Fire on the Landscape:

Planning for Communities, Fire, and Forest Health

Report of the
Arizona Forest Health Council

June 2008

Cover image: The 2003 Aspen Fire burns above the City of Tucson.
Photo courtesy Ellis Margolis, University of Arizona.

STATEWIDE STRATEGY FOR
RESTORING ARIZONA'S FORESTS

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Contents

List of Figures

Executive Summary

Throughout the western United States, including recent severe events in Arizona and southern California, wildfires are a reminder that fire is a common and widespread phenomenon on the landscape. As the human-built environment intrudes more and more into formerly uninterrupted areas of forest, the dynamics of natural systems—such as fire and insect outbreaks—have changed dramatically over the past few decades. Increased fire suppression has altered the natural role of fire in reducing fuel loads. One result of the absence of natural fire, combined with the effects of multi-year drought, has been an increase in the number and size of large, high-intensity wildfires. The threat of these fires leads to ever more fire suppression, which is increasingly costly to taxpayers, destructive of property and life, and detrimental to local economies. This cycle is troubling for the prospects for Arizona's forests.

This paper explores some key recommendations developed by the Arizona Forest Health Council in the Statewide Strategy for Restoring Arizona's Forests (State of Arizona, 2007). The Statewide Strategy is a comprehensive plan to restore forest health, protect communities from fire, and encourage appropriate forest-based economic activity. Thus, the Statewide Strategy provides the larger context for restoring forest health on a large scale in Arizona.

In this paper we explore the consequences of land use patterns for maintaining and restoring the health of Arizona's forests, including the relationship of development patterns and trends to potential increases in large and destructive fires. Among the topics discussed are:

- Natural and historic fire regimes of Arizona forests
- Fundamental principles of fire behavior, including extreme events on forested landscapes
- How fire interacts with the built environment at the landscape scale, in terms of risk, effects on forest health, and implications for land management
- Financial and human costs for dealing with severe fires in landscapes with private interests requiring protection, including suppression costs and firefighter safety
- Precedents for land use and growth management controls that could be applied to relieve conflicts between development and fire behavior
- Technical tools that can help translate landscape fire science into useful information for public policy-makers, land managers, and the public

Our primary findings are:

- *Fire is inevitable and an integral component of healthy forests in many parts of the Southwest. Natural fire behavior, frequency, and effects vary between different forest types.To a great extent, the increased frequency, intensity, and size of extreme fire events are a direct result of excluding natural fires from the landscape, combined with multi-year drought conditions in the Southwest.*
- *High-intensity fires are a natural, and probably inevitable, occurrence in upper-elevation forests. A completely fire-free landscape is neither ecologically desirable nor logistically or financially possible. The occurrence of high-severity fires in middle and upper elevation forests can be delayed but not prevented.*
- *High-intensity crown-fire events are becoming more frequent at lower and middle elevations, and are often difficult or impossible to control. Across most of Arizona, the large fires that burn the most acres are those that are too intense to control. The location and type of development have a significant impact on forest and fire management, and thus on forest health and sustainability.*
- *The location and type of development have a significant impact on forest and fire management, and thus on forest health and sustainability.*
- *Reducing conflicts between society and fire will require land-use planning that mediates where both fire and development can occur on the landscape.*
- *Communities will benefit if they can learn to live with prescribed burning and occasional smoke, thinning, and other practices, as the price of maintaining healthy forests.*

- *In the long term a sound statewide growth management and land use policy can ensure that new development responds to the imperatives of forest health, including wildland fire management.*
- *A wide range of land-use planning tools exists to negotiate a sustainable resolution for forest health and development patterns. These tools offer valuable resources for planning a healthy future for Arizona's forests and communities.*

Our main recommendations for action include:

1. *Classify undeveloped lands based on relative fire hazard, analogous to other existing recognitions of risk and public expense from natural hazards.*
2. *Require new development plans to contain an evaluation of fire probability, based on surrounding vegetation types, topography, and known weather patterns.*
3. *Review land-use ordinances and building codes and adopt or revise as necessary to minimize communities' exposure to fire danger.*
4. *Incorporate perimeter protection ("buffer zones") into the design of new developments to allow for maintaining natural fire in adjacent forests.*
5. *Revise planning requirements under Growing Smarter legislation to encourage communities and counties to deal with fire risk proactively at the landscape scale.*
6. *Create programs to educate residents of forest communities and developers about steps that they can take to reduce exposure to fire hazard and improve forest health.*

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1 Introduction: Fire and people together on the landscape

The Guiding Principles adopted by the Arizona Forest Health Advisory Council in 2003 (http://www.azgovernor.gov/fhc/documents/FinalGuidingPrinciples.pdf) recognize that restoration of natural fire regimes is an essential goal for achieving healthy forests:

> *Effective forest ecosystem restoration should reestablish fully functioning ecosystems.* A primary goal of forest restoration is to enhance ecological integrity, natural processes, and resiliency to the greatest extent possible. Fire hazard reduction must be linked to the reintroduction of fire as a keystone ecological process. An active program of prescribed and maintenance burns and natural fire use is essential for ecosystem restoration by land managers.

At the same time, the Guiding Principles acknowledge that fire is a landscape issue that is impacted strongly by land use:

> *Forest ecosystem issues and solutions exist in a context of land use.* In fire prone areas community officials must develop, adopt, and enforce comprehensive land use plans, zoning regulations, and building codes for community protection, forest restoration, ecosystem health requirements, and long-term fire management. Zoning and land use have a major impact on fire management, and can make a significant contribution to restoring forest health and protecting communities.

The reconciliation of these two principles lies at the heart of future forest health in Arizona.

In 2007 the Governor's Forest Health Advisory and Oversight Councils completed the Statewide Strategy for Restoring Arizona's Forests (State of Arizona, 2007). The document provides fifty recommendations and actions for restoring Arizona's forests over the next twenty years, and incorporates key elements of the Guiding Principles. The Strategy recognizes the imperative to reconcile forest management with the exponential population growth and land development occurring in Arizona. It provides the background, logic and recommendations needed for forest restoration and forest communities to move forward in a coordinated fashion to ensure healthy human and natural landscapes. The Statewide Strategy thus provides the context for this paper exploring landscape and land-use issues relevant to fire policy and forest health.

Among the "Key Strategies and Recommendations" articulated in the Strategy is the following:

> *"The Arizona State Legislature, county and local governments, tribal governments, and state agencies should develop land use policies and practices that support forest restoration, community protection, and fire management efforts." (Recommendation 2.2, p.9).*

The objective of this paper is to explore our understanding of fire as a landscape phenomenon, and land-use practices that affect it, in order to support fire policy and forest health as articulated in the Guiding Principles and The Statewide Strategy for Restoring Arizona's Forests.

The landscape context of development affects forest health in profound ways (Lertzman and Fall 1998; Gardner et al. 1999; Barton et al. 2001; Sisk et al. 2005). In large, contiguous, forested landscapes, fires spread naturally, consuming available fuels and eventually becoming extinguished when conditions no longer favor combustion and spread. However, once houses, roads, and other infrastructure are introduced into the landscape, a social expectation develops that these human elements will be protected from the effects of fire. When fire is controlled to protect houses and roads, the entire landscape is modified. Thus, the presence of development can have a direct and lasting effect on the dynamics and health of the forest (ESA 2000).

Many forest types in Arizona (such as ponderosa pine forests and pine-juniper and oak woodlands) support a naturally low-severity fire regime. Fires in these forests occur frequently, and suppression of fires leads directly to the accumulation of high fuel loads (Omi and Joyce 2003; Moore et al. 2004). As Arizonans know all too well, however, suppression of naturally occurring or prescribed surface fires increases the eventual likelihood of a catastrophic fire event.

Maintaining the natural fire regime can be complex in developed areas. For example, surface fires create smoke, often lasting for several days, which some homeowners may find objectionable (Viers 2005). Thus, residential development in areas where prescribed or natural surface fires should occur frequently can complicate restoration of the natural fire regime. Implementation of wildland fire use (WFU) programs, which allow public agencies to permit some natural ignitions to spread and thus re-establish, in part, their natural ecological role, may also be difficult (Gregory 2004). Thus, even in forest types where the natural fire regime is of a lower intensity (such as ponderosa pine forests and pine-juniper and oak woodlands), the location of development can significantly affect the prospects for maintaining forest health.

