WILDLAND FIRE/FUELS ASSESSMENT

The US Forest Service spends considerable time and energy training fire professionals. The need for fire on the landscape is, and always has been, an important occurrence in maintaining the health of our forests; however, when listing the undesirable effects of wildfires, natural or human caused, it can appear that there are contradictions when describing the need for prescribed burns. It is important to recognize that wildfires are often unpredictable, and therefore, desired effects can be difficult to achieve. The reasons include: location is unplanned, resources to manage the fire may or may not be readily available, human life and property may be at risk, weather conditions may not be ideal, and smoke could be difficult to manage. These are only a few of the variables to consider with wildfire. Considering the complexities mentioned above, coupled with increased human populations adjacent to forested areas, we have no option but to continue the use of best practices for managing unplanned fires.

The answer to keeping fire on the landscape to the benefit of the forest is through implementation of prescribed burns and management of lightning caused fires to meet specific resource objectives. Unlike most wildfires, prescribed burning requires that fire managers use a diversity of tools when planning a burn. The tools include, but are not limited to, selecting the location of the burn, desired weather conditions, planned resources, smoke models, fire behavior models and a burn prescription. All of these tools allow us to burn on days that are most likely to reach the intended objectives and desired future conditions, while mitigating risks to human life and property.

In preparing this document we have attempted to remove or explain information that appears conflicting. However, you may still find information that seems to be conflicting. This is due in part because many different research studies, spanning many years and different focuses, were utilized in its preparation. Most resource managers and scientists agree that we need fire on the landscape to continue to move toward or maintain the desired future condition.

Over the past century, our understanding of wildland fire continues to evolve. In response to requirements of the Federal Land Assistance, Management, and Enhancement (FLAME) Act of 2009, the Wildland Fire Leadership Council (WFLC) directed the development of the Cohesive Strategy. The Cohesive Strategy is a multilateral effort by federal, state, local, and tribal governments, NGOs and other partners, working to address wildfire challenges across all lands and jurisdictions in a collaborative manner. The Cohesive Strategy has adopted three principal goals that summarize the most significant fire-related challenges and opportunities for positive change. The three goals as defined by the National Strategy Committee and adopted by the Southern Regional Strategy Committee:

- Restoring and maintaining resilient landscapes
- Creating fire-adapted communities
- Effectively responding to wildfire

EXISTING INFORMATION

This assessment contains a concise summary of some of the available information, rather than a stand-alone science synthesis or analyses. The term wildland fire, as used in this assessment, refers to any vegetation fire occurring in nature, and is specific to either planned (prescribed) and/or unplanned (wildfire) ignitions. The risk of wildfire increases as a result of natural events. Wind, ice, disease and insects can create large areas of downed timber and increased fuels (vegetation), leading to exacerbated wildfire conditions. All ecosystems can experience short and long-term wildfire hazards if these fuels remain in place. The removal of fuels before a wildfire is crucial as human populations continue to increase in forested areas, with homes and infrastructure in close proximity to wildland fuels.

BACKGROUND

Regional Perspective

No other ecosystem driver, across the U.S. and specifically the Southeastern U.S., has had a more profound and influencing role upon the ecological processes of plant and animal diversity than wildland fire. Numerous studies and evidence (Cooper 1961; Komarek 1965; Van Lear and Waldrop 1989) suggest that wildland fire has played a critical role in shaping southeastern ecosystems prior to the arrival of humans until present.

Before European settlement, oak and oak-American chestnut forests on mesic slopes were maintained by a combination of lightning and human-set fires. Fire suppression facilitated the increased dominance of shade-tolerant species such as red maple. The fire program includes response to wildfires (both human-caused and lightning) as well as the use of prescribed fire to reduce risk of damaging high intensity fires, re-establish historic fire regimes, and restore native ecosystems. Above all else in the management of fire is the priority given on firefighter and public safety.

Scientists believe that naturally occurring fire from lightning, in addition to utilitarian, anthropogenic fire use by Native Americans and early European settlers, caused frequent fire occurrence across the southeast for a time spanning more than 10,000 years (Table 1) (Fowler and Konopik 2007).

