CHANGING FIRE FREQUENCIES ON IDAHO'S SNAKE RIVER PLAINS: ECOLOGICAL AND MANAGEMENT IMPLICATIONS

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ABSTRACT

Prior to the arrival of white settlers, fire-return intervals in the sagebrush (Artemisia)*-steppe probably varied between 60 and 110 years, but much of the region now burns at intervals of less than 5 years. Cheatgrass* (Bromus tectorum *L.), an introduced annual, increases fire frequencies by creating a more continuous fuelbed. More-frequent fires and reduced patchiness prevent, or greatly retard, normal vegetation replacement sequences leading to vegetation resembling less-frequently burned areas. Reducing the frequency and size of fires on these areas should be a primary management objective.*

INTRODUCTION

Much of the sagebrush (*Artemisia*)-steppe of western North America has been converted to an annual grassland dominated by introduced species. Cheatgrass (*Bromus tectorum* L.) is the dominant species on more than 100 million acres (40 million ha) of the Intermountain west (Mack 1981). This conversion has often been attributed to the seedling vigor and reproductive potential of cheatgrass (Mack 1981; Young and Evans 1985). Fire has been described as a factor in these changes, but most research and rehabilitation efforts have focused on finding and establishing species with more competitive seedlings. Cheatgrass seedlings are very competitive, but many native and introduced perennials are capable of establishing in competition with cheatgrass. Effective procedures for improving weed control during revegetation operations have also been developed (Evans and Young 1977). However, on Idaho's Snake River Plains, and possibly in much of the Great Basin, only a small percentage of the cheatgrass-dominated area has been successfully revegetated. Fiscal restraints prevent land management agencies from making significant progress in the rehabilitation of these fire-devastated areas. Despite having species capable of competing with cheatgrass and effective revegetation techniques, the rate of conversion from sagebrush-steppe to annual grassland continues to accelerate.

An overlooked aspect is the importance of changing fire regimes and the inability of perennial plants to tolerate new fire regimes. Prior to the arrival of white settlers, fire covered contiguous units of sagebrush-steppe in northern Yellowstone National Park at intervals of between 32 and 70 years (Houston 1973). Within this area, fire burned smaller areas at least every 17 to 41 years. In the more xeric big sagebrush communities [for example, Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*)], the natural fire-return interval may have been as low as 100 years (Wright and Bailey 1982). Piemeisel (1951) and Pickford (1932) were among the first to identify this fire-driven conversion of sagebrush-steppe to annual grassland as being a result of increased fire frequencies. Young and Evans (1978) described this as a cyclic phenomenon accelerating in a concentric spiral, with conversion to annual grassland as the ultimate result.

Large areas of the Snake River Plains now burn every 3 to 5 years. Not only are large areas burned more often, but the fires are more uniform, with fewer patches of unburned vegetation remaining within the burns. These changing landscape patterns and dynamics have important ecologic and management implications. Spot disturbance patches result from the disturbance of a small area within a matrix of undisturbed vegetation (Forman and Godron 1981). A remnant patch is a remnant of the previous community embedded within a matrix of disturbed vegetation. In more pristine areas of the Snake River Plains, fire tends to create spot disturbance patches. As the fire-cheatgrass cycle accelerates, fire creates a few, small remnant patches. Eventually, the fires are very large and uniform with no remnant patches.

A heterogeneous landscape matrix implies a large variety of species in the matrix with a strong influence of matrix species on the patches. A large, species-poor matrix would have a strong isolation effect on patches within that matrix. Patch area and isolation are the major variables controlling species diversity in a patch. Forman and Godron (1981) hypothesized that species diversity in a landscape patch is a function of the following patch variables in order of importance: habitat diversity ± disturbance + age + matrix heterogeneity – isolation – boundary discreteness. Where + indicates a positive relationship to diversity; – is negatively related; ± is usually negatively (but sometimes positively) related. Changing from a species-rich, pristine matrix to a species-poor matrix dominated by exotic, annual species must have important implications on the successional trajectory of the region. This appears to have occurred on much of the Snake River Plains.