The natural fire regime in other Arizona forest types (such as spruce-fir, mixed-conifer, and chaparral vegetation types) tends toward high-intensity, high-severity fires. Such fires may occur only once every few decades or longer, but when they do, the natural dynamics of fire behavior tend to create relatively large areas of high-intensity fire that spread rapidly across the landscape (Schoennagel et al. 2004). Safely restoring and maintaining more natural fire regimes in these forests is of national importance, both for human safety and for maintaining ecological integrity (Noss et al. 1995; ESA 2003; Trust 2004).

However, acceptance of natural fire regimes in such forest types becomes less tenable, socially and politically, with the introduction of built infrastructure. High-intensity fires in these forest types are often difficult, if not impossible, to control. Firefighter and citizen safety is difficult to ensure under these dangerous circumstances, and such fires can be extremely expensive to suppress. Thus, when fire is excluded to protect development in forest systems where high-severity fires are the norm, forest health, human safety, and conservative use of scarce fiscal resources are all significantly compromised.

"Three factors are responsible for our current wildland fire crisis: landscape-scale fuel accumulation due to fire suppression, global climate change and suburbanization of fire-prone landscapes." (Covington 2007)

A typical result of this tension between fire and development, already evident in many areas of Arizona, is that fires are not allowed to burn as frequently as needed to maintain low fuel loads. Reduced fire frequency is accompanied by increased fuel loads, forest density, and canopy connectedness, all of which increase the likelihood of uncharacteristically severe fire events. If not considered carefully, development can compromise forest health in frequent, low-severity fire ecosystem types as well as in forest systems where high-severity fires are a natural process.

Moving toward a solution

Ongoing development into wildland forests perpetuates and potentially exacerbates fire threats to rural communities. These potential conflicts between development and forest health can be avoided or mitigated, however, if fire management and land-use planning are based upon an understanding of the underlying nature of the fire regimes of Arizona's forests (Sisk et al. 2005; Dickson et al. 2006). For example, large-scale mapping of fire hazards can highlight risks associated with locating new development in fire-prone areas. Mapping of Fire Regime Condition Classes (how much present conditions have diverged from a natural and healthy condition) can inform communities and planners about where forest conditions pose potential risks to both human and forest health (Hann and Strohm 2003). Geographic fire behavior simulations and a variety of other technical tools can illustrate the type, frequency, and severity of fires that will eventually occur on the landscape, despite suppression efforts.

Planning that includes an understanding and consideration of areas that are at greatest risk for wildland fire can minimize future risks to lives and property. Public land managers and policy makers can use a variety of tools, such as fire mapping, zoning, and inclusion of buffer zones, to help guide future development so that communities are not exposed to unnecessary fire risk. This approach can also fulfill the goal of restoring fire to its essential role in maintaining forest health.

2 Fire regimes and fire behavior in Southwestern forests

Fire is a basic ecosystem process shaping the structure, composition, and pattern of Arizona's fire-adapted forests (Weaver 1951; Ffolliott et al. 1996; Allen et al. 2002; ESA 2003). Fires are often called a "keystone" ecological process, meaning that they regulate a wide range of other ecological factors, including species composition, forest structure (size and spatial distribution of trees), population dynamics (recruitment and mortality), soil development and retention, insect and other animal populations, nutrient cycling, forest hydrology, and carbon storage (Pearson 1950; Cooper 1960; Covington and Sackett 1990; Swetnam 1993). Fires are a natural and fundamental component of the forests of the Southwest, and have played a central role in shaping them for thousands of years (Pyne et al. 1996). Nationally, fire-adapted forest ecosystems comprise more than 1.2 billion acres within the coterminous United States (Schmidt et al. 2002), mostly in non-Federal ownership.

"Fires are a natural and fundamental component of the forests of the Southwest, and have played a central role in shaping them for thousands of years (Pyne et al. 1996)."

Natural fire regimes in Arizona forests.

The natural fire regimes of Southwestern forests vary significantly among forest types (Swetnam and Baisan 1996). In lower-elevation woodlands (below 6,000 ft), pinyon (*Pinus edulis*) and junipers (*Juniperus* spp.) are the dominant trees. Herbaceous cover—such as annual and perennial grasses—is often relatively low and discontinuous, resulting in patchy, generally low-intensity surface fires. As elevation increases (6,000 – 8,500 ft), tree size, density, and herbaceous cover increase in oak woodlands and ponderosa pine (*Pinus ponderosa*) communities (Brown and Lowe 1980 (Figures 1 and 2). Ponderosa pine forests typically experience frequent low-intensity, low-severity fires, with flame lengths typically are less than 4 ft and little or only patchy mortality of large overstory trees. Under natural conditions such fires occur on average every 4-8 years within forest stands. These surface fires kill small tree seedlings and saplings, but generally do not harm (and may even benefit) mature overstory trees.

Figure 1. Oak woodland with abundant native perennial grass understory, Santa Rita Mountains. Photo: Don Falk

At higher elevations, mixed-conifer and closed-canopy forest types dominate, with multiple species of dominant trees including Douglas-fir (*Pseudotsuga menziesii*), southwestern white pine (*Pinus strobiformis*), white fir (*Abies concolor*), and others (Figure 3). These forests are often characterized by denser canopies and reduced herbaceous cover, due to reduced light penetration to the forest floor. Fire regimes in mixed conifer forests are highly variable, including both low-intensity surface fires and periodic high-intensity, stand-replacing fires (Touchan et al. 1996; Veblen et al. 2000; Margolis et al. 2007). Spruce-fir forests dominate the highest elevations (above 9,000 ft), composed of Engelmann spruce (*Picea engelmannii*), corkbark fir (*Abies lasiocarpa*), and stands of quaking aspen (*Populus tremuloides*) (Figure 4). Fires in subalpine forests are believed to be primarily of overstory trees, although lower

Figure 2. Typical open ponderosa pine forest structure, with clumps of large overstory trees and grasses and forbs in the understory. Photo courtesy Ecological Restoration Institute, Northern Arizona University.

Figure 3. Mixed-conifer forests at middle and upper elevations (> 8,500 ft) include a diverse assemblage of conifer species. Fires in high-elevation systems are often mixed and high severity. Photo courtesy Ecological Restoration Institute, Northern Arizona University.

severity fires also occur (Margolis et al. 2007). All fire regimes reflect complex interactions between vegetation, topography, fuels, and both local and regional climate (Swetnam 1990; Harrington and Sackett 1992; Allen 1996; Barton et al. 2001; Fulé et al. 2002; Swetnam and Baisan 2003; Dickson et al. 2006).

Fire as a landscape process

Historic fire sizes can be difficult to reconstruct, but most evidence indicates that before ca. 1890, fires in Southwestern forests were highly variable in size, ranging from small spot fires to extensive burns. Spreading across spatially heterogeneous fuel strata for weeks or months, fires sometimes covered areas of a million or more acres (Kaufmann et al. 2005). However, larger fires were not necessarily more destructive; for instance, smoldering ground fires or low-intensity surface fires could burn through ponderosa pine forests over long periods, spreading over large landscapes until extinguished by cooler fall weather (Pearson 1950; Cooper 1960; Fulé et al. 2003).

Figure 4. Spruce-fir forests dominate the highest elevations in Arizona's mountains. Photo: Don Falk.

Fire sizes in higher-elevation mixed conifer forests can be inferred by several convergent lines of evidence, including fire scars, tree death dates, and recruitment of post-fire species such as aspen (*Populus tremuloides*) (Margolis et al. 2007). Fire severity in these highly variable forest types probably left a mosaic of high- and low-severity patches on the order of tens to a few thousand acres (Figure 5). In both cases, the largest and most severe fires tended to burn during the driest years, often reflecting multi-year climate patterns (Baisan and Swetnam 1990; Kaib et al. 1996; Westerling et al. 2006).

Figure 5. Mixed- and high-severity fires and middle and upper elevations leave a mosaic of high- and low-severity patches on the landscape, as indicated by large post-fire stands of aspen (Populus tremuloides). Photo: Ellis Margolis, University of Arizona.

Fire behavior and fire suppression

The behavior of a fire is characterized by properties such as flame length and temperature, fireline energy, rate of spread, duration, the fuel layer that burns, and other variables (Agee 1993; Whelan 1995; Pyne et al. 1996; Johnson and Miyanishi 2001). How a fire behaves on a landscape is governed further by interactions of the "fire triangle" elements: fuels, topography, and weather. The behavior and location of fires is used to classify events as ground fires (those that burn in the litter and soil duff layers), surface fires (burning litter and a range of woody fuels on or near the forest floor), passive crown fires (where tree crowns are ignited by flames rising from the forest floor), and active crown fires (where fire propagates through tree crowns independently of ignition from below).