Table 1. Major Periods of Human-Caused Fire Regimes in the Southeast

Fire Regime	**Native American Pre history**	**Early European Settlers**	**Industrialization**	**Fire Suppression**	**Fire Management**
Dates	12,500 BP to 1500s AD	1500s AD to 1700s AD	1800s to 1900s	1920s to 1940s/1980s	1940s/80s to Present
Typical Burns	Low intensity brush fires	Low intensity brush fires mainly for agricultural purposes	Stand replacing fires set by loggers and farmers	Federal lands protected from fire	Prescribed fires of mixed intensity and frequency

Of all the natural disturbances that affect ecosystems in our area, fire is perhaps the one that humans have had the most influence over, both in suppressing and causing. Most of the fires in western North Carolina area are the result of human-caused ignitions. There are two seasonal peaks in wildland fire occurrences, the primary one in March and a secondary one starting in October. These months correspond with weather and fuel conditions that are conducive to easy fire ignition and spread (dry, low humidity, windy and no canopy cover of leaves). In the southern Appalachians, the peak of the lightning fire season usually occurs in May; before thunderstorms reach their greatest frequency in July and August (Alexander 1935). More than 90 percent of all lighting fires occur from April through August.

The 2009 update to the Federal Fire Policy categorizes two kinds of wildland fires, prescribed fire and wildfire. Prescribed fire is fire applied to ecosystems, at specific locations, and under specific weather conditions, to accomplish predetermined management objectives. Fire prescriptions typically control effects on ecosystems by controlling fire intensity, either by choosing the proper environmental conditions – wind, humidity, fuel moisture – or through site preparation. Fire prescriptions also address fire behavior and spread, by moving flames with the wind (heading fire), against the wind (backing fire), or at right angles to the wind (flanking fire). Because wind patterns and fuel conditions are more variable in the mountains compared to other regions of the south, considerable experience and training are required to conduct a successful prescribed fire in the southern Appalachians (Achtemeier 2008).

Wildfires, on the other hand, are unplanned. Although prescribed and wildfires can share many characteristics, wildfires are more likely to burn under severe fuel and weather conditions, creating hot fires that are difficult, and dangerous to control. Because they are more likely to burn hot, wildfires are also more likely to adversely affect southern Appalachian forests, killing desirable trees and consuming the organic portion of the soil.

Fires can also be classified by intensity and season. Hotter, more intense fires, for example, are more likely to produce early successional habitat than cooler, less intense fires. The effects of fire intensity, however, also depend upon the season. The effects of low-intensity fires during the growing season, however, can be similar, or even more severe, than high-intensity fire during the dormant season, because the stem of most woody plants is severely damaged when the cambium layer reaches 145^{o} F (Wright and Bailey 1982), and this temperature is more easily reached during the heat of the growing season. In addition, growing-season fire typically kills woody species more effectively than dormant-season fires, because most of the carbohydrates in shrubs and trees are located aboveground (Knapp et al. 2009). When these plants are top-killed, the plant contains fewer reserves for re-sprouting (Drewa et al. 2002).

Early results from ongoing research suggest that multiple growing-season burns reduce woody cover while increasing herbaceous cover (Harper, unpublished data). In general, however, the effect of growing-season fire on plant and animal communities in the southern Appalachians is poorly documented, and not well understood (see Knapp et al. 2009). Recent studies on the Forest and elsewhere in the Appalachians have investigated the historic role of fire in our ecosystems. By examining basal fire scars in tree trunks using dendrochronology (study of tree rings) and microscopic charcoal in bog and pond sediments, it has been shown that fire was widespread and occurred frequently across our landscape.

Historical Role of Fire

The following is a section from *Restoration in the Southern Appalachians: A Dialog among Scientists, Planners, and Land Managers* (Rankin and Herbert, editors, in press, 2014) submitted by Waldrop and Knoepp:

"Historical accounts suggest anthropogenic fire, often used to affect forest structure and composition, was common both before and after European colonization (DeVivo 1991, Van Lear and Waldrop 1989, Stewart 2002, Fowler and Konopik 2007). In addition, many of the traits

characteristic of plant species in the southern Appalachians can be interpreted as evolutionary responses to fire (Christensen 1977, Lorimer 1985, Landers 1991).

Fowler and Konopik (2007) outlined five periods of anthropogenic fire regimes in the southern Appalachians, based on changing cultures, population sizes, and land use priorities:

- *During the first period, approximately 12,000 BP to 1500 AD, Native Americans most likely burned valleys near settlements to clear land for agriculture, while upper slopes and ridges were selectively burned to promote wildlife habitat. Based on estimates of population size and the amount of cleared land necessary to support these populations, the spatial effects of Native American burning may have reached one quarter to one half the amount of the current farmland in the eastern states (Stanturf et al. 2002), with return intervals varying between 1 and 12 years, depending on elevation, slope, aspect, and proximity to native villages (Frost 1995, Delcourt and Delcourt 1997, Barden 1997).*
- *The second era of fire use began with the arrival of European colonists in the 16th Century. As the number of colonists increased, much of the landscape was occupied by settlers who adopted Native American practices. Recent dendrochronologies addressing this time period have documented fire return intervals in xeric, central Appalachian oak and pine forests between 5 and 20 years (Aldrich et al. 2009).*
- *The third era of fire coincided with industrialization, beginning in the latter 19th century, as railroads improved both the access to the mountains, and the movement of large amounts of commodities. Large-scale timber harvests between 1880 and 1920 resulted in heavy fuel loads from slash, and created drier, more open stands. Fires were used to both burn slash and enhance grazing. Because of the high fuel levels produced by the slash, this era produced much higher intensity fires than previous eras, although the frequency of the fires remained similar to previous eras (Harmon 1982).*
- *The fourth era of fire began in the early 20th Century. Following the high intensity fires of the third era, forest managers actively suppressed wildfire and discontinued the use of anthropogenic fire. Fire exclusion, however, caused important changes in the structure and function of southern Appalachian forests, especially increases in fire intolerant species, and concomitant decreases in fire tolerant species (Vose 2000, 2003).*
- *The fifth era of fire began in the late 20th Century. A half century of fire suppression created forests with heavy fuel loads, creating the potential for unwanted fire effects. Beginning in the 1970s, forest managers in the southern Appalachians began using prescribed fire, especially in xeric forests dominated by pines and oaks, to reduce fuel loads and improve forest health. Prescribed fires are now the most common form of anthropogenic fire in the Southern Appalachian Mountains.*

Throughout the past several hundred years, agriculture, urban growth, and wildland fire suppression have completely altered natural fire cycles, and fire exclusion has created a trend of larger fires with the potential to be more destructive (Duncan and Mitchell 2009). It is believed that the effects of fire suppression have been dramatic in terms of large scale fuel accumulations and changing structure and composition within many forest communities in North Carolina."

Fire Regime Condition Class (FRCC)

A natural fire regime is a general classification of the role fire would play across a landscape in the absence of modern human mechanical intervention, but including the influence of indigenous burning (Brown 1995). Coarse scale definitions for natural (historical) fire regimes have been developed by Hardy et al. (2001) and Schmidt et al. (2002) and interpreted for fire and fuels management by Hann and Bunnell (2001). The five natural (historical) fire regimes are classified based on average number of years between fires (fire frequency) combined with the severity (amount of replacement) of the fire on the dominant overstory vegetation. These five regimes include:

- I – 0-35 year frequency and low (surface fires most common) to mixed severity (less than 75% of the dominant overstory vegetation replaced);
- II – 0-35 year frequency and high (stand replacement) severity (greater than 75% of the dominant overstory vegetation replaced);
- III – 35-100+ year frequency and mixed severity (less than 75% of the dominant overstory vegetation replaced);
- IV – 35-100+ year frequency and high (stand replacement) severity (greater than 75% of the dominant overstory vegetation replaced);
- V – 200+ year frequency and high (stand replacement) severity.

A fire regime condition class (FRCC) is a classification of the amount of departure from the natural regime (Hann and Bunnell 2001). Coarse-scale FRCC classes have been defined and mapped by Hardy et al. (2001). They include three condition classes for each fire regime. The classification is based on a relative measure describing the degree of departure from the historical natural fire regime. This departure results in changes to one (or more) of the following ecological components: vegetation characteristics (species composition, structural stages, stand age, canopy closure, and mosaic pattern); fuel composition; fire frequency, severity, and pattern; and other associated disturbances (e.g. insect and disease mortality, grazing, and drought). All vegetation and fuel conditions fit within one of the three classes. The three classes are based on low (FRCC 1), moderate (FRCC 2), and high (FRCC 3) departure from the central tendency of the natural (historical) regime (Hann and Bunnell 2001, Hardy et al. 2001, Schmidt et al. 2002). The central tendency is a composite estimate of vegetation characteristics (species composition, structural stages, stand age, canopy closure, and mosaic pattern); fuel composition; fire frequency, severity, and pattern; and other associated natural disturbances. Low departure is considered to be within the natural (historical) range of variability, while moderate and high departures are outside the natural range of variability.