This discussion focuses on how a fire regime could change so dramatically and identifying predictable

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Table 1—Fire history, species, fuel characteristics, and elevation of selected sites in the Snake River Plains

Site	Fire frequency	Fine-fuel frequency	Fine-fuel quantity	Elevation	Dominant species	Age when sampled
	Fires/year	*Percent*	*Lb/acre*	*Feet*		*Years*
Paul	0.00	40	875	4,410	*Artemisia tridentata* ssp. *tridentata, Stipa thurberiana, Poa sandbergii, Agropyron spicatum*	>100
Castleford	.00	37	910	4,500	*Artemisia tridentata* ssp. *wyomingensis, Stipa thurberiana, Agropyron smithii, Agropyron cristatum*	55
Carey kipuka	.00	35	1,200	5,300	*Artemisia tridentata* ssp. *tridentata, Stipa thurberiana, Elymus cinereus, Agropyron spicatum, Purshia tridentata*	>100
Paul	.03	43	905	4,410	*Chrysothamnus nauseosus, Artemisia tridentata* ssp. *wyomingensis, Bromus tectorum, Poa sandbergii, Stipa thurberiana*	5
Castleford	.03	28	810	4,500	*Bromus tectorum, Stipa thurberiana, Agropyron smithii, Agropyron cristatum, Chrysothamnus nauseosus, Salsola iberica*	4
Shoshone	.03	37	855	3,970	*Chrysothamnus nauseosus, Artemisia tridentata* ssp. *wyomingensis, Bromus tectorum, Poa sandbergii, Stipa thurberiana*	3
Gooding	.06	50	705	3,570	*Bromus tectorum, Chrysothamnus nauseosus, Poa sandbergii, Vulpia octoflora*	6
Wilson	.13	33	650	3,985	*Bromus tectorum, Chrysothamnus nauseosus, Artemisia tridentata* ssp. *wyomingensis, Poa sandbergii*	5
Twin Falls	.23	65	710	3,760	*Bromus tectorum, Chrysothamnus viscidiflorus, Sisymbrium altissimum, Salsola iberica*	1
King Hill	.42	81	515	3,220	*Bromus tectorum, Erodium cicutarium, Salsola iberica, Sisymbrium altissimum*	1
King Hill	.44	92	400	3,220	*Bromus tectorum, Erodium cicutarium, Salsola iberica, Sisymbrium altissimum, Poa sandbergii*	2
Twin Falls	.61	88	610	3,746	*Bromus tectorum, Erodium cicutarium, Salsola iberica, Sisymbrium altissimum*	1

patterns of vegetative change. Of primary importance is the extent to which changing wildfire dynamics has altered both the fire-return interval and landscape patterns of the Idaho Snake River Plains. I will present preliminary data designed to:

1. Describe the relative importance of quantity and continuity of fine fuels in changing the fire regime of Idaho's Snake River Plains.
2. Discuss the changes in landscape diversity and how that may affect secondary succession.
3. Describe predictable patterns of vegetative change associated with increasing fire frequencies.
4. Suggest management strategies.

Within the Snake River Plains of Idaho, I used the following criteria to select 12 sites with different fire histories: (1) known fire history; (2) no artificial revegetation; and (3) domestic livestock have not affected the vegetation. These restrictions were necessary to eliminate the influence of chronic overgrazing practices and artificial revegetation. Chronic overgrazing reduces bunchgrass density and diversity while increasing shrub density. The effects of fire were studied on sites with no livestock grazing or a history of light grazing.

The Bureau of Land Management office in Shoshone, ID, has fire records covering the last 31 years. Fire dates, climatic records, and some vegetation data are available for most of the sites. Several of these areas are isolated from human and livestock activity by extremely rough lava flows. As a result, these areas contain pristine vegetation and provide an excellent reference base against which we can compare areas burned at various frequencies. Many of these sites have different vegetative potentials, which may contain different species and subspecies of sagebrush (subgenus *Tridentatae* of *Artemisia*) or rabbitbrush (*Chrysothamnus*) (table 1). The mechanisms of change are addressed by avoiding discussions of subspecies and even species differences. I will emphasize changes based on differences on plant regenerative strategies, since the most predictable effects occur at that level and the implications of that approach can be transferred to other situations.