Ground and surface fires are characterized by relatively low temperatures, short flame lengths, and low to moderate rates of spread. Such fires cause little mortality of overstory trees, and most wildlife species can persist through these events (Figure 6). However, "ladder" fuels can provide a pathway for fire to move from the surface into the forest canopy, contributing to high severity and difficult fire suppression conditions (Figure 7), and in some cases the initiation of a canopy or crown fire. Crown fires are fast moving, high temperature events that can move through a forest at more than 30 mph and burn large areas in minutes (Figure 8). Crown fires can achieve such high intensities that they create plumes of flame hundreds of feet tall and develop enormous convection columns of smoke rising more than 10,000 feet into the atmosphere (Figure 9). The repeated rise and collapse of these enormous smoke columns creates unpredictable and chaotic winds blowing the crown fire in multiple directions (Schroeder et al. 1964). The behavior and effects of crown fires are highly dependent on both fuels and weather conditions: when fuels are abundant, temperatures are high, humidity is low and winds are strong, fires can spread rapidly over the landscape, generating huge amounts of destructive heat energy.

Crown fires can achieve such high intensities that they create plumes of flame hundreds of feet tall and develop enormous convection columns of smoke rising more than 10,000 feet into the atmosphere.

Figure 6. Ground and surface fires are characterized by relatively low temperatures, short flame lengths, and low to moderate rates of spread. Such fires cause little mortality of overstory trees, and most wildlife species can persist through these events. Photo courtesy John H. Dieterich.

Reconstruction of historic fire regimes in the Southwest indicates that large stand-replacing crown fires were rare in most woodlands and ponderosa pine forests before the 1950s (Cooper 1960; Covington and Moore 1992; Swetnam and Baisan 1996). In recent years the natural history and dynamics of forest fire have been studied in great detail, using the record provided by tree-ring dating of fire-scarred trees (Figure 10). Relatively small, patchy crown fires occurred in some mixed conifer forests and chaparral stands, and larger crown fires occurred at intervals of centuries in spruce-fir forests, but there is little evidence of the frequent high-severity fires burning over large areas of low and middle elevation forest as we experience today (Swetnam 2002).

The ability to suppress or alter the behavior of a fire is linked directly to its type and intensity. While ground and surface fires can be controlled relatively successfully, passive and active crown fires are much more difficult to contain, especially under extreme weather conditions of high temperature, low humidity,

Figure 7. Ladder fuels provide a pathway for fire to move between the surface and the forest canopy, contributing to tree mortality and fire severity.

Figure 8. Crown fires are fast moving, high temperature events that can move through a forest at tremendous speed and burn large areas in minutes, consuming a large proportion of flammable material. Panoramic view of Rodeo-Chediski fire courtesy US Forest Service and Ecological Restoration Institute, Northern Arizona University.

Across most of Arizona, the large fires that burn the most acres are those that are too intense to control.

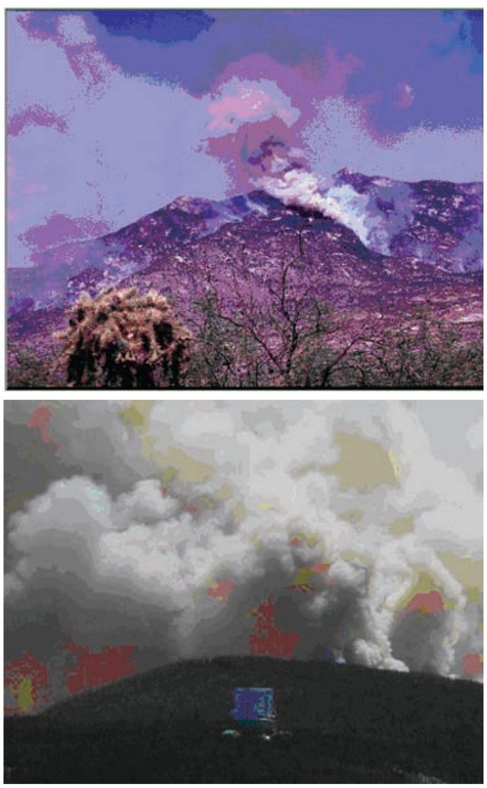

Figure 9. Under extreme conditions, crown fires can generate flames hundreds of feet high and enormous smoke plumes. Plumes from the (top) 2003 Aspen Fire, Santa Catalina Mountains, and (bottom) 2004 Nutall Complex, Pinaleño Mountains (Photo P. Small, US Forest Service).

and strong winds (Agee 1993; Pyne et al. 1996). Every fire season, news accounts of hundreds of firefighters, supported by aircraft and extensive logistics, yet unable to control a severe wildfire somewhere in the western US, convey dramatically the difficulty of altering the behavior of intense events burning under extreme weather conditions (Figure 11).

Because high-intensity fires are a natural and inevitable occurrence in upper-elevation forests, as well as occurring occasionally at lower elevations, it follows that a fire-free landscape is neither possible, nor even desirable. A recent White Paper by the Ecological Society of America (2003) concludes: “Crown fires cannot and should not be eliminated from all forests. Different ecosystems require different approaches to fire management. In some forest types, crown fires are a natural, indeed inevitable, part of the regime. For example, chaparral, lodgepole pine, boreal forest, pitch pine and sand pine have long experienced crown fires. Attempting to eliminate such fires in these ecosystems is not ecologically justified and is unlikely to succeed.”

Recent fires in Arizona and elsewhere in the Southwest illustrate how quickly fires can spread over landscapes under extreme weather and fuel conditions. The 2002 Hayman fire in southern Colorado raced across 19 miles of forest in a single day, burning almost 60,000 acres (24,300 ha) and sending convection plumes more than four miles into the atmosphere. At its peak, the fire burned 138,000 acres in 10 days, until cooler weather finally slowed it down (Kaufmann et al. 2005). Similar recent fires in Arizona (including the 2002 Rodeo-Chediski and Bullock fires and the 2003 Aspen fire), typically burned under extreme weather conditions when control is difficult if not impossible (Figure 12). Fires in other vegetation types, such as chaparral and shrublands, also burn under extreme weather conditions (high temperatures, low humidity, and high wind) under which fire control, let alone suppression, is virtually impractical (Keeley and Fotheringham 2001; Krist 2006). Although Arizona does not experience the Santa Ana winds that blow westward into southern California, the state is no stranger to hot, dry weather that can cause shrub and forest fires to spread rapidly out of control.

Decades of fire suppression, drought and insect outbreaks are contributing to large increases in fuel loads (Covington 2000; Omi and Joyce 2003; Kaufmann et al. 2005). These new forest conditions, combined with the current multi-year regional drought, may be pushing southwestern forests outside of their range of natural variability (Breshears et al. 2005; Swetnam and Betancourt 1998). When fires occur under such modified landscape fuel conditions, the result may catastrophic, leading to severe degradation of fundamental ecosystem productivity, such as when severe soil erosion and loss follows an extreme fire event (Allen 1996)(Figure 13). Such outcomes can be devastating to important economic infrastructure, wildlife habitat, watershed function, and biological and aesthetic values that managers and the public cherish.

Ironically, many of the highly destructive fires of recent years in Arizona are at least in part the legacy of decades of fire suppression. Frequent, natural fires reduce fuel accumulation on the forest floor and break up continuous fuel complexes and "ladders" that carry fire from the surface into the forest canopy (van Wagtendonk 1985; Swetnam and Baisan 1996; Reinhardt and Ryan 1998). A 2004 report by the US General Accounting Office (GAO 2004) notes: "Decades of fire suppression, in conjunction with land management activities that have excluded fire from the nation's forests and rangelands, such as roads and trails, grazing, and development near public land, have caused the accumulation of brush, small trees, and other vegetation on federal and other lands. Recent fire seasons have shown that these land management practices have had unforeseen consequences. The accumulation and alteration of vegetation, in combination with an extended drought that has covered much of the country, has caused wildland fires to burn more intensely than they would under more natural or historical vegetation conditions." This sequence of events has been repeated throughout the western United States.

Fire is a permanent and unavoidable process in the Arizona landscape (Figure 14). The increased frequency, intensity, and size of extreme and

Figure 10. Tree-ring studies of fire-scarred trees have demonstrated that low-severity fires were common historically in many Arizona forests. Photo: Laboratory of Tree-Ring Research, University of Arizona.

Figure 11. High-intensity fires frequently burn under extreme weather conditions when control is difficult if not impossible. Photo US Forest Service/ Ecological Restoration Institute, Northern Arizona University.