Characteristic vegetation and fuel conditions are considered to be those that occurred within the natural (historical) fire regime. Uncharacteristic conditions are considered to be those that did not occur within the natural (historical) fire regime, such as invasive species (e.g. weeds, insects, and diseases), “high graded” forest composition and structure (e.g. large trees removed in a frequent surface fire regime), or repeated annual grazing that maintains grassy fuels across relatively large areas at levels that will not carry a surface fire. Determination of amount of departure is based on comparison of a composite measure of fire regime attributes (vegetation characteristics; fuel composition; fire frequency, severity and pattern) to the central tendency of the natural (historical) fire regime. The amount of departure is then classified to determine the fire regime condition class. Table 2 gives a simplified description of the fire regime condition classes and associated potential risks.

Table 2. Fire Regime Condition Class Definitions

Fire Regime Condition Class	**Description**	**Potential Risks**
CC 1	Within the natural (historical) range of variability of vegetation characteristics; fuel composition; fire frequency, severity and pattern; and other associated disturbances	Fire behavior, effects, and other associated disturbances are similar to those that occurred prior to fire exclusion (suppression) and other types of management that do not mimic the natural fire regime and associated vegetation and fuel characteristics. Composition and structure of vegetation and fuels are similar to the natural (historical) regime. Risk of loss of key ecosystem components (e.g. native species, large trees, and soil) are low.
CC 2	Moderate departure from the natural (historical) regime of vegetation characteristics; fuel composition; fire frequency, severity and pattern; and other associated disturbances	Fire behavior, effects, and other associated disturbances are moderately departed (more or less severe).. Composition and structure of vegetation and fuel are moderately altered. Uncharacteristic conditions range from low to moderate; Risk of loss of key ecosystem components are moderate
CC 3	High departure from the natural (historical) regime of vegetation characteristics; fuel composition; fire frequency, severity and pattern; and other associated disturbances	Composition and structure of vegetation and fuel are highly altered. Uncharacteristic conditions range from moderate to high. Risk of loss of key ecosystem components are high

Current Ecosystem Vegetation Types

The following ecosystems occur in the southern Appalachians, and are therefore potentially subject to prescribed fire. For each ecosystem, Reilly et al. (2010) have assessed the fuel loads and the potential effects of prescribed fire:

These ecosystems tend to be the more xeric ones at mid-elevations, typically dominated by oaks or pines. Because the more mesic ecosystems in the southern Appalachians, such as cove forests, are still subject to high severity fire under drought conditions, prescribed burning may be useful, under carefully-controlled conditions, to minimize the likelihood of these fires in the future.

- **Spruce-Fir Forests.** Spruce-fir forests occur at the highest elevations in the southern Appalachians, generally above 5,000 feet. These forests are dominated by Fraser fir and red spruce, with thick litter and relatively few understory plants. Growing seasons are short, and the weather is characterized by abundant moisture, high humidity, and frequent cloud cover. The disturbance regime includes wind and ice storms.

  These forests are structurally similar to boreal forests, and large, high-severity fires may occur during periods of prolonged drought (White et al. 1985). More recently, acid precipitation and balsam woolly adelgid infestations have resulted in large-scale mortality of canopy trees, creating hazardous fuel conditions, and areas disturbed by ice or the adelgid may contain abundant coniferous regeneration capable of carrying intense fire (Smith and Nicholas 2000). On the other hand, fire frequency is very low, with estimated return intervals reaching into the millennia (White et al. 1985).

- **Northern Hardwood Forests.** In the southern Appalachians, northern hardwood forests occur in coves, and on upper slopes, at elevations above 4,000 feet. These stands are dominated by hardwood species characteristic of northern forests, such as beech, sugar maple and yellow birch. The understory tends to be moist, and dominated by ferns.

  Disturbance in northern hardwood forests is primarily due to wind (Lorimer and Frelich 1994). Due to high rainfall and soil moisture, fuel moisture is relatively high, and fire has probably been infrequent, with return intervals between 300 and 500 years (Lorimer 1977). Because of the infrequent fire intervals and the overall resistance of the ecosystem to burning, fire does not appear to be an important element of these forests, and northern hardwood forests do not appear suitable for prescribed fire.

- **Mixed Mesophytic/Rich Cove Forest.** Mixed mesophytic forests, also known as rich cove forests, are among the most diverse communities in the southern Appalachians. These forests are typically found on moist, east- and north-facing slopes and sheltered coves, at low and mid-elevations. The forests are dominated by yellow-poplar, sweet birch, sugar maple, and black cherry, and generally support a diverse herbaceous flora.