IMPORTANCE OF FINE-FUEL CONTINUITY

The herbaceous vegetation in a pristine sagebrush-steppe is dominated by perennial bunchgrasses. Bunchgrasses in arid and semiarid ecosystems are typically widely spaced, resulting in a discontinuous fuelbed that does not easily carry fire. Fires in these communities tend to burn small areas and require hotter, drier conditions to burn. Thus, within the Snake River Plains, areas dominated by perennial bunchgrasses should have lower ignition probabilities and fires should be smaller than fires in cheatgrass-dominated areas. Overgrazing may create areas dominated by dense stands of big sagebrush that are susceptible to crown fires. However, most fires in the Snake River Plains are carried by fine fuels.

Fine-fuel frequency was used as an estimate of fine-fuel continuity and was measured by determining the percentage of 0.10-m^2 quadrats containing fine fuel.

As cheatgrass became a more important component of the community, the frequency of fine fuels increased (fig. 1). This relationship between a grass species (cheatgrass) and fine-fuel frequency did not occur for the wheatgrass (*Agropyron*), needlegrass (*Stipa*), or wildrye (*Elymus*) species present on the study sites.

There is also a positive correlation between the relative abundance of cheatgrass and fire frequency. Fire frequency (fires/yr) and the relative frequency of cheatgrass were significantly correlated (r^2 = 0.65) (fig. 2). Increased

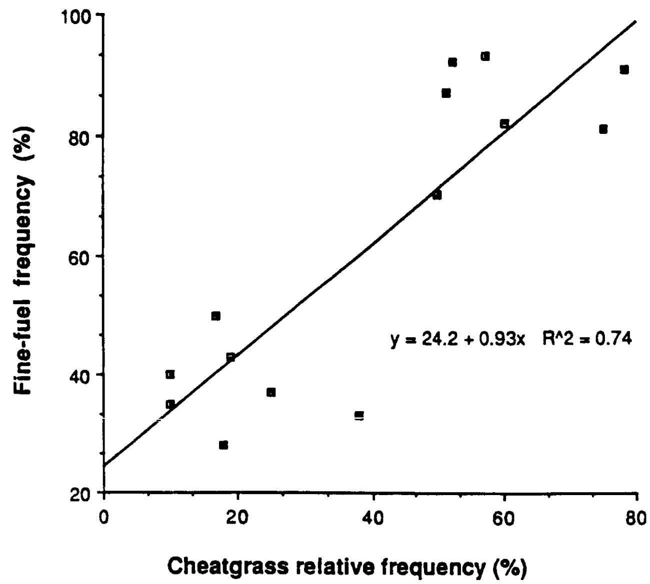

Figure 1—Relationship between relative frequency of cheatgrass in the community and fine-fuel frequency.

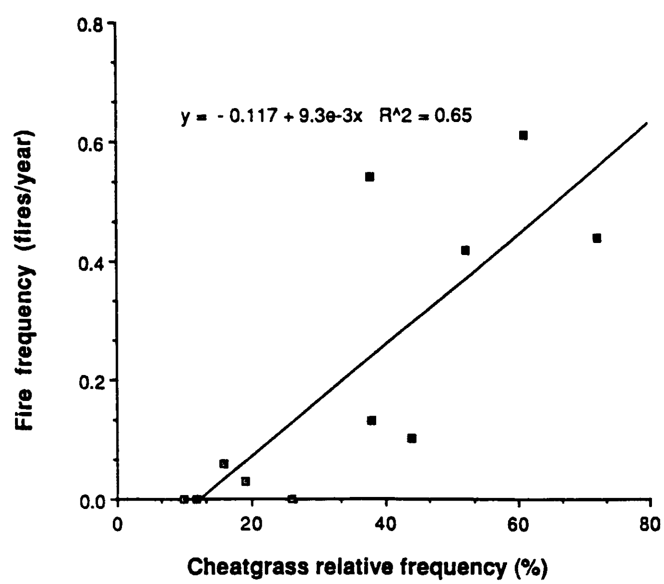

Figure 2—Relationship between relative frequency of cheatgrass in the community and fire frequency.

