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Chapter 13:

Effects of Fuel and Vegetation Management Activities on Nonnative Invasive Plants

Introduction

Twentieth century land use and management practices have increased the vertical and horizontal continuity of fuels over expansive landscapes. Thus the likelihood of large, severe wildfires has increased, especially in forest types that previously experienced more frequent, less severe fire (Allen and others 2002). Disturbances such as fire may promote nonnative plant invasions by increasing available light and nutrients, as well as by decreasing competition from native plants for these resources (Fox 1979; Melgoza and others 1990). Once established, nonnative species may further alter fuel bed characteristics and increase the likelihood of future wildfires (Whisenant 1990a). Land managers increasingly rely on prefire fuel manipulations to reduce wildfire potential, and these efforts have expanded significantly under the current National Fire Plan (USDI and USFS 2001).

However, fuel treatments themselves are disturbances that may promote invasion by nonnative plant species. Depending on the intensity, severity, size, and seasonality of a fuel treatment, increased availability of light, water, and nutrients may result (Covington and

others 1997; Gundale and others 2005; Kaye and Hart 1998); these conditions can favor spread of nonnative species (Brooks 2003; Hobbs and Huenneke 1992; Stohlgren and others 1999b). Response of nonnative species to fuel treatments may also vary by treatment type, whether accomplished by means of prescribed fire, heavy equipment, hand tools, or chemicals. For example, unseen nonnative seeds may be carried by humans and mechanical equipment used in some types of fuel reduction treatments. This can increase propagule pressure of nonnative species in an area, which is an important factor in predicting success of nonnative plant invasions (D'Antonio and others 2001b; Lockwood and others 2005). Use of mechanical equipment may also result in soil disturbances that favor nonnative plant establishment (Hobbs and Huenneke 1992; Kotanen 1997). Based on the potential effects of fuel treatments on ecosystem structure and function, it is possible for nonnative species to thrive in areas treated for fuels reduction (Sieg and others 2003).

Potential treatment outcomes are myriad, from interactions among the wide variety of possible fuel treatment characteristics discussed above, and site factors such as topography, soils, climate, and proximity

to existing nonnative seed sources. As with most topics related to fire ecology, confusing and conflicting literature that addresses fuel treatment effects on nonnative species has begun to accumulate. A fire regime construct often provides the most useful organization for such literature (Kilgore and Heinselman 1990). For example, ecosystems where surface fire has become less frequent due to changes in land use practices are the most common locations for fuel treatments that target hazardous accumulations of native fuels. But these ecosystems may also be the most resilient to post-treatment invasion by nonnative species due to adaptations of the native species that evolved under a regime of frequent disturbance in the past. Contrastingly, in ecosystems where fire has become more frequent due to the establishment of a positive feedback cycle between fire and nonnative grasses, fuel treatments often focus on the nonnative species themselves, and subsequent treatments may be necessary to prevent their reestablishment (chapters 3 and 4).

Here we review the extant research that addresses effects of fuel modification on nonnative invasive plant species. The discussion is organized by broad ecosystem types that are based on historic fire regimes: (1) those characterized by frequent, low-severity fires; (2) those characterized by mixed fire regimes; and (3) those characterized by infrequent, high severity fire regimes. The third group is subdivided into ecosystems where fires have become more frequent due to a type conversion to more flammable nonnative species and ecosystems where the fire regime has remained essentially unchanged. The discussion is limited to studies conducted in the United States and focuses mainly on nonfire vegetation management activities to avoid overlap with the other chapters of this volume, though some of the reviewed studies address treatment combinations that include prescribed fire. A discussion of the literature on combining fire with other fuel treatments is also provided in chapter 2 (see “Question 3. Does Additional Disturbance Favor Invasions?” page 22).