  Because they occur in sheltered coves that collect and retain moisture, rich coves are generally more mesic than other mid-elevation forest communities in the southern Appalachians, with higher fuel moistures. As a result, fires in these forests were historically infrequent. Disturbance in cove forests is more typically associated with canopy gaps produced by the fall of one or a few trees (Runkle 1982). Periods of prolonged drought can exacerbate overstory mortality, which may increase surface fuels and midstory density, especially in canopy gaps, increasing the possibility of catastrophic fire (Olano and Palmer 2003). As a result, prescribed fire may help reduce the likelihood of devastating fire in these ecosystems. Compared to oak and pine ecosystems, however, the role of fire in rich cove forests has been rarely studied, and remains poorly understood (Wade et al. 2000). In general, rich cove forests do not appear suitable for a program of prescribed fire.

- **Oak Forests.** Oak forests are the most extensive ecosystems in southern Appalachians, occurring across a wide range of elevations, and varying in topographic moisture. Xeric oak forests are frequently dominated by chestnut and scarlet oaks, with an abundant ericaceous shrub layer, while mesic oak forests are dominated by white oak and northern red oak. A thick layer of potentially flammable shrubs, primarily mountain laurel, blueberry and huckleberry, is often present in oak forests, especially in more xeric conditions (Waldrop et al. 2007). Shrubs can represent a large proportion of the hazardous fuels in the community, particularly when composed of mountain laurel, and frequently poses a serious problem for fuel management (Waldrop and Brose 1999).

  Most studies show only limited benefits to oak following prescribed fire (Signell et al. 2005; Wendel and Smith 1986; Hutchinson et al. 2005; Alexander et al. 2008). Although the relationship between oak regeneration and fire is complex, periodic fire appears necessary to maintain oak forests in the face of succession towards a more mesic condition, in which stands currently dominated by oaks would be replaced by stands dominated by species such as red maple (Nowacki and Abrams 2008). In addition, prescribed fire appears to increase herbaceous cover and diversity in the understory of oak forests (Hutchinson 2006, Burton et al. 2011).

  Because of the historical role of fire in creating and maintaining healthy oak forests, prescribed burning can be a valuable management tool in these ecosystems.

- **Bottomland Hardwood Forests.** Bottomland hardwood forests are found at the lowest elevations in the major river valleys. These forests are very productive, with rapid decomposition rates due to seasonal flooding and high soil moisture. Floods play an important role in the disturbance regime, and may redistribute coarse woody debris and remove litter, especially after large events.

  Floodplain forests are particularly prone to invasion by exotic species (Brown and Peet 2003), and these species have potentially altered the fuel structure in bottomland hardwood forests. For example, dense thickets of Chinese privet and multiflora rose may form large patches of continuous fuels capable of carrying fire under dry conditions, and kudzu may reach into forest canopies along forest edges, creating ladder fuels. The presence of invasive species may warrant the use of fire to reduce localized fire hazards.

  On the other hand, the role of fire in these ecosystems is poorly understood. Wade et al. (2000) caution the tree species associated with bottomland forests tend to be sensitive to fire, and the species patterns in these communities tend to reflect the hydrology of the system, not the fire regime. As a result, bottomland forests in the southern Appalachians do not appear to be fire-adapted ecosystems suitable for prescribed burning.

Structure

Beginning in the 1920's, fire was actively suppressed, changing plant communities across the region (Clark 1990, Wolf 2004). In oak and pine communities, these changes combined to produce dense forests dominated by mesophytic trees species:

- Compared to pre-suppression communities, oak-pine communities are now structurally dense, with stem densities as much as ten times higher (Nowacki and Abrams 2008). Higher tree densities have increased stand basal areas, despite declines in average tree diameters, because the stands contain many more trees in smaller size classes (Fralish et al. 1991).

- *Changes in community composition*. In the absence of fire, mesophytic tree species, such as yellow poplar, maple and cherry, tend to be competitively superior to more xeric oak and pine species. Fire suppression allowed fire-sensitive, shade-tolerant mesophytic species to replace more fire-dependent, shade-intolerant oaks and pines (Nowacki and Abrams 2008).

  Changes in community composition affect the future role of fire in the community, because increases in mesophytic tree species decrease the likelihood of fire (Abrams 1992, Nowacki and Abrams 2008). For example, the high leaf area of shade-tolerant, mesophytic species casts heavy shade and limits air movement, decreasing wind speeds, increasing relative humidity, and creating a moist, cool forest floor (Nauertz et al. 2004).