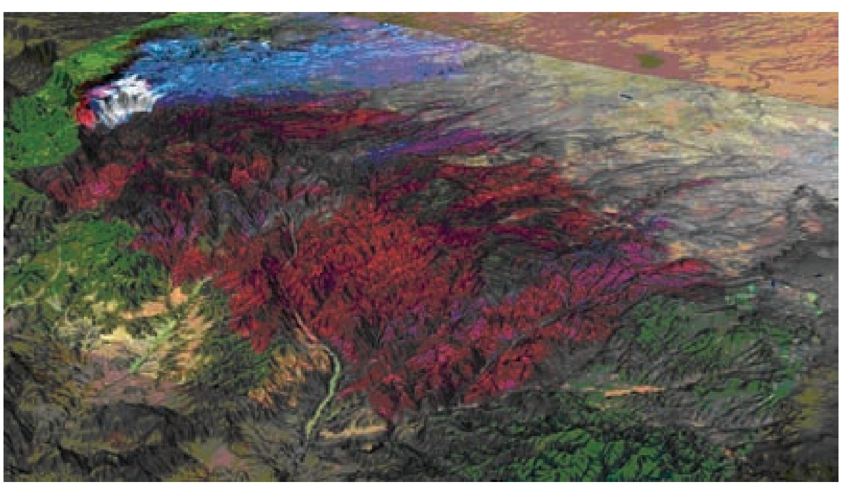

Figure 12. The 2003 Rodeo-Chediski complex burned more than 468,000 acres before it was finally controlled weeks after ignition. Colorized Landsat image courtesy US Geological Survey.

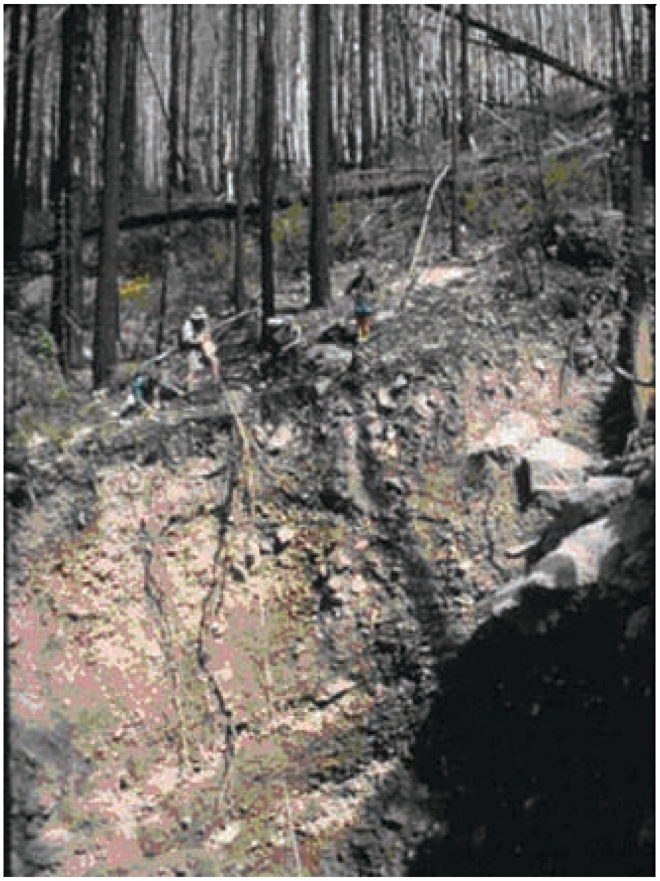

Figure 13. Extreme fire events can leave lasting legacies of soil erosion and reduced ecosystem function. Photo of massive downcutting following the 1994 Rattlesnake Fire, Chiricahua Mountains. Photo: Laboratory of Tree-Ring Research, University of Arizona.

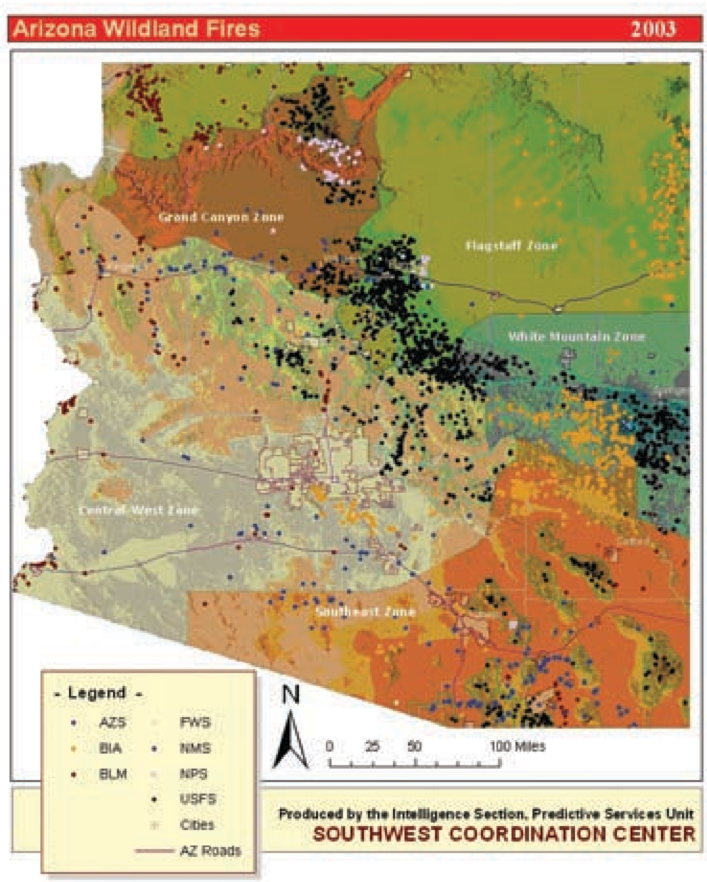

Figure 14. In certain years, fire is ubiquitous in the Arizona landscape. Image of fire occurrence for 2003 from the Southwest Coordination Center (SWCC), http://gacc.nifc.gov/swcc/index.htm.

uncontrollable fire events are at least in part the direct and inevitable result of excluding natural fires from the landscape, leading to the exponential irruption of small diameter trees that act as fuel. In fact, measuring fuel accumulations resulting from fire suppression is the basis of emerging methods for assessing the risk of extreme fires over large landscapes, such as the Fire Regime Condition Class (Hann and Strohm 2003). These accumulated fuels pose an even greater hazard in the context of regional climate warming, and the spread of invasive species which can bring fire to ecosystems that historically have experienced it only infrequently. High-intensity fires will remain part of the Arizona landscape as long as the natural fire regime is suppressed, and until land managers are able to conduct large scale, statewide prescribed and managed fires and restore natural fire regimes.

3 Fire on developed landscapes

The science of fire behavior indicates clearly that fires will continue to occur in Arizona's forests. We now review the consequences of land-use and development patterns for large-scale ecology and land management, and ask two central questions: What is the resulting risk to individual existing homes and developments, and what are the effects of development on the forest fire regime and, more broadly, on forest health?

Changes in landscape development patterns

Like many Western states, homes, roads, and other infrastructure have become dispersed at low density in many Arizona forests. Many public lands – which the general public may perceive as homogenously managed for the public good – are actually perforated extensively by small private inholdings, and increasingly surrounded by development up to the public-private boundary. For example, a single district on the Tonto National Forest has more than 75 private inholdings, composed of nearly 3,000 subdivided parcels (Figure 15). Although these areas constitute only 4.7% of the approximate 463,760 acres of the District, they often influence land management decisions over a much larger area.

> *Since 1982, an estimated 8.6 million houses have been built inside or within 30 miles of national forest boundaries.*

The Wildland-Urban Interface (WUI) is defined as areas "where humans and their development meet or intermix with wildland fuel (USDA-USFS et al. 2001) (Figure 16). WUI's comprise 273,000 square miles or 9.3% of the contiguous 48 states (Stewart et al. 2003). WUI areas are estimated to cover approximately 2-3 million acres in the southwestern states (Federal Register 2002); this estimate may be conservative, depending on the criteria used to define the WUI (Stewart et al. 2006). Nationwide, development into forested areas is increasing exponentially. As many as 42 million homes are now in WUI zones, including commuter homes near major metropolitan areas as well as second homes in formerly remote forested areas; 26 million of these are near forested or other flammable areas (AP 2007). Most estimates indicate that total WUI area is increasing rapidly, particularly in the western states where development into forested areas is often at low density but extensively distributed (Moore 1981). Stewart et al. (2006) note that in the Southwest, "virtually every urban area has a large ring of WUI reflecting sprawling patterns of recent growth, with extensive medium- and low-density housing near or in low-elevation forested areas." Since 1982, an estimated 8.6 million houses have been built inside or within 30 miles of national forest boundaries (AP 2007).