High-Frequency, Low-Severity Historic Fire Regime

Ecosystems where frequent fires historically limited fuel accumulation and favored fire resistant plant species have been most affected by the fire exclusion practices of the 20th Century (Allen and others 2002). Fires in these ecosystems have become less frequent and tend to be more severe when they do occur. Management activities in these ecosystems are thus most likely to include fire hazard reduction and/or ecological restoration as a primary objective. This ecosystem group includes vegetation dominated by long-needled conifers in the West and Southeast, as well as oak

savannas in the Midwest. While a few publications from eastern forests with a high-frequency and low-severity historic fire regime discuss the effects of silvicultural treatments on understory vegetation, none mention nonnative species (Dolan and Parker 2004; Gilliam and others 1995; Ruben and others 1999; Stransky and others 1986). This lack of mention does not necessarily imply that nonnative species were absent from treated areas, only that these studies did not include an assessment of nonnative species as a research objective. Investigators who are currently monitoring the effects of fuel treatments as part of the national Fire and Fire Surrogates study in the piedmont of South Carolina (Waldrop, personal communication, 2006) and the coastal plain of Florida (Brockway, personal communication, 2006) indicate that nonnatives are generally not a concern in their study areas. Thus most of the information on the effects of fuel treatments on nonnative plant species in ecosystems with a frequent, low-severity fire regime comes from ponderosa pine (*Pinus ponderosa*) forests, particularly those in the Southwest.

Prescribed fire and mechanical thinning of trees, alone and in combination, are common treatments used to reduce the potential for spread of hazardous wildfire in ponderosa pine forests throughout the West (Agee and Skinner 2005; Arno and Fiedler 2005; Covington and others 1997; Kaufmann and others 2003). Such treatments have been shown to be effective in reducing the severity of wildfires in ponderosa pine forests (Cram and others 2006; Finney and others 2005; Martinson and Omi 2003; Martinson and others 2003; Pollet and Omi 2002). However, an undesirable consequence of such treatments may be the creation of environments that are conducive to nonnative species establishment and spread.

Investigations of nonnative species abundance following fuel treatments in ponderosa pine forests have shown mixed results. Higher nonnative species cover was found following thinning and burning treatments in ponderosa pine forests in Montana (Metlen and Fiedler 2006). In northern Arizona and New Mexico, higher cover of nonnative plants has been found following some thinning and burning treatments but not others (Abella and Covington 2004; Fulé and others 2005; Griffis and others 2001; Hunter and others 2006; Moore and others 2006; Speer and Baily in review). Results have also been mixed in the Black Hills of South Dakota (Thompson and Gartner 1971; Uresk and Severson 1998; Wienk and others 2004). However, research to date has not found significant increases in nonnative species following thinning and burning treatments in ponderosa pine forests of the Pacific Northwest or in the Front Range of Colorado. Several studies found no evidence of nonnative species following fuel treatments in ponderosa pine forests of the Pacific

Northwest (Busse and others 2000; McConnell and Smith 1965, 1970; Metlen and others 2004), while one study found post-treatment nonnative cover to be very low (Page and others 2005). Neither Fornwalt and others (2003) nor Hunter and others (2006) found any difference in nonnative species cover between treated and untreated areas of the Colorado Front Range, and both studies found overall nonnative cover to be very low.

Researchers have proposed several hypotheses for the observed variability in the response of nonnative species to fuel treatments. Nonnative species cover tends to increase following intense treatments that result in severe site disturbances, such as extensive canopy removal or soil alteration. Higher nonnative species cover has been found in areas where large portions of the overstory were removed (Fulé and others 2005; Uresk and Severson 1998; Wienk and others 2004). Burned slash piles, which produce intense soil heating on a small scale, are also prone to invasion by nonnative species (Korb and others 2004). Several studies have found that a combination of thinning and burning resulted in higher cover of nonnatives than either thinning or burning alone (Fulé and others 2005; Metlen and Fiedler 2006; Moore and others 2006; Wienk and others 2004).

Treatments involving high-severity disturbance do not always result in invasion by nonnative species (Laughlin and others 2004); variations are sometimes related to propagule availability. For example, nonnative species were abundant after fuel treatments in northern Arizona in areas that have a history of human caused disturbance and numerous nonnative seeds in the seed bank; however, they were not found following restoration treatments in more remote areas without substantial nonnative plant populations (Korb and others 2005). Correspondingly, Fornwalt and others (2003) found little difference in nonnative species richness between adjacent heavily managed and historically protected ponderosa pine landscapes in the Colorado Front Range that likely had similar pressure from nonnative seed sources. However, site factors such as topography, soil characteristics, and weather conditions may also influence invasion success (Hunter and others 2006).

