLANTS DISCUSSED IN TEXT

Common name	Scientific name
Trees	
Douglas-fir	*Pseudotsuga menziesii*
ponderosa pine	*Pinus ponderosa*
limber pine	*Pinus flexilis*
lodgepole pine	*Pinus contorta*
Rocky Mountain juniper	*Juniperus scopulorum*
cottonwood	*Populus* spp.
aspen	*Populus tremuloides*
Shrubs and Subshrubs	
antelope bitterbrush	*Purshia tridentata*
curlleaf mountain-mahogany	*Cercocarpus ledifolius*
mountain big sagebrush	*Artemisia tridentata vaseyana*
three-tip sagebrush	*Artemisia tripartita*
silver sagebrush	*Artemisia cana*
fringed sagebrush	*Artemisia frigida*
rubber rabbitbrush	*Chrysothamnus nauseosus*
green rabbitbrush	*Chrysothamnus viscidiflorus*
squaw currant	*Ribes cereum*
white spiraea	*Spiraea betulifolia*
snowberry	*Symphoricarpos* spp.
kinnikinnick	*Arctostaphylos uva-ursi*
buffaloberry	*Shepherdia canadensis*
western serviceberry	*Amelanchier alnifolia*
elderberry .	*Sambucus racemosa*
chokecherry	*Prunus virginiana*
snowbrush ceanothus	*Ceanothus velutinus*
Scouler willow	*Salix scoulerana*
rose	*Rosa* spp.
blackberry	*Rubus* spp.
Graminoids	
Idaho fescue	*Festuca idahoensis*
rough fescue	*Festuca scabrella*
bluebunch wheatgrass	*Agropyron spicatum*
slender wheatgrass	*Agropyron trachycaulum*
thickspike wheatgrass	*Agropyron dasystachyum*
needle-and-thread	*Stipa comata*
western needlegrass	*Stipa occidentalis*
Richardson needlegrass	*Stipa richardsoni*
junegrass	*Koeleria cristata*
carex	*Carex* spp.
pinegrass	*Calamagrostis rubescens*
oatgrass	*Danthonia intermedia*
basin wildrye	*Elymus cinereus*
mountain brome	*Bromus marginatus*
Forbs	
western yarrow	*Achillea millefolium*
puccoon	*Lithospermum ruderale*
heartleaf arnica	*Arnica cordifolla*
fernleaf fleabane	*Erigeron compositus*
aster	*Aster* spp.
Missouri goldenrod	*Solidago missouriensis*
prairiesmoke	*Geum triflorum*
strawberry	*Fragaria virginiana*
sulpur eriogonum	*Eriogonum umbellatum*
common dandelion	*Taraxacum officinale*
lupine	*Lupinis sericeus*
violet	*Viola* spp.
Oregon-grape	*Berberis repens*

APPENDIX II: FLAMMABILITY OF GRASS FUELS

Burning can be difficult if fuel quantities are insufficient to support sustained fire spread. The situations in figure 9 illustrate the influence of grazing on fuel quantities and flammability. Figure 9 can serve as a guide for planning adequate fuels to carry prescribed fires.



*A. Grazed, 300 **lb/acre.** Grass alone will not support **fire** spread. Addition of sagebrush exceeding 20 percent cover can support fire spread with winds of 8 to 14 **mi/h.***