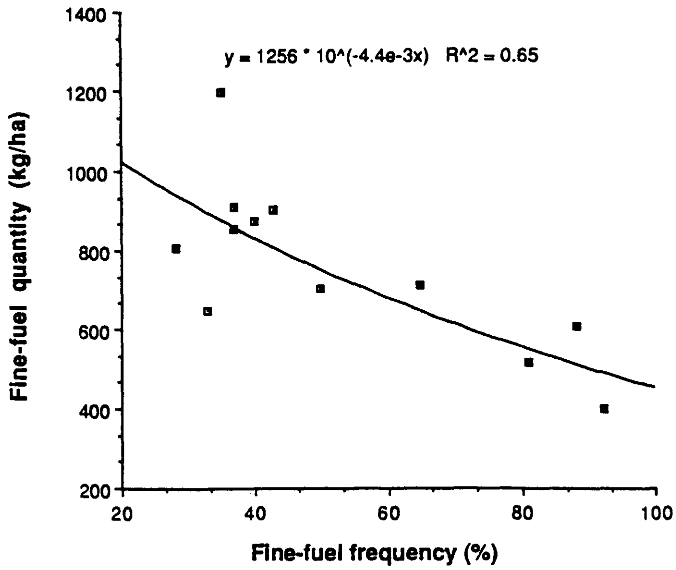

Figure 3—Relationship between fine-fuel frequency and the amount of fine fuel.

fire frequencies are associated with the introduction of cheatgrass. Cheatgrass changes the fire regime of the sagebrush-steppe by creating a more continuous fuel that carries wildfires to more widely spaced shrubs.

Fire management records at the Shoshone District office of the Bureau of Land Management indicate that at least 80 percent of the fires in that district were in cheatgrass-dominated areas and 90 percent of burned acreage occurred in cheatgrass-dominated areas. These figures do not include areas that contained shrubs but also had an abundance of cheatgrass. As a result, these figures probably underestimate the importance of cheatgrass to fire occurrence.

The relationship between cheatgrass abundance and fire frequency is not surprising, but remarkably, the amount of fine fuel does not necessarily increase as cheatgrass begins to dominate. There is a weak, negative correlation ($r^2 = 0.65$) between fine-fuel frequency and fine-fuel quantity indicating that fine-fuel quantity decreases with increasing fine-fuel frequency (fig. 3).

Cheatgrass was present on all sites in this study, but existed as a relatively minor component of more pristine areas. With disturbance (fire or chronic overgrazing), cheatgrass begins to dominate. The more pristine areas contained large bunchgrasses, wheatgrass, needlegrass, or ryegrass, which dramatically increased the amount of fine fuel without increasing fine fuel continuity. The amount of fine fuel decreased as cheatgrass became a more important component of the community. Management strategies focusing on reducing the continuity of fine fuel may reduce fire frequency and fire size without reducing forage production.

SPECIES DIVERSITY-AREA RELATIONSHIPS

Another consideration involves the influence of changes in the fire regime on species richness, landscape patchiness, and secondary succession. Species area curves indicated sites with greater fire frequencies had fewer species (fig. 4). Virtually all of the species on the most frequently burned sites were introduced annuals. Species richness was higher on areas with less-frequent fire (fig. 4). At the landscape spatial scale, landscape richness and diversity are greatest when a mosaic of unburned areas is mixed with areas in various stages of postfire succession.

The sagebrush-steppe of Idaho's Snake River Plains probably evolved with fire-return intervals of 35 to 100 years. With the introduction of cheatgrass and domestic livestock, the fire-return interval has decreased to between 2 and 4 years on many sites. This has converted millions of acres from sagebrush-steppe to annual grasslands dominated by introduced species. As these fires became larger, more uniform, and more frequent, species richness dramatically decreased at several spatial scales of resolution. Reduced fire-return intervals and reduced patchiness prevent, or greatly retard, normal vegetation replacement sequences leading to vegetation resembling less-frequently burned areas. In the more pristine areas of the Snake River Plains, fire tends to create spot disturbance patches, but in cheatgrass-dominated landscapes, fire creates a few, small remnant patches. Reducing the fire frequency on these areas should be a primary management objective. Revegetation efforts on these areas will be largely ineffective until fire sizes and fire frequencies are greatly reduced.