Most of the nonnative species found following fuel treatments in ponderosa pine forests (such as common mullein (*Verbascum thapsus*), lambsquarters (*Chenopodium album*), and prickly lettuce (*Lactuca serriola*)) are not considered a threat to native plant communities. Wienk and others (2004) suggest that observed increases in such species after fuel treatments may not be problematic in the long term, since the species are usually transient members of recently disturbed communities. However, only one study has reported data to support this presumption

of no long-term effect from management activities on the abundance of nonnative plants in ponderosa pine forests (Fornwalt and others 2003). The lack of long-term studies is conspicuous and requires attention before conclusions can be made regarding the effects of fuel treatments on nonnative species and potential mitigation strategies.

If nonnative invasive species are present in an area, they are likely to be favored by fuel treatments (Wolfson and others 2005) and may create problems for long-term native species diversity and ecosystem function. Seeding treatments may provide a deterrent to nonnative establishment (Korb and others 2004), although contaminated seed mixes can render such treatments counterproductive (Hunter and others 2006; Springer and others 2001). Some authors question the benefits of seeding entirely (Keeley and others 2006a). Careful monitoring and control actions should take place following fuel treatments, particularly if known nonnative invasive populations are in the vicinity of treatment areas.

Mixed-Severity Historic Fire Regime

Mid-elevation mixed conifer forests in the western states exhibit historical evidence of surface fires as well as less frequent crown fires (Agee 1993). The mesic environmental conditions in these ecosystems are such that fuels are less frequently available for combustion than in the fire regime discussed above (Martin 1982). Canopies tend to be denser and ladder fuels more abundant, facilitating crown fire ignition when surface combustion becomes possible, such as following a prolonged drought. Fuel treatment efficacy is less well established in these ecosystems. Most of the evidence is from commercial harvests rather than from treatments to reduce fire hazard *per se* (for example, see Weatherspoon and Skinner 1995). Likewise, most of the research on how fuel manipulation affects invasion by nonnative species in these ecosystem types is from commercial harvests.

The studies that represent mixed fire regime ecosystems are all from mixed conifer forests in the Cascade and Sierra Nevada ranges of California, Oregon, and Washington. All but one (Dyrness 1973) found significant increases in nonnative species following timber harvest, though severity of invasion varied substantially. Much of this variation may be attributable to the intensity and age of treatments.

Several short-term (1 to 6 years following treatment) studies have compared nonnative species cover in different types of harvest that varied in intensity. Nelson and Halpern (2005) found the frequency of nonnative species to range from 0 percent in intact mixed conifer forest to 1 percent in aggregated retention harvests, to

as high as 31 percent in clearcuts. North and others (1996) compared the effects of clearcutting and green tree retention (27 live trees/ha) and found that both treatments resulted in significantly higher nonnative species cover than found in intact forest, though the clearcuts had slightly higher nonnative cover than the green tree retention harvests. Thysell and Carey (2001a) found significantly higher nonnative cover 3 years after second-growth stands were treated with variable-density thinning than in untreated second-growth stands. They hypothesize that variable-density thinning may result in less persistence of nonnatives than conventional thinning, since variable density thinning produces greater within-stand heterogeneity. However, no data were presented to support this hypothesis.

Longer term studies have found nonnative species to persist for several decades after intense fuel treatments. Thomas and others (1999) surveyed plots from three levels of thinning intensity (retention of 1,236, 865, and 494 trees/ha, respectively) and found that the more intense treatments resulted in increased levels of three nonnative species for as long as 27 years after treatment. Battles and others (2001) found nonnative species richness to be slightly higher in selection harvests than in control plots (two species versus one), but substantially higher in shelterwood cuts and clearcut plantations (seven nonnative species). The selection cuts were surveyed 1 year after the last entry, while the shelterwood and clearcut harvests were 20 years old. Several other studies from commercial harvests report increases in nonnative species richness or cover for as long as 30 years after treatment (Bailey and others 1998; Gray 2005; Isaac 1940; Thysell and Carey 2000), but these do not include treatment type or intensity as an explanatory variable.

Several chronosequence studies of harvests that were similar in type but spanned a range of ages have found a negative correlation between treatment age and nonnative abundance, but all found a nonnative presence for at least 20 years after treatment. DeFerrari and Naiman (1994) sampled clearcuts on the east side of the Olympic peninsula that ranged from 2 to 30 years old and found that the richness and cover of nonnative species began to decline after about 8 years. Similarly, Schoonmaker and McKee (1988) found nonnative abundance to peak at about 5 years in the Cascades of Washington and Oregon after sampling clearcuts up to 40 years old where the slash was subsequently broadcast burned. Halpern and Spies (1995) analyzed 27 years of repeated samples following two clearcuts that were subsequently burned in Oregon and found that nonnative cover peaked in year 2.