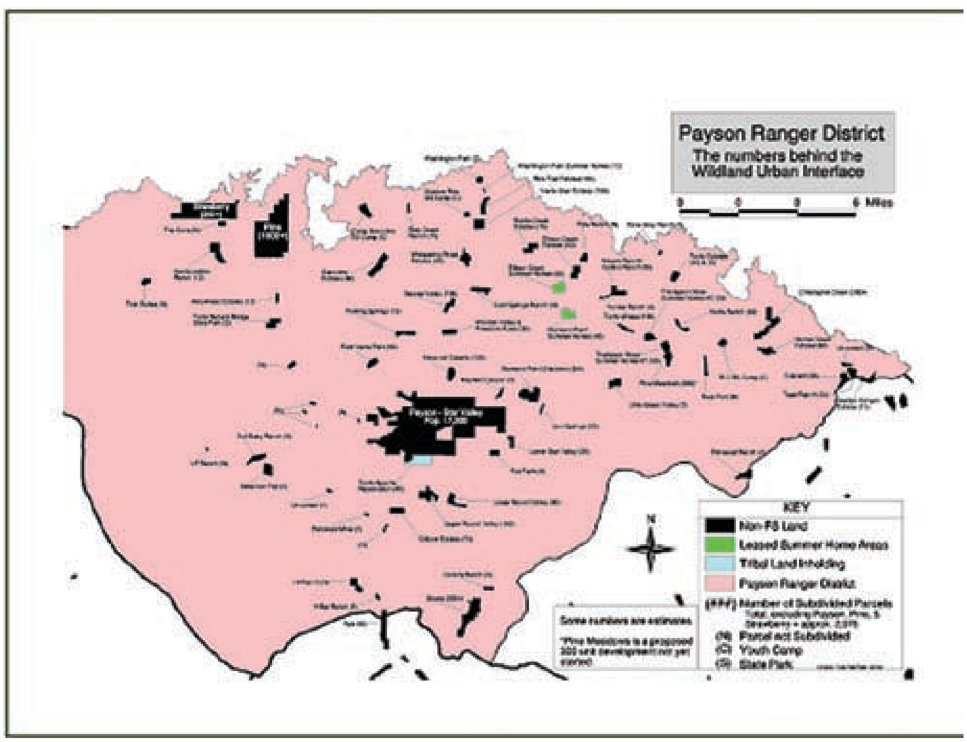

Figure 15. Development patterns on the Payson Ranger District, Tonto National Forest. Black polygons are privately-held parcels within the District boundary.

Figure 16. The Wildland-Urban Interface often places homes and highly flammable fuels in close juxtaposition, creating potentially hazardous situations. Photos: Coronado National Forest, Pinaleño Mountains.

Fire risks associated with increased forest development

Fire and development interact, not only in the WUI areas themselves, but also in surrounding areas of forest, where nearby development can influence management of public lands. As we now see nearly every year, wildland fire can affect humans and developments with smoke, altered aesthetics of surrounding landscapes, and damaged infrastructure, as well as the more immediate loss of life and property. Cumulatively, these losses have amounted to billions of dollars in Arizona and southern California during recent wildland fires, and such large-scale financial impacts are expected to continue. The evacuation of more than half a million people from the 2007 California fires—the second largest emergency evacuation in the nation's history, exceeded only by Hurricane Katrina—provides a glimpse of the scale of the problem (Steinhauer 2007).

Arizona has experienced these interactions of fire and development multiple times. Thousands of residents had to evacuate during the 468,000-ac (189,400 ha) Rodeo-Chediski fire in 2002; by the end of this event more than 420 structures had been destroyed. Rodeo-Chediski was the largest fire in the state's history and at the time it occurred, the third largest in US history. The 2003 Aspen fire in the Santa Catalina Mountains north of Tucson burned 84,750 acres (35,000 ha) over a month of hot, dry weather; fire control was extremely difficult in the rough, rocky terrain, and more than 320 homes and other buildings were destroyed in the mountain-top community of Summerhaven. In 2004 the Nuttall-Gibson complex burned over 30,000 acres (12,100 ha) in the Pinaleño mountains, creating huge erosion-prone areas of burned soil on steep slopes and nearly destroying part of the multi-million dollar Mount Graham International Observatory (Figure 17).

One short-term response has been to encourage homeowners to reduce structural ignitability and increase wildfire preparedness in at-risk communities (Arizona Forest Health Advisory Council 2003). There is increasing awareness that homeowners have a responsibility to make their properties less prone to destruction by fire, and to avoid unnecessary risk for firefighters and public service personnel, particularly in WUI areas, which have been involved in some of the state's most costly and destructive fires in recent years (Cohen 2003). For example, in 2006 the 250-square mile Day Fire in California required the mobilization at public expense of more than 200 engines and 4,000 firefighters to protect homes built in flammable chaparral and semi-arid forest types (AP 2006).

In southern California, losses of property and lives have increased exponentially in the past 50 years, largely because of enormous increases in population, and development patterns on the landscape, often clustered right against highly flammable landscapes (Figure 18) (Keeley and Fotheringham 2001; Krist 2006). A 2006 study in

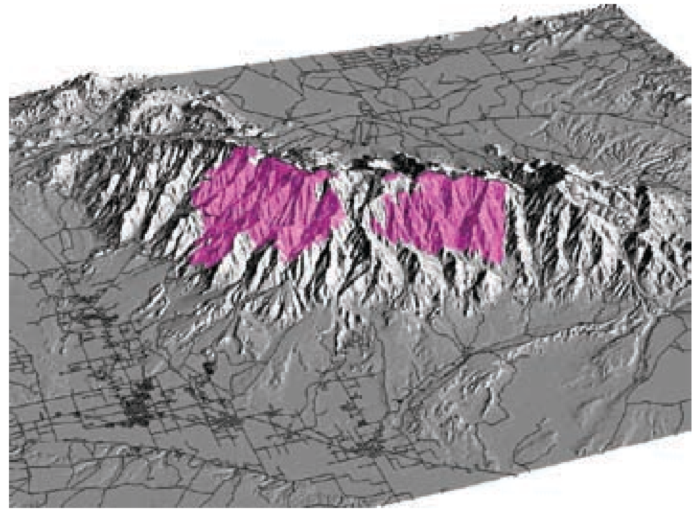

Figure 17. The 2004 Nutall-Gibson complex in the Pinaleño Mountains (left) burned a large proportion of the mountain's forested area (right) and threatened a multi-million dollar astronomical complex.

northern Arizona (Dickson et al. 2006) found that human-caused ignitions, which accounted for approximately one-third of fires for the years 1986-2000, were positively associated with road density, suggesting that vehicular access into the forest contributes to ignitions and thus, with fire frequency.

The presence of buildings can actually alter fire behavior when a fire enters a developed area. Cohen (2003) analyzed the behavior of the 2003 Aspen Fire in the community of Summerhaven in the Santa Catalina Mountains of Arizona, and found that the fire entered the area primarily as a surface fire. High local fire intensities were generated by improperly fireproofed properties, further fueling spread of the fire within the development; in other words, flammable homes and infrastructure actually accelerated the spread of the fire. Cohen and colleagues observed, "Crown fire originates and ends in association with home destruction." Similar conclusions were reached in the 2000 Cerro Grande Fire, where fireproofing of some homes saved them from the destruction that destroyed neighboring structures.

Figure 18. Residential development abutting densely vegetated public lands have contributed to wildfire risk in southern California.

In the dry foothills of the Washington Cascades, formerly large forested areas are now dotted with private homes that are essentially indefensible in the event of a high-intensity fire. A recent article noted that "More than 90 percent of wildfires here now threaten private homes, many of them situated on narrow cul-de-sacs; a local fire manager with the South Puget Sound Region of the Department of Natural Resources says, "So many people have moved into more remote areas that just about every fire we get is in close proximity to homes," (Rowe 2004). These effects are increased by the common practice of building in areas of dense fuels and steep topography, which promote rapid spread of crown fires (Figure 19).