- *Changes in fuel loads*. Fire suppression also changed the fuels in oak and pine communities (Washburn and Arthur 2003). Compared to the leaves of mesophytic trees, oak leaves are typically thicker, stiffer, and more resistant to decomposition (Abrams 1990, Carreiro et al. 2000). Their rigid and irregular structure allows oak leaves to dry more effectively, and remain dry over a longer period of time, than mesophytic leaves, improving aeration, and therefore flammability, in the litter layer (Scarff and Westoby 2006). Mesophytic leaves, on the other hand, tend to lie flat and adhere to the forest floor, trapping moisture, minimizing air pockets, and enhancing decomposition (Lorimer 1985, Van Lear 2004). Oak leaves also contain high amounts of lignin, which delays decomposition, allowing oak leaves to remain in the litter for a relatively long time (Cromack and Monk 1975). The leaf litter produced by mesophytic tree species tends to contain small amounts of lignin, and the leaves decompose rapidly into a moist organic layer that is more likely to resist burning (Washburn and Arthur 2003, Nowacki and Abrams 2008).

All of these changes – increases in stand density, shifts in community composition, and alterations in fuel loads – reduce the flammability of oak and pine communities in the southern Appalachians. This process – fire suppression leading to increases in mesophytic species that, in turn, reduce the flammability of the community – has been called mesophication (Nowacki and Abrams 2008). It appears to be a common outcome in oak and pine forests wherever fire has been suppressed (Bond et al. 2005). The more mesic and fertile the ecosystem, the more rapidly it will undergo mesophication (Nowacki and Abrams 2008).

Once communities become mesophytic, however, returning fire and fire-adapted communities to the landscape can be challenging, due to the increased difficulty of burning, the loss of fire-adapted species, and the increased costs associated with the restoration (Abrams 2005). As a result, the mesophication of southern Appalachian forests, especially oak-pine forests, is likely to continue (Nowacki and Abrams 2008). In summary, fire suppression, especially in oak-pine and pine communities, has produced structural and compositional changes in southern Appalachian forests that led towards a more mesophytic condition. This so-called mesophication of oak and pine forests becomes a positive feedback loop, because mesophytic trees species produce leaf litter and woody debris that is less likely to burn than oaks and pines, further suppressing fire. In the absence of prescribed fire, we expect mesophication of oak and pine forests to continue, increasing the challenges facing land managers face as they attempt to restore oak and pine forests in the southern Appalachians.

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Soil charcoal, tree-ring scars, and fire-adapted vegetation all provide evidence for the role of fire as a natural process over the past several thousand years (Aldrich et al. 2010, Fesenmyer and Christensen 2010, Flatley et al. 2013, Zobel 1969). Beginning in the early 20th century, however, land managers in the southern Appalachians began to prevent or suppress forest fires, effectively excluding fire from the landscape for nearly 80 years (Aldrich et al. 2010, Flatley et al. 2013). Long-term exclusion of fire has led to major changes in forest structure, function, and composition, particularly among forest types dominated by yellow pines and oaks. For example, excluding fire has increased the density of fire-sensitive trees and shrubs, which, in turn, have prevented pine and oak regeneration, shaded out grasses and forbs, and reduced the diversity of vegetation across the southern Appalachians (Harrod et al. 2000, Harrod et al. 1998, Turrill et al. 1995).

Since the mid 1990’s, land managers throughout the Appalachians have sought to use natural and prescribed fires to reverse the effects of fire exclusion. Fire exclusion, however, has contributed to a buildup of wildland fuels that make wildfires more difficult to control, and that pose a threat to forest health: when these forests eventually burn, they often burn with undesirable intensity and/or severity (Reilly et al. 2012, Vose 2000, 2003). As a result, land managers restoring fire in the southern Appalachians face two, inter-related questions: first, how to effectively reduce hazardous fuels, and second, how to restore fire-dependent communities, especially pine and/or oak forest, while minimizing undesirable effects.

Hazardous Fuels.

Wildland fuels in Appalachian forests fall into two general categories -- live and dead. Live fuels consist primarily of evergreen shrubs, particularly mountain laurel, that can pose serious problems for fire control, but do not typically contribute significantly to available fuels during landscape-level burns. Dead fuels, on the other hand, are flammable vegetation at or near the forest surface, such as leaf litter, duff, and woody debris. Organic duff is the most common form of dead fuel (50-70% of the total). Other dead fuels include litter (10-20%) and logs >3" (also called 1000-hour fuels, 10-20%). These fuel classes are not consumed at the same rate by dormant-season burning (Jenkins et al. 2011, Vose et al. 1999, Waldrop et al. 2010). Dormant-seasons burns, which occur in late winter and early spring, consume relatively high amounts of litter, but most of the heavier, longer-burning fuels are not consumed.