Noble and Slatyer (1980) stated, "In a particular system the biota evolved in the presence of the natural, recurrent disturbance regime . . . succession following (disturbance)

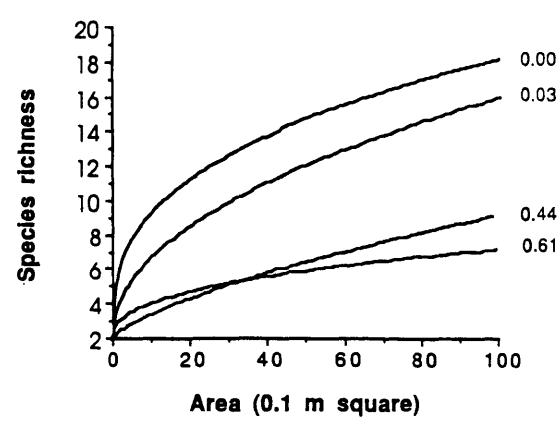

Figure 4—Species diversity-area curves for areas with four different fire frequencies. Each curve represents data from 100, 0.10 m^2, sampling areas from sites with different fire frequencies.

then will generally tend to induce replacement sequences which lead to communities resembling those in undisturbed areas." What happens when the natural disturbance regime is dramatically altered? Previous researchers examined natural disturbance regimes and have rarely evaluated the consequences of changes in the natural disturbance regime.

Christensen (1985) stated that fire has been associated with the maintenance of species diversity in virtually all shrubland types. Species richness tends to be highest immediately following fire and declines thereafter (Christensen 1985). Most postfire regeneration is vegetative or from the prefire seed bank, although seed dispersal from adjacent burns or communities may eventually replenish seed banks (Westman 1979). Current disturbance theory concerning shrublands is based on fire-tolerant communities. Most of these studies were conducted in the California chaparral, shrub-forest communities, or mesquite-acacia (*Prosopis-Acacia*) shrublands adapted to more-frequent fire. For example, Trabaud (1982) manipulated fire frequency and found that, in southern France, the development of garrigue vegetation after fire follows the "initial floristic composition" model of Egler (1954). In this model, many mature plants survive the fire and regenerate vegetatively following the fire. On the Snake River Plains, species richness apparently decreases as return intervals become shorter, but this hypothesis has not been adequately tested. Vegetation communities on the Snake River Plains, with short fire-return intervals, remain dominated by cheatgrass.

The sagebrush-steppe of the Snake River Plains is an excellent location for studies of fire frequency and related patch dynamics because it appears to be an exception to many accepted disturbance theories. Fire frequency and landscape patchiness are greatly altered in this area by the introduction of cheatgrass and related changes in the fire regime. Resistance to fire is low in this community and reduced fire-return intervals prevent normal replacement sequences considered essential to secondary succession. Reduced patchiness may also reduce the contribution of seed from fire-sensitive species.

REGENERATIVE STRATEGIES AND RESPONSE TO FIRE

Clementsian successional theory (Clements 1936) holds that following a disturbance, such as fire, several assemblages of species progressively occupy a site, each giving way to its successor until a community develops that is able to reproduce itself indefinitely. This assumes that each suite of species modifies the conditions of the site so that it becomes less suitable for its own persistence and more suitable for its successor. Egler (1954) stated that these classical successional patterns or "relay floristics" may be much less widespread than commonly assumed and may be associated with the delayed entry of species into communities. Egler (1954) concluded that in many situations, the "initial floristic composition" following disturbance determines species composition, with certain species successively becoming dominant as a result of their regenerative strategies. Egler believed that site occupancy by a particular species or suite of species restricted the subsequent entry of other species. This view contrasts with the classical view that each suite of species acts altruistically to facilitate the entry of its successor.