Fire behavior can be altered in some circumstances by fuel reduction treatments in forests, such as mechanical thinning and prescribed burning (Figure 20) (Graham et al. 2004; Omi and Joyce 2003; Hunter, Shepperd et al. 2007). For example, Strom and Fulé (2007) found that pre-fire thinning treatments were effective at modifying both fire behavior and post-fire effects in the area affected by the 2002

Figure 19. New home construction in a potentially hazardous setting near the Tonto National Forest.

Rodeo-Chediski fire. Similarly, Fulé et al. (2006) found that treatment intensity (for example, number of trees or basal area removed) could influence the effectiveness of thinning in altering fire behavior. However, treatments cannot always guarantee a reduction in fire intensity or severity under extreme weather conditions. Embers traveling long distances, especially under severe fire weather conditions, may ignite structures far from the flaming front. Consequently, the landscape configuration of treated areas is recognized increasingly as an important property. For example, Finney and colleagues (2005) found that prescribed burning treatments modified the behavior and effects of the Rodeo-Chediski fire, but only if treatments were relatively large (> 1,000 ac) and less than 10-15 years old; smaller treatments and those conducted more than 15 years before the fire had relatively little effect under the extreme conditions that prevailed at the time of the fire. In sum, fire risk on the landscape scale cannot be solved entirely by reliance on fireproofing homes, or thinning and fuel treatments, although these are valuable tools for smaller areas, particularly WUI's. The pressure to suppress natural and prescribed fires may remain even when these measures are taken.

In any event, it is unlikely that mechanical treatments will extend across entire forested landscapes in Arizona over a meaningful time frame. Expanded use of landscape-scale prescribed burning and wildland fire use (WFU) will be central to maintaining forest health. A long-term response must also include assessing the costs to society of development into forested areas, as well as its impacts on forest health. In the case of high-intensity fires during extreme weather conditions, fireproofing of individual homes and communities cannot resolve the potential conflicts between development and forest fire alone—consideration of the landscape as a whole is required.

Effects of development on ecosystem management and fire planning.

The presence of homes and infrastructure has a profound impact on how ecosystem managers care for the surrounding public lands. Development-induced fire suppression includes direct suppression during wildland fire events, as well as reduced use of prescribed fire or WFU. Fragmented ownership patterns and associated differences in fire management policies, conflicts over smoke from prescribed and management fires, and liability concerns often constrain the ability of fire management agencies to plan and conduct wildland fire in an efficient, safe, or effective manner (Viers 2005). These constraints can affect programmatic and project-level plans for wildland fires, which are widely recognized as beneficial modes of landscape-fire management.

A 2-million-acre analysis area in the vicinity of Flagstaff, Arizona illustrates the implications of fragmented ownership patterns for wildland fire management (Figure 21). Ponderosa pine forests, typified historically by fire intervals of 4-8 years, dominate the vast majority of the analysis area. Fire intervals, small tree densities, and fuel loads have increased radically during the past century. Six

Figure 20. Areas where fuels have been reduced by mechanical thinning or prescribed burning can alter fire behavior and effects under some conditions. Photo of prescribed fire in Gila National Forest courtesy Tyson Swetnam, National Park Service/University of Arizona.

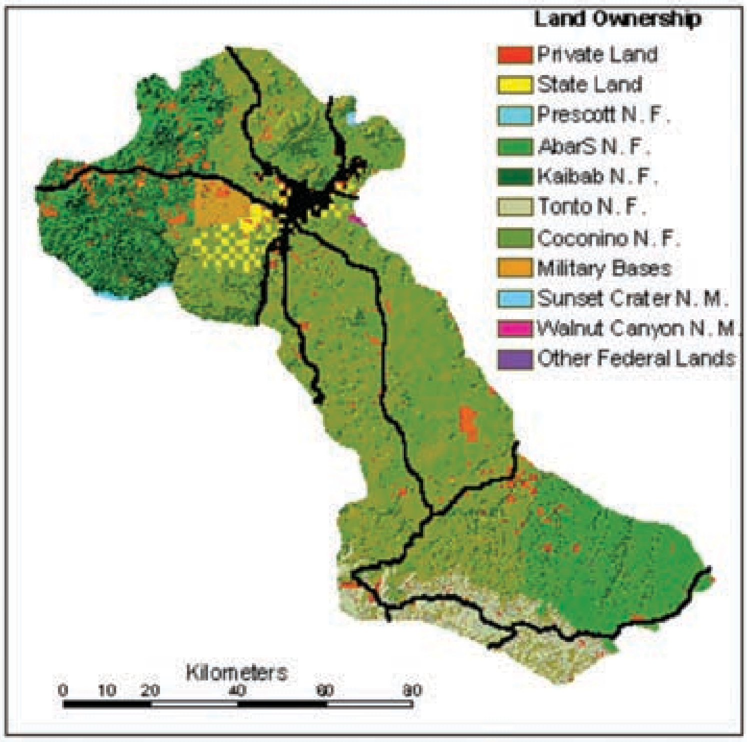

Figure 21. Multiple land jurisdictions can complicate fire management, especially at the landscape scale. Figure courtesy ForestERA, Northern Arizona University.

land jurisdictions are distributed unevenly across the study area. Each has unique policies and liabilities for wildland fire management. National forest system lands are the largest component, and the US Forest Service is responsible, not only for managing the public landscape for multiple uses, but also for confining wildland fire to their jusrisdiction and preventing it from burning into the smallest and most geographically dispersed land ownership—private land. Fragmented ownerships compromise the Forest Service's ability to restore and maintain fires in ponderosa forests at scales even remotely similar to natural variability.

Smoke

Fires generate smoke, and smoke generates resistance to prescribed burning. Public land managers and many members of the public understand that returning prescribed fire to the landscape is imperative, not only for ecological sustainability, but also to reduce the risk of catastrophic fire and the expenditure of billions of dollars of taxpayers' money for suppressing wildfire (McCaffrey 2006). Understandably, however, some homeowners experience smoke as an inconvenience and, in some cases, a significant health issue. Such concerns are raised regularly at the local level, such as in public planning meetings for prescribed burns on a Forest Service District. Fire managers on public lands across the western US frequently encounter opposition to prescribed burning, even though these fires are clearly a preferred alternative compared to an uncontrollable conflagration that could occur without fuel treatments and regular prescribed burning. As a consequence, in some areas where small inholdings and WUI's surround and penetrate public lands, managers often find it difficult to conduct the needed prescribed burns because of local objections, although in recent years generally public support for prescribed burning has increased (Viers 2005; McCaffrey 2006). Education programs for residents may be changing attitudes toward prescribed burns in some areas, but overall, managers need to educate the public continually about the ecological and safety need for prescribed burning.

Effects on prescribed fire and Wildland Fire Use programs

Wildland fire use (WFU) is emerging as an important framework for managing fire across whole landscapes (Zimmerman, Frary et al. 2006). WFU is defined as the practice of allowing naturally-ignited fires to spread within previously defined spatial areas and weather conditions. When an ignition (for example, by lightning) occurs within a WFU area, managers assess probable fire behavior and pathways of spread given prevailing and projected weather conditions. If projected spread and behavior are found to fall within specified ranges (the "prescription"), the fire is permitted to spread instead of being suppressed (Figure 22). Most WFU fires burn themselves out when fuels or weather limit their spread. In a minority of cases, suppression teams are called in to contain a WFU event that spreads beyond its pre-determined boundary area, or if weather conditions become more severe.

Many areas of public lands nationally are implementing WFU policies for large wilderness areas, including the Gila Wilderness in New Mexico and the Selway-Bitterroot Wilderness in Montana and Idaho. WFU is also an important step toward allowing fire to regain its crucial natural role in forested ecosystems, because fires burn at their natural intensity and pace, often leaving legacies of complex burn severity mosaics over the landscape.

Figure 22. Wildland Fire Use can allow fire to regain its natural ecological role and reduce the risk of catastrophic fire. Photograph courtesy Coronado National Forest.

Of course, WFU cannot be implemented casually, especially where decades of fuel accumulation can become highly dangerous under severe fire weather. Nonetheless, WFU is an important policy direction that is helping agencies, states, and communities to understand—and plan for—fire as a landscape process. Clearly, the presence of dispersed development constrains when and where WFU can be implemented. Some Arizona National Forests have WFU authority but are rarely able to implement it, due to the existence of homes or other development within their boundaries as inholdings, or in development close to the perimeter of public lands. Problems commonly cited in developing WFU programs near development include smoke and the potential hazard of escaped fires to reach developed areas.