In contrast, Jenkins et al. (2011) found late summer and fall burns consumed a much higher percentage of duff and 1000-hour fuels. These growing season burns generally coincided with the annual peak of the drought index for the region (as measured by the Keetch-Byram Drought Index; Keetch and Byram 1968). While higher levels of heavy fuel consumption were associated with successful pine regeneration, they were also strongly correlated with higher levels of mortality in the pine and oak overstory, which led to large increases in fuel loading, as dead trees fell to the ground. In addition, growing season burns and wildfires frequently increase the rate at which non-native plants invade the community (see Kuppinger 2008).

Specific objectives for restoring pine and oak communities usually center on reducing the abundance of fire-sensitive trees and shrubs, increasing pine and oak regeneration, and increasing the abundance of grasses and forbs. Several burning techniques have been used to achieve these objectives, with mixed results:

Single, and even multiple, low-intensity burns (backing/flanking fires with flame length < 3') during the dormant season have not achieved objectives for pine and oak restoration (Chiang et al. 2005, Elliott and Vose 2005a, Jenkins et al. 2011). In general, pine and/or oak regeneration did not increase following low-intensity burns, and, although all of the studies documented initial reductions in fire-sensitive trees and shrubs, these and other studies also documented prolific and repeated basal resprouting for many of these species.

High intensity burns (headfires with flame length > 8') have also been used during the dormant/early season to address pine and oak restoration objectives. A common response to high-intensity, early-season burns, which has not been widely reported, is for these fires to kill large numbers of overstory trees, creating large, stand-level gaps that subsequently become dominated by hardwood resprouts. This can happen with fires at any time of the year, although pines can regenerate after late season fires where a seed source exists (Jenkins et al. 2011). High-intensity burns have been shown to be successful in regenerating Table-Mountain pine (Waldrop and Brose 1999), and may contribute to oak regeneration in formerly pine-dominated sites (Elliott et al. 2009). In general, however, these types of fires are not effective in regenerating oak stands, and are not recommended for restoration projects, due to concerns about fire control, burn effectiveness, and the loss of seed trees (Brose et al. 2006, Elliott et al. 2009, Jenkins et al. 2011, Waldrop and Brose 1999).

In summary, we have found the combination of vegetation change and fuel accumulation, attributed to fire exclusion, coupled with the topographic complexity of the landscape and the operational constraints in applying fire, poses a challenge for land managers in the southern Appalachians.

CURRENT CONDITIONS AND TRENDS

Wildfire presents a significant and growing threat to people and landscapes throughout the Southern Appalachians and specifically the area in and around the Nantahala and Pisgah National Forests. Each year, an average of 200 unplanned ignitions burn a total of 8,732 acres on these lands. Ninety-five percent of these wildfires potentially involve the Wildland Urban Interface (WUI). Population growth has recently outpaced other parts of the nation, leading to the development of dense human communities in extensive fire adapted landscapes that require frequent burning for hazardous fuel reduction and ecosystem maintenance. The changing population and land fragmentation is testing the ability of agencies, organizations, and landowners to deal appropriately and effectively with wildfire, while also safeguarding communities, protecting firefighters and treating the landscape. Major factors influencing wildland fire management include:

- Significant wildfire activity and prescribed fire need: between 2001 and 2010 nearly half of the national ignitions and over 40 percent of the nation's largest wildfires occurred in the Southeast, which requires significant resources and tremendous firefighting capacity (National Interagency Coordination Center). Coinciding with this pull for local resources throughout the Southeast is the need to implement fuels reduction and prescribed fire at the local level.
- Large and rapidly expanding WUI. Driven by swiftly expanding population growth and urbanization. The Southern U.S. is projected to experience the largest decline in forest area by 2060, losing about 17 million acres in one population growth scenario. These large losses in the South reflect both an abundant forest resource and the region with the highest projected population growth and urbanization (Bowker et al. 2012)
- Smoke management poses a significant challenge for wildland fire managers. Smoke can impact safety, health, and quality of life.
- The area in and around the forest is comprised of land with frequent fire regime requirements; fuel growth is rapid and fire return interval is short, which requires frequent retreatment of fuels.

With the majority of land fragmented and in private ownership, wildland fire management is significantly more complicated in the Southern Appalachian and in the Southeast than it is in other areas of the country.

PRESCRIBED FIRE

Prescribed fire is a useful tool for managing our national forest land. Prescribed burning occurs under preplanned conditions, considering social concerns for smoke management, public health and safety, and welfare of property. It is a recommended treatment for a specific area with specific objectives documented in a prescribed fire burn plan. Weather conditions are carefully monitored before and during a burn. Weather is a major factor and has a great influence on whether or not a burn will achieve the desired results.