Horn (1976) suggested that in addition to relay floristics, a competitive hierarchy between species tended to produce a directional succession in which certain species achieved final dominance. He proposed that in situations where there was chronic disturbance there may be successional patterns in which almost any community composition was a possible result of a particular initial composition. Connell and Slatyer (1977) suggested that most successional sequences involve one of three main types of pathways. The first, facilitation, is the classical relay floristics pathway in which the presence of early occupants facilitates the entry of successive suites of species. The second, or "tolerance" pathway, describes a situation where later species are successful whether or not earlier species have preceded them. Species following the tolerance pathway can become established and grow to maturity in the presence of other species. The last, or "inhibition" pathway, describes the situation in which later species cannot grow to maturity in the presence of earlier species. Unless these species are initially present on the site, their entry may be inhibited by the earlier occupants. Both the tolerance and inhibition pathways demonstrate the importance of initial floristic composition.

More recent successional theories (Horn 1976; Connell and Slatyer 1977) stress the importance of individual rather than community properties. Noble and Slatyer (1977, 1978, 1980) developed a scheme for describing successional sequences, based on specific life-history characteristics (regenerative strategies) of the key component species. Information about regenerative strategies can be used to describe the pattern of interaction between these species following a disturbance. This scheme is based on individual properties but, because it examines those properties in a community context, permits interactions leading to a variety of different successional outcomes. These concepts suggest that an approach to successional studies based on patterns of response of individual species leading to community development may be the most useful for understanding why certain successional patterns occur following a disturbance. The application of this approach to vegetative communities of the Snake River Plains might improve our ability to predict, and understand, successional relationships with changing fire regimes.

The response of sagebrush-steppe species to changing fire frequency is relatively predictable when the species are grouped by regenerative strategies. The diversity of regenerative strategies in the community is reduced as fire becomes more frequent (fig. 5). The proportion of annuals in the community increases dramatically at higher fire frequencies, while all other life forms decrease. Sprouting shrubs increase initially and then decrease. At fire frequencies between 0.23 and 0.43, even sprouting shrubs (rabbitbrush) are lost from the community. Cryptogam ground cover also decreases dramatically as fire becomes more frequent (fig. 6).

Sagebrush can reestablish from seed following fire. However, the seeds are shortlived and if a second fire occurs before the new plants produce seed (~4-6 years) the species may undergo local extinction. This would be less of a problem if the fires occurred on relatively small areas, because seed from adjacent unburned areas would be naturally transported back into the burned areas. As

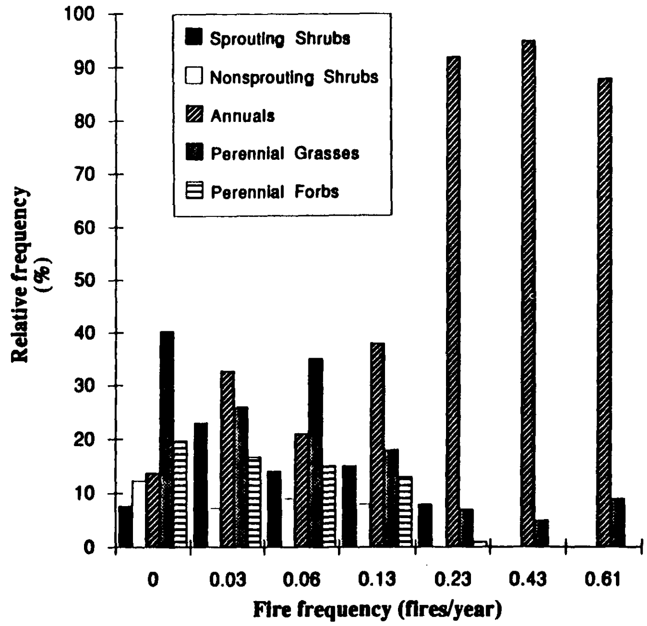

Figure 5—Relative frequency of five different life-history groups on areas with different fire frequencies. This illustrates how fire frequency affects the diversity of plant lifeforms.