Overall, a strategic combination is required, applying WFU and prescribed fires implemented at the landscape scale. It is at these larger scales that the presence of elements of the built environment – buildings, roads, infrastructure – can have a significant impact on forest management, even within the perimeter of public lands. It is reasonable for some forest management practices to respond to the presence of development, but in the longer term a more sound policy will include finding ways for development to respond in kind to the imperatives of forest health, including wildland fire management.

4 The costs of severe forest fires

In addition to ecological effects, substantial fiscal and human costs are associated with attempting to suppress wildfires. Increasing community preparedness may reduce, but cannot eliminate, the risks and expenses of suppression prior to and during severe fire conditions. Those risks and costs include "pre-suppression" costs incurred preparing for fire season, such as purchase and maintenance of fire suppression equipment and hiring and training of personnel. Costs incurred during suppression include incident planning, management, implementation, and associated administrative, personnel, contractual, equipment, and supply expenses. Post-fire costs include rehabilitation of burned areas, as well as rebuilding damaged infrastructure.

Nationally, the cost of fighting wildfires has exceeded appropriated funds almost every year since 1990 (Wagner 2004). In 2002-04, federal spending alone (FY 2000-2005 Wildland Fire Management Appropriations) for fire management exceeded $2 billion annually, nearly 70% of which ($1.3 billion) was allocated for suppression (Gregory 2004; Trust 2004; Headwaters 2007). According to the Congressional General Accounting Office, from 2000 to 2004 the U.S. Forest Service and the Department of Interior transferred more than $2.7 billion from other programs because, in their budgeting, they "repeatedly underestimated how much money would be needed to pay for fire suppression" (GAO 2004). These expenses are borne by taxpayers, reflecting increasing costs at all levels of government (Krist 2006).

Homeowner reliance on the federal government to provide wildfire suppression services places an enormous financial burden on the U.S. Forest Service and other public agencies providing such services.

A recent internal audit of the Forest Service's fire program noted that the "escalating cost to fight fires is largely due to its efforts to protect private property in the wildland urban interface (WUI). Homeowner reliance on the federal government to provide wildfire suppression services places an enormous financial burden on the Forest Service and other public agencies providing such services. It also removes incentives for landowners moving into the WUI to take responsibility for their own protection…." (AP 2007). In a very real sense, fire suppression represents a subsidy of development patterns that, in turn, increases the need to suppress more fires.

States often bear much of the cost of fighting fires in developed areas. For example, the 2006 fire season cost the state of Montana more than $37 million, largely to protect developments near Billings and Big Timber. In October 2007, the Montana legislature met in special session to set aside another $82 million for the next two years. It is not unusual for several million dollars to be spent controlling a single fire, primarily to protect structures near or in public lands.

Suppressing fire to protect private property in fire prone landscapes can contribute to increasingly severe fires later on, resulting in costs that include injury or death to citizens and firefighters, and huge financial expenditures. The 2003 fires in southern California burned three-quarter of a million acres and caused more than $4.8 billion in property damage (Ritter 2004; Krist 2006). Within the more than 750,000 acres burned, 3,640 homes were destroyed, along with 33 commercial properties and 1,141 other structures (Chi 2004; Ritter 2004). Just four years later, the 2007 southern California fires, also pushed by strong Santa Ana winds, swept through seven counties, at one point reaching from Santa Barbara to the Mexican border and causing federal designation as disaster areas. Half a million people had to leave their homes in the largest emergency evacuation in U.S. history, save for Hurricane Katrina. The 2007 California fires killed 10 people, injured 130, destroyed more than 2,000 homes, and caused property damage estimated initially at more than $2 billion. We have every reason to expect that severe fires of this magnitude will continue to occur regularly, due to the combined effects of increasing development and warming trends (Westerling et al. 2006).

Current development trends in western states, including Arizona, suggest that these problems may increase in the future. A recent economic analysis by the Headwaters Institute of Bozeman, Montana examined current rates of development around the boundaries of public lands in the eleven western states. They found that the developed proportion of these areas could rise from the current 14% to as much as 50% if current development trends continue. At 2008 costs, this increased area could raise federal firefighting costs to $2.4 – $4.3 billion annually (for comparison, the total current Forest Service budget is $4.5 billion). Arizona ranks fifth among western states in WUI development, with approximately 17% of the forested public-private boundary already developed. Approximately 55,000 houses are in this 482 square mile area, of which 34% are occupied only seasonally (Headwaters 2007).

Fighting wildfires also has a very personal cost. Dozens of firefighters have been injured or killed in recent years fighting fires to protect private property within or near public lands. From 2003 to 2007, at least 113 wildland firefighters died during fire season in the U.S. For the past 20 years (1987-2007), an average of 19 wildland firefighters have died each year, compared to 6-7 in the 1930's. The worst years were 1994 and 2003, when 30 and 29 firefighters died respectively (NWCG 2006). Twenty-five lives were lost in the 2003 Southern California fires alone.

Part of the reason for these accelerated fatality rates is that fighting fires in the WUI can be more dangerous than firefighting in more remote areas. When a wildfire is approaching a subdivision, fire teams will go to heroic lengths to save houses, whereas in the wild they might simply retreat and establish a new position. Firefighters are wounded every year from other hazards unique to the WUI, such as exploding propane tanks and collapsing utility infrastructure. For this reason, many fire bosses are increasingly reluctant to send fire teams into potentially fatal situations, especially where houses have not been properly fire-proofed (AP 2007).

The costs of wildfire suppression also include the costs of rehabilitating areas that burn with high intensity (burned area emergency rehabilitation, referred to as BAER). Tens of millions of dollars are spent annually on slope stabilization and aerial seeding. Other common activities of BAER include major earth movements by machines to open roads and clear culverts, especially in response to debris flows which may be drastically increased by heavy rain events following an intense fire (GAO 2004).

Better landscape-scale fire management, including the use of mechanical treatments in critical areas, more frequent prescribed burning, and wildland fire use (WFU), can reduce the severity of wildfires and dramatically lower costs of emergency rehabilitation. In addition to its ecological benefits, WFU can help prevent serious adverse environmental impacts from catastrophic events, as well as chemical contamination and extensive bulldozing of fire lines during fire suppression itself (Gregory 2004). WFU costs are an order of magnitude lower than emergency fire suppression and post-fire rehabilitation; WFU costs the public an average of just $43/acre, in contrast to the $500/acre commonly spent on suppression efforts (many of which fail) and upwards of $750 - $1,000/acre for fuel reduction thinning (Black 2004).

Collisions between fire and development can be costly, deadly, and harmful to the environment. For these and other reasons, there is a compelling public interest in developing a more sustainable and rational approach to development in fire-prone landscapes. The sections that follow outline some of the tools and approaches that are available to public officials and communities in Arizona.

5 Land-use solutions for reducing conflicts between fire and society

Two general approaches exist for negotiating the relationship between fire and society: structure-oriented and landscape-scale. *Structure-oriented* approaches address the fire issue primarily through building codes related to individual buildings and deal with flammability of materials, "defensible space" requirements on the basis of fuel type and slope or other factors, emergency egress routes, and improved emergency communications and evacuation techniques. Such codes are often voluntary, although movements exist in many western states (including Arizona) that attempt to make such codes mandatory. Structure-oriented approaches are most useful for existing developments, where the immediate priority is community protection.

> *"Community residents and their leaders must be able to understand the rationale for fuel treatments and for how community structures and plans can be modified to reduce overall fire risks…while letting fire play its natural role." – USDA, National Fire Plan: Research and Development (USDA-USFS 2003).*

By contrast, *landscape-scale approaches* address the more fundamental issue of where on the landscape development should occur in relation to forest health priorities and fire risk. Landscape approaches may include the use of mapping strategies to determine where fire is most likely to occur (Dickson et al. 2006); assessing the effects of development on the ability of public lands managers to maintain important values, such as wilderness and roadless areas; and evaluating the long-term impacts of development in fire-prone areas on forest health, firefighter safety, and public costs at all levels of government, as well as the private economy (Sisk et al. 2005). Land-use policies can be implemented in existing developed areas and as a proactive, community-based strategy for helping new development work within the landscape.

Communities and statewide policy makers can implement a landscape-scale approach to managing fire and forest health in many ways. We suggest several related approaches for reducing conflicts between forest health and society, landscape-scale spatial fire analysis and land use controls.

Landscape-scale spatial fire analysis

Because both fire and development occur in a spatial context, it follows that their interaction can also be evaluated using various tools of spatial analysis. A variety of methods are available, many based on geographic information systems (GIS) and new fire behavior models (Stratton 2006). We review several examples here.