Few studies have investigated the effects of post-harvest slash treatments on nonnative species in ecosystems with mixed-severity fire regimes. Slash

treatments, such as burning, yarding, or crushing unmerchantable material, is necessary for timber harvest to be an effective fuel treatment in these systems (Weatherspoon and Skinner 1995), but adding surface disturbance to canopy removal might result in even greater potential for invasion by nonnative plants. Scherer and others (2000) compared nonnative plant cover among various methods of post-harvest slash treatment at several sites in eastern Washington, but their findings were inconclusive. At their lowest elevation site, nonnative cover was about four times greater where slash was burned or mechanically chopped than in stands that were not harvested or where slash was left untreated or simply piled. However, at other sites there was either no difference among treatments or nonnatives were most abundant in the stands that were not harvested or where the slash was untreated.

Additional research is needed to clarify the benefits and undesirable consequences of treatments for reducing fire hazard in ecosystems with a mixed-severity fire regime. However, a recent study suggests that areas burned by wildfire may be at greater risk of nonnative invasion than are treated areas in these types of ecosystems. Freeman and others (2007) studied the effects of several forestry practices (shelterwood cutting, commercial and precommercial thinning, underburning, broadcast burning, and pile burning) on nonnative invasive species in western forests, including mixed conifer forests of northern California, Oregon, and Washington. Treatments did not produce clear increases in nonnative species, whereas wildfire was associated with significant increases in both richness and cover of nonnative invasives.

Low-Frequency, High-Severity Historic Fire Regime

Fire ignition and spread in ecosystems where environmental conditions limit the availability of fuel for combustion require extreme weather that typically produces rare, but severe, stand-destroying events (Martin 1982). Such ecosystems include high elevation and boreal forests dominated by spruce (*Picea* spp.) and fir (*Abies* spp.) (Bessie and Johnson 1995) and low elevation ecosystems dominated by shrub and woodland (Moritz 2003). Human activities have altered the historic fire regime in many shrublands (Keeley and Fotheringham 2003), while the fire regime of high elevation and boreal forests remains essentially unchanged (Gutsell and others 2001). The threat posed by nonnative plants is likewise very different between these two types of ecosystems, and they are thus considered separately.

Altered Fire Regime

Many western shrublands, such as Intermountain sagebrush (dominated by *Artemisia* species), Hawaiian dry tropical woodland, California chaparral, and California coastal scrub, have been converted into grasslands dominated by highly flammable nonnative species (Keeley 2006b). This, in addition to increased ignition sources from encroaching human habitation, has resulted in a fire regime that has become much more frequent but somewhat less severe than in the past due to decreased woody fuel loads. Frequent fire and nonnative grasses seem to have become symbiotic in these systems, each supporting the persistence of the other.

Fuel treatments in shrublands, particularly in southern California, have traditionally focused on the woody fuels, disrupting continuous shrub canopies with fuel breaks to provide ingress and egress for firefighters as well as anchor points for prescribed fire operations (Agee and others 2000). Prescribed fire is advocated by some as a fuel treatment for chaparral in southern California to create a mosaic of stand ages, since younger stands tend to be less flammable (Minnich and Chou 1997). However, others have suggested that heterogeneous fuel conditions are overwhelmed by the extreme weather conditions that accompany most wildfires, making fuel treatments in chaparral largely ineffective (Moritz 2003). Further, management ignitions may strengthen the positive feedback between fire and nonnative grasses (chapter 3; Keeley and Fotheringham 2003).