Prescribed burning in the mountains did not begin until the 1980's but this practice is gaining acceptance for some management objectives. Prescribed fire is primarily used in the Nantahala and Pisgah National Forests for the following reasons:

1) Hazardous Fuel (vegetation) Reduction: Fuels such as logs, branches, slash, grass, leaves brush, and pine needles accumulate and can create a fire hazard. By burning the area under the desirable conditions these fuels are removed, decreasing the amount of fuel that is available to burn during a wildfire. Wildfires that burn into areas where fuels have been reduced by prescribed burning cause less damage and are much easier to control.

2) Site Preparation: Certain trees cannot tolerate shady conditions created by other species. In areas being managed for pines, prescribed fire reduces certain types of vegetation that compete for light, moisture and nutrients. Prescribed fire also reduces the leaf litter on the forest floor which often prevents seed germination for natural reproduction of desirable vegetation.

3) Wildlife Habitat: Prescribed fire promotes new sprouts and herbaceous growth that serves as beneficial food for many animals. New travel routes are opened up through dense vegetation and are created with the use of prescribed fire. Fire effects on wildlife are most closely associated with changes to habitats and microhabitats in the forest, such as changes to the trees, shrubs and leaf litter. Low intensity burns generally do not kill trees. Because the trees are not killed, the general structure of the forest remains unchanged, and microhabitats within the stand are either little affected or recover quickly.

4) Fire Adapted vegetation: Few species require fire to break seed dormancy for regeneration. Table mountain pine (*Pinus pungens*) is one species found in the Southern Appalachians that does. Table Mountain pine cones are distinctly serotinous, but on southerly and easterly exposures many cones open soon after maturing. Maintenance of natural table mountain pine stands can be most often ascribed to periodic fire. A fire's generated heat, while not required, can greatly improve seed germination for many species. Some species, such as many pitcher plants including the federally listed green pitcher plant, bloom more prolifically in the year following a fire. Other species take advantage of a fire's ability to expose mineral soil or reduce competition from adjacent shrubs and trees. *Hudsonia montana* provides the best example of this fire adaptation and was federally listed due to population declines resulting from fire suppression. Many other plant species, including 64 rare plant species, take advantage of the soil and structural changes following a wildfire or prescribed burn.

One of the outcomes of using prescribed fire is that it has multiple benefits; reducing wildfire hazards by reducing fuels, improving habitat for some wildlife species, reducing competition, enhancing appearance and improving access. Fire, especially low-intensity, high-frequency fire, has been a component of the southern Appalachians for many years (Wade et al. 2000). Many of our native ecosystems are fire-adapted, especially drier forests dominated by pines or oaks, and these forests have proven to be unstable in the eighty years since fire suppression became widespread in the southern Appalachians (Nowacki and Abrams 2008).

Some of the ways in which fire restores and maintains native ecosystems include:

- Killing and consuming a portion of the above-ground vegetation with very little impact to the mineral soil.
- Rapidly recycling nutrients back into the ecosystem.

- Fire improving seed germination by removing thick layers of duff and coarse fuels.
- Selectively removing fire-intolerant species, restoring ecosystem composition and structure.
- Improving wildlife value for many game species in the southern Appalachians, including white-tailed deer, wild turkey, and ruffed grouse.

Prescribed fire can play an integral role in maintaining biodiversity and reducing hazardous fuels on the Nantahala and Pisgah NF. Currently, the Nantahala and Pisgah NFs plan for approximately 6,000 acre per year to be treated, costing on an average of $55.00 per acre to implement.

Many variables influence the forest's ability to meet the current prescribed fire goals. Factors that can constitute a barrier to the implementation of prescribed burns are air quality concerns, weather, and lack of resources (Southeastern Regional Assessment, Cohesive Strategy). The expanding wildland urban influence also influences burning opportunities. At times, budget constraints limit the availability of personnel and equipment.

Table 3. Summary of Prescribed Fire from 2007-2012. (Data from 2007 to 2012 was pulled from Forest Service ACtivity Tracking System (FACTS**)**

Ranger District	2007	2008	2009	2010	2011	2012
Nantahala	1865	1370	1412	1301	1318	1734
Cheoah	721	1005	942	1099	1465	1900
Tusquitee	1672	1400	2308	3444	3302	2396
Grandfather	550	988	1075	1025	3350	2490
Pisgah	940	1268	1024	10	1200	1019
Appalachian	1640	350	650	450	150	0
Total	7388	6381	7411	7329	10785	9539

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