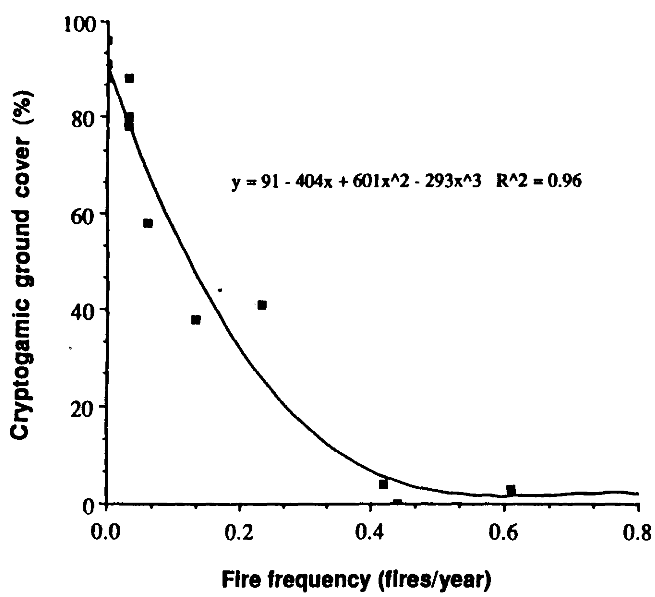

Figure 6—Relationship between fire frequency and cryptogamic ground cover.

fires become larger, the opportunity for seed immigration into these areas is dramatically decreased. Sites burned twice within the last 10 years were primarily dominated by resprouting species. Resprouting shrubs were lost from the community as fire-return intervals continued to shorten.

These data are from relatively recent fires. Older, low-frequency sites were difficult to locate since fire records are only available for the last 30 years. Each fire occurs at shorter intervals than previous fires, making it difficult to find low-frequency fires more than 5 years old. Fire-return intervals derived over the last 10-20 years may be better indicators of plant composition than are fire-return intervals derived over longer time periods.

SUMMARY AND IMPLICATIONS

Cheatgrass ranges characteristically burn too frequently. This has usually been viewed as a symptom of cheatgrass dominance rather than as a causal factor. The objective of most management and research efforts has been to find species that can successfully establish in competition with cheatgrass. This has focused attention on symptoms of the problem rather than on causal mechanisms. Conversion of the sagebrush-steppe is largely the result of alterations in fuel continuity that have resulted in more frequent and larger fires. Reducing fire frequency and fire size should reduce degradation and enhance the success of both artificial revegetation and natural recovery. Fine-fuel continuity has more effect on changing the fire regime on the Snake River Plains than the amount of fine fuel. This indicates that we can manage for increased herbaceous production without necessarily increasing fire frequency.

Predictable vegetative changes occur as fire frequency increases. Nonsprouting shrubs are quickly lost from the community as fire frequencies increase. Nonsprouting shrubs are more tolerant of burning, but cannot tolerate the short fire-return intervals now common on the Snake River Plains. As fire frequencies continue to increase, all perennial plants are lost. Plant species diversity decreases at the local (within patch) level and at the landscape level. The result of this accelerating frequency of fire is large areas of exotic, annual species and a fire regime that excludes perennial plants. Less patchiness reduces the exchange of propagules between patches of different ages, thus increasing the time required for vegetative recovery.

Management strategies that reduce the size and frequency of fire should have the greatest potential for long-term success. The greenstrip program of the Bureau of Land Management seeks to establish strips of less-flammable or less-continuous vegetation. The cost per acre may be high for this program, but establishing greenstrips should reduce the frequency of fire on much larger areas. This will allow natural succession toward recovery. This program might initially focus on protecting existing shrublands, since it is easier to prevent degradation than to restore degraded communities.

After reducing the frequency of fire, artificial revegetation techniques should be used in selected areas and a program developed to stimulate natural recovery by developing and applying concepts and methodologies of "restoration ecology." This approach would seek to enhance natural recovery by creating conditions conducive to more aggressive colonization by desired species. Significant advances are necessary before these concepts can be practically used to enhance natural recovery.

An approach seeking to leverage artificial revegetation efforts by using those areas to stimulate and enhance natural recovery of surrounding areas might be the most reasonable objective. Improving our ability to direct or stimulate recovery processes through enlightened artificial revegetation might be the only practical means of rehabilitating these areas. We must improve our understanding of inter- and intraspecific interactions, facilitation, and plant-soil interactions. We must understand how grazing management practices affect recovery processes. This will take decades, but it may be the only method of producing positive results on such a large scale, since it is unlikely we can artificially revegetate the entire area.

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