Mechanically constructed fuel breaks have also been found to promote invasion by nonnative plants in California shrubland ecosystems. Merriam and others (2006) inventoried numerous fuel breaks in various vegetation types that ranged in age from 1 to 67 years. Nonnatives were found on 65 percent of the fuel break plots and 43 percent of plots in adjacent untreated areas. Relative nonnative cover was greatest in coastal scrub (68 percent), followed by chaparral (39 percent), oak (*Quercus* spp.) woodland (25 percent), and coniferous forests (4 percent). Cheatgrass (*Bromus tectorum*) and red brome (*Bromus rubens*) were the most frequently encountered nonnative species and were most highly correlated to disturbance severity as indicated by method of fuel break construction; those created with bulldozers had significantly greater nonnative cover than those constructed by hand crews. Time since treatment was a marginally significant predictor but indicated a disturbing trend toward greater abundance of nonnatives as treatments age. Giessow and Zedler (1996) also sampled numerous fuel breaks in California coastal scrub and found them to promote invasion of nonnative species into these systems.

There is some evidence that mechanical treatments promote nonnative invasion into shrubland and woodland ecosystems in regions outside California, as well. Haskins and Gehring (2004) found percent cover of nonnative species to be nearly 8 times greater in Arizona piñon-juniper (*Pinus* spp.-*Juniperus* spp.) woodlands 5 years following thinning and slash burning than in adjacent control areas.

The most effective fuel treatments in shrubland systems that have become dominated by flammable nonnative grasses are likely to be those that focus on eradication of the nonnative species and reestablishment of less flammable native species. Cione and others (2002) found that both herbicide application and hand removal effectively reduced the cover of wild oats (*Avena fatua*) in a California coastal sage scrub habitat. Seeded native shrubs established only in areas where the nonnative annual grass was successfully removed. A subsequent accidental fire burned through areas that remained grass-dominated but did not enter areas where native shrub cover had been restored, suggesting that restoration of the scrub habitat may have also been an effective fuel treatment.

Nonnative eradication efforts have been successful in other shrubland systems, at least on small scales in the short term. Herbicide applications successfully removed cheatgrass from sagebrush systems in Wyoming (Whitson and Koch 1998) and Nevada (Evans and Young 1977), medusahead (*Taeniatherum caput-medusae*) from Utah sagebrush (Monaco and others 2005), and fountain grass (*Pennisetum setaceum*) from tropical dry forest in Hawai'i (Cabin and others 2000, 2002). Older studies also found medusahead to be effectively controlled in California with herbicides that are no longer available (Kay 1963; Kay and McKell 1963). In Hawai'i, D'Antonio and others (1998) found native shrub biomass increased where nonnative grasses were removed by hand weeding, and Cabin and others (2002) found that bulldozing was more effective than herbicides for removing fountain grass and establishing seeded native species.

Seeding with native species over expansive landscapes may not always be possible due to budget or resource limitations. Thus noninvasive nonnative species have been used as a strategy to reduce reestablishment by more invasive nonnative species, particularly after large wildfires (chapter 14). For example, tilling followed by seeding with introduced wheatgrasses (Triticaceae) reduced reestablishment of cheatgrass in Idaho (Klemp and Hull 1971) and Wyoming (Whitson and Koch 1998). Ott and others (2003) found that wheatgrass seeding after wildfire in a Utah piñon-juniper woodland reduced cheatgrass proliferation if the area was subsequently chained to bury the seeds. Aerial seeding alone was found to be

ineffective, which is commonly the case (Robichaud and others 2000).

Postfire rehabilitation seeding may also inhibit establishment of native species (Beyers 2004). The chained areas sampled by Ott and others (2003) had lower cover of some native species as well as cheatgrass. This may have been due to the effects of the chaining treatment itself or competition from the seeded species. Use of native species for seeding treatments would, therefore, seem to be imperative (Richards and others 1998), though we are unaware of any research that compares the cost-effectiveness of the three alternatives for rehabilitation seeding: native species versus noninvasive nonnative species versus no seeding treatment.

Unaltered Fire Regime

In contrast to many shrubland ecosystems, the infrequent crown fire regime of forests at high elevations and latitudes remains essentially unchanged (Gutsell and others 2001). These ecosystems tend to have low priority for fuel treatments, though silvicultural treatments may affect the distribution of nonnative invasive species and may also alter the severity of subsequent wildfires. Omi and Kalabokidis (1991) found that the effects of a wildfire were less severe in lodgepole pine (*Pinus contorta*) stands that originated from clearcuts on land managed by the U.S. Forest Service than in adjacent stands in a National Park that had received no active management; nonnative species were not investigated. Caution is warranted in applying treatments with the intent of reducing fire hazard in ecosystems with historically infrequent, severe fire. Observations from the International Crown Fire Modeling Experiment in the Northwest Territories of Canada suggest that fuel treatments can create environmental conditions, such as lower fuel moisture and higher wind speed on the forest floor, that will exacerbate fire behavior in boreal forests (Alexander and others 2001).