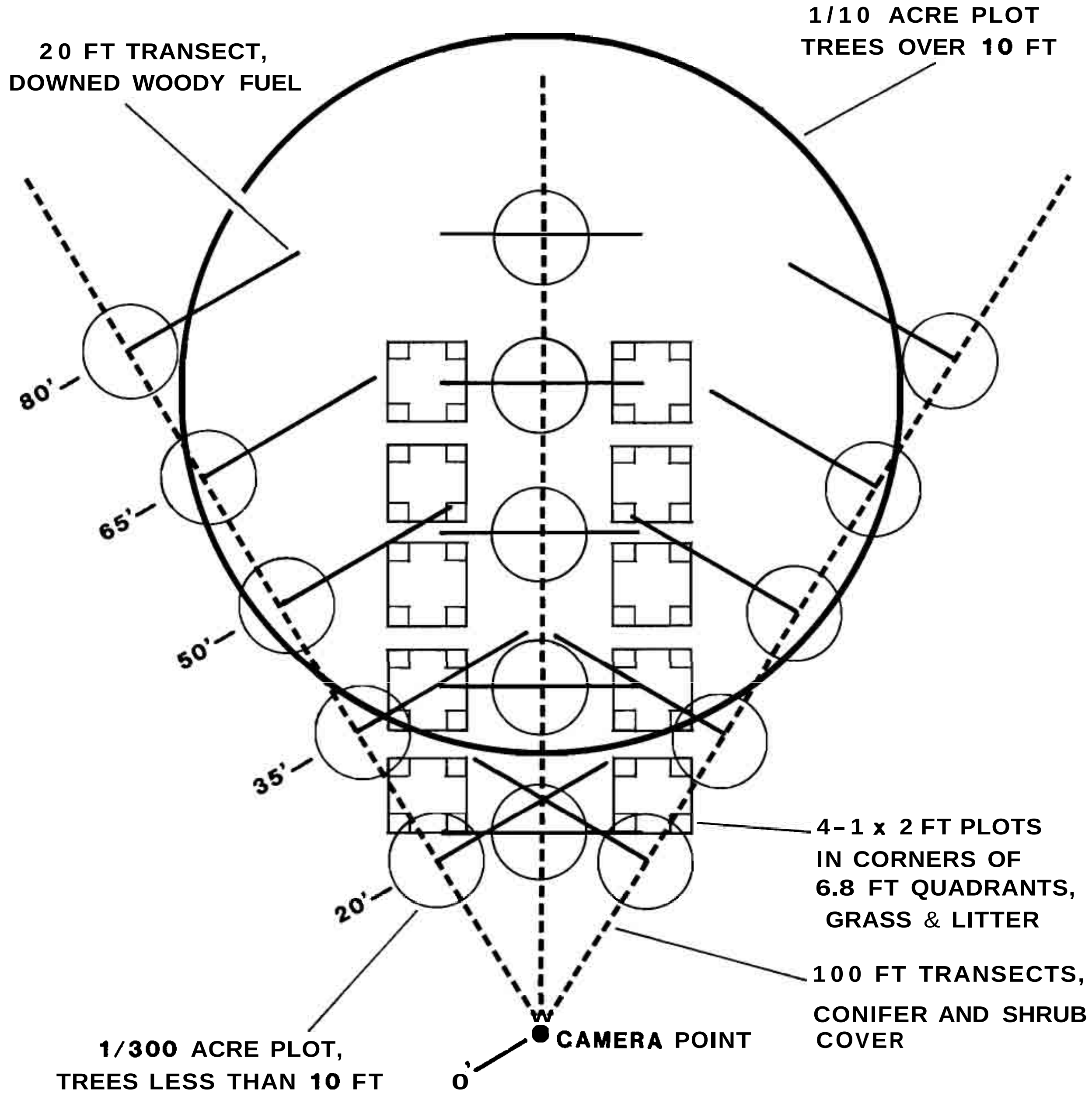
*B. Grazed, 465 **lb/acre.** Grass alone **will** not support fire spread. Addltlon of sagebrush exceeding 15 percent cover can support fire spread with winds of 8 to 14 **mi/h.***

*C. **Light** grazing, 765 **lb/acre.** Fire may spread in grass alone, but continuity of fuel is marginal. Addition of sagebrush exceeding 10 percent cover can support fire spread with winds of 8 to 14 **mi/h.***

*D. Ungrazed, 1,200 **lb/acre.** Grass alone can support fire spread. Additlon of sagebrush increases flre intensity.*

*Figure 9.—Fuel loadings of a mixture of junegrass, bluebunch wheatgrass, and rough fescue, and flammability based primarily on a hypothetical relationship by **Britton** and **Ralphs** (1979).*

APPENDIX III: LAYOUT OF SAMPLING PROCEDURE USED TO MEASURE VEGETATION AND FUELS AT PHOTO PLOTS



Gruell, George E.; Brown, James K.; Bushey, Charles L.
Prescribed fire opportunities in grasslands invaded by Douglas-fir: state-of-the-art guidelines. General Technical Report INT-198. Ogden, UT: U.S. Department of Agriculture, Intermountain Research Station; 1986. 19 p.

Provides information on use of prescribed fire to enhance productivity of bunchgrass ranges that have been invaded by Douglas-fir. Six vegetative "situations" representative of treatment opportunities most commonly encountered in Montana are discussed. Included are fire prescription considerations and identification of the resource objective, fire objective, kind of fire needed, and fuels.

KEYWORDS: Douglas-fir, bunchgrass, mountain big sagebrush, prescribed fire, livestock, big game

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The Intermountain Research Station provides scientific knowledge and technology to improve management, protection, and use of the forests and rangelands of the Intermountain West. Research is designed to meet the needs of National Forest managers, Federal and State agencies, industry, academic institutions, public and private organizations, and individuals. Results of research are made available through publications, symposia, workshops, training sessions, and personal contacts.

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