Remoteness and unfavorable environmental conditions have thus far limited invasion of nonnative species into treatments that have been implemented in most boreal and high-elevation areas. Deal (2001) inventoried understory vegetation in Alaskan spruce stands that had been thinned in the past 12 to 96 years but noted no nonnative species. Dandelion (*Taraxacum officinale*) occurred on 1 out of 72 plots established 6 months after thinning in a spruce-hemlock (*Tsuga* spp.) forest in coastal Oregon, but no nonnative plants were found when the plots were resampled 17 years later (Alaback and Herman 1988).

Nonnative invasive species have invaded some harvested sites in forests with long-interval, severe fire regimes. Selmants and Knight (2003) found at least one nonnative species present in 26 of 30 old (30 to

50 years) harvest treatments in Wyoming montane and subalpine forests, though nonnative cover was insignificant on all plots. DeFerrari and Naiman (1994) found up to seven species of nonnative plants on clearcuts of various ages in spruce-hemlock forest on the west side of the Olympic Peninsula. Disturbingly, no relationship was found between nonnative cover and time, with cover of four unspecified nonnative species remaining as high as 40 percent in the oldest clearcut sampled (24 years old).

Summary

Much research remains to be conducted on the subject of fuel treatment effects on nonnative species. Many ecosystems are not represented in the literature and longer-term monitoring is needed in most of the ecosystems that have been studied. Several critical issues have received little scientific attention, including (1) the challenge of balancing invasion potential in fuel treatments versus large wildfires, (2) the cost effectiveness of alternative reseeding treatments to deter invasions after wildfires, and (3) the influence of fuel treatment size and seasonality on nonnative invasion.

Nonetheless, the extant literature does suggest some trends. Broad ecosystem groups distinguished by historic fire regime exhibit different responses by nonnative plant species to disturbances created by fuel treatment activities, at least in the western United States. Potential for invasion by nonnative species appears to increase with treatment intensity in most of the ecosystems that have been studied, though persistence seems to vary by fire regime type. Undesirable impacts from fuel treatments should be weighed against the possible benefits (such as reduced wildfire hazard), which also vary by fire regime.

Continued application of fuel treatments in ecosystems with high-frequency, low-severity fire regimes is probably justified in most cases, though most of the supporting research is from ponderosa pine systems. Fuel treatments have been effective in reducing wildfire severity in some of these systems, and several studies suggest that wildfire may pose a greater threat than fuel treatments with respect to establishment and spread of nonnative species (Freeman and others 2007; Grifis and others 2001; Hunter and others 2006). Also, nonnatives appear to be more ephemeral in these systems than others, at least in the short term. Long-term studies are needed. The short- and long-term effects of fuel treatments should be carefully monitored, as should treatments to reduce nonnative species cover and richness.

The benefits of fuel treatments for fire hazard reduction are not well established in ecosystems where a mixed-severity fire regime was the historical norm.

There are theoretical reasons to suspect that fuel treatments in these systems may increase fire hazard by creating greater exposure to wind and solar radiation, as well as encouraging production of fine surface fuels by herbaceous species (Agee 1996c). Nonetheless, fuel treatments probably have a role to play in mixed-severity fire regimes to forestall a shift to more frequent crown fires. Based on studies that have been conducted primarily in Douglas-fir forests of the Pacific Northwest, nonnative species appear to decline with time since treatment in systems with mixed-severity fire regimes, though the process may take several decades.

Nonnative species that establish after disturbances in low frequency crown fire regimes may become

persistent members of the vegetation community. While opportunities for establishment of nonnative species may be currently rare in the coldest and most remote of these ecosystems, such as boreal and subalpine forests, nonnative species have already become dominant in more favorable environments, such as some shrublands in the Great Basin and southern California. Nonnative species are favored by traditional fuel treatments that focus on removal of woody vegetation from these shrubland systems, and the undesirable influence of nonnative grasses on fire hazard is evident. Thus the only effective fuel treatments in crown-fire regime ecosystems that have been altered by a grass/fire cycle may be those that focus on eradication of nonnative species themselves.

Notes

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