Fireshed analysis. One example of a landscape spatial approach is the delineation of firesheds. Firesheds are "large (thousands of acres) landscapes delineated according to fire regime, condition class, fire history, fire hazard and risk, and potential wildland fire behavior" (Bahro 2004; Mislivets and Long 2003). Thus, the fireshed includes the natural biological and physical environment, as well as human development patterns and their associated risk. The central concept in fireshed analysis is to identify areas of the landscape with characteristic probabilities of fire occurrence that are important for guiding development.

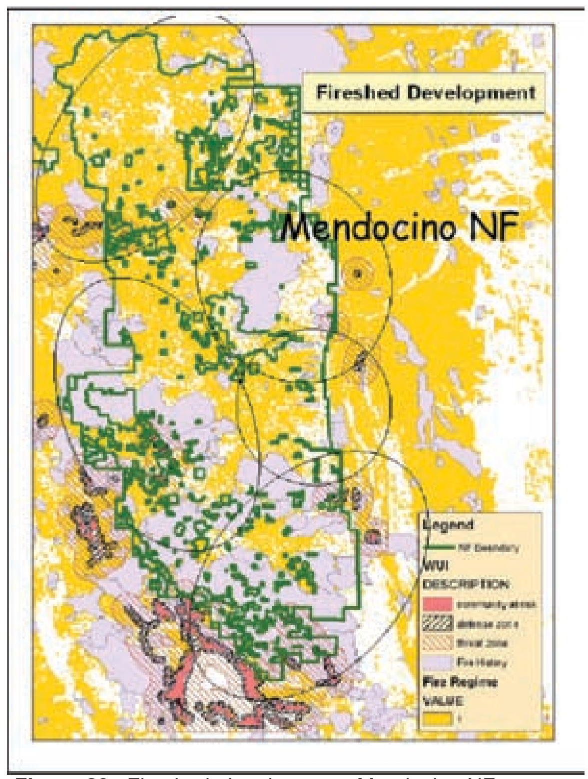

Figure 23. Fireshed planning area, Mendocino NF, California. From Bahro (2004).

Fireshed delineation focuses attention on portions of the landscape where fires are most likely to occur, informing development patterns and linking fire management and restoration planning. Once delineated, firesheds can clarify the hazard rating of development and can help identify natural burn paths, fire management zones, and containment zones for Fire Management Plans. Fireshed methodology has been used in several western states with positive outcomes in large-scale land use planning. One output of fireshed analysis is a detailed map of fire risk that can be used by state and county planning officials, as well as members of the public and insurance companies (Figure 23).

Forest Ecosystem Restoration Analysis. A related approach can be applied using tools developed at Northern Arizona University in the Forest Ecosystem Restoration Analysis (ForestERA) project (http://www.forestera.nau.edu/index.htm). ForestERA is "a collaborative process that views forest ecosystems from a landscape perspective to discover better ways to restore their health and protect our communities. Stakeholders representing diverse backgrounds, priorities, needs and points of view work together in small groups using the best scientific information and tools available." ForestERA integrates a number of variables including fire risk and fire hazard, locations of communities and infrastructure, and natural resource values in a spatially-explicit framework (USDA-USDOI 2005; Sisk, Prather et al. 2006).

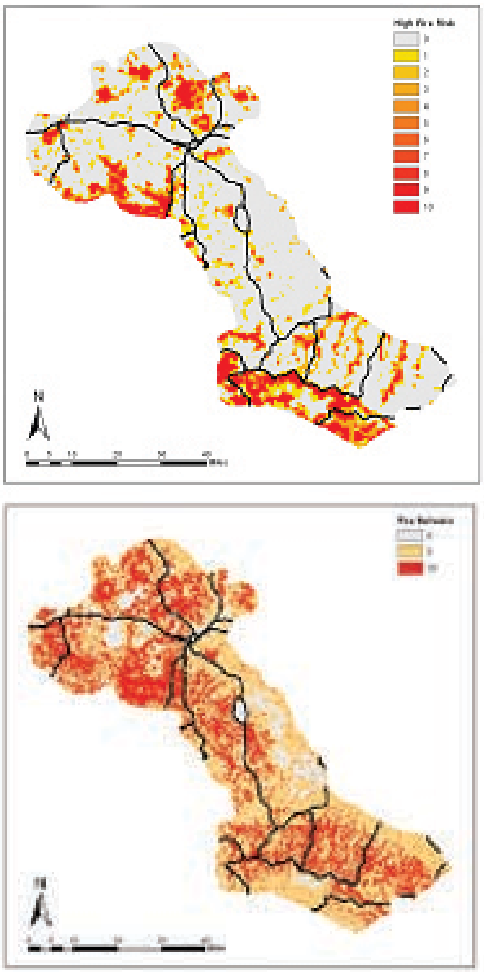

Figure 24. ForestERA analysis of the central Mogollon Rim near Flagstaff, Arizona. Top panel: Spatial pattern of fire risk (probability of ignition and initiation of large fire events), color coded from lowest (white) to highest (dark red). Bottom panel: Spatial pattern of potential fire behavior (fire type, rate of spread) from predominantly surface fire (white) to high crown fire potential (red). ForestERA is a program of Northern Arizona University; analysis by Steve Fluck and Ethan Aumack, Grand Canyon Trust.

ForestERA datasets (derived primarily from remote image sources such as the Landsat TM satellite), tools, and approaches can be used to evaluate large landscapes in terms of their fire risk and hazard, and thus the potential risks and costs associated with development in fire-prone areas. As a case study for this report, the Grand Canyon Trust analyzed the area of the central Mogollon Rim near Flagstaff pictured in Figure 21 (analysis by Steve Fluck and Ethan Aumack). They used the Forest ERA program to predict fire behavior (surface fire, passive crown fire, active crown fire), areas of high fire risk (probability of ignition and initiation of large fire events), and areas of potential fire spread downwind of high fire risk areas for the area (Figure 24). When fire behavior, risk, and potential spread are combined, the result is essentially a map of the probability of large and severe events (Figure 25). Such visualizations are potentially powerful tools for communities and public officials who wish to consider the risks and impacts of development in forested lands for the landscape.

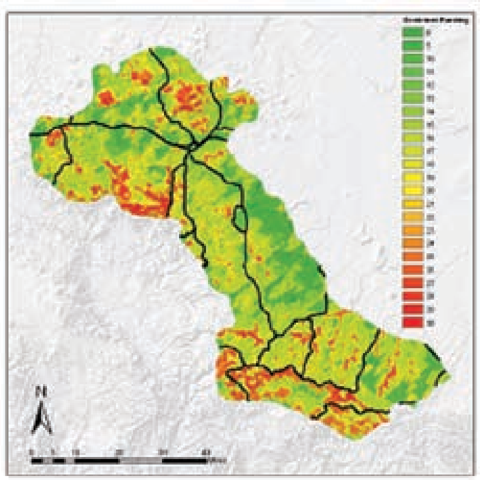

Figure 25. Combined fire risk and hazard produced by ForestERA for the central Mogollon Rim near Flagstaff, Arizona. Areas encoded in green (composite scores of 12 and under) have lower probability of high-severity fires, while red and orange areas (scores greater than 23) have high probability of such events. Analysis by Steve Fluck and Ethan Aumack, Grand Canyon Trust.

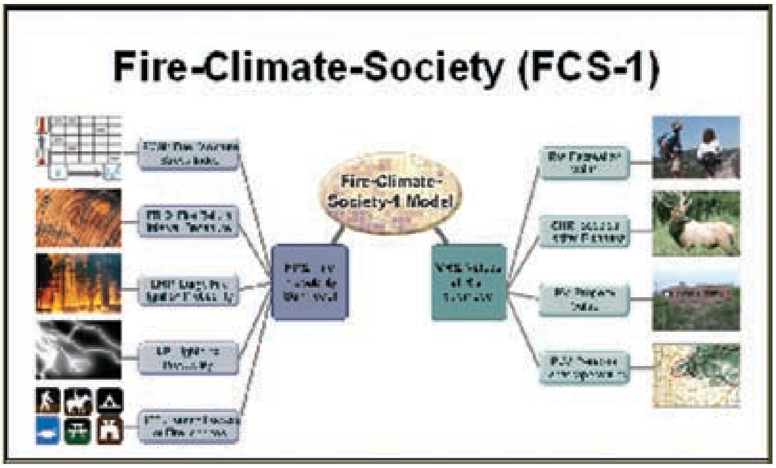

Figure 26. The WALTER program (University of Arizona) allows users to produce maps of fire risk in relation to values at risk, such as developed areas, recreational sites, important ecological areas, and other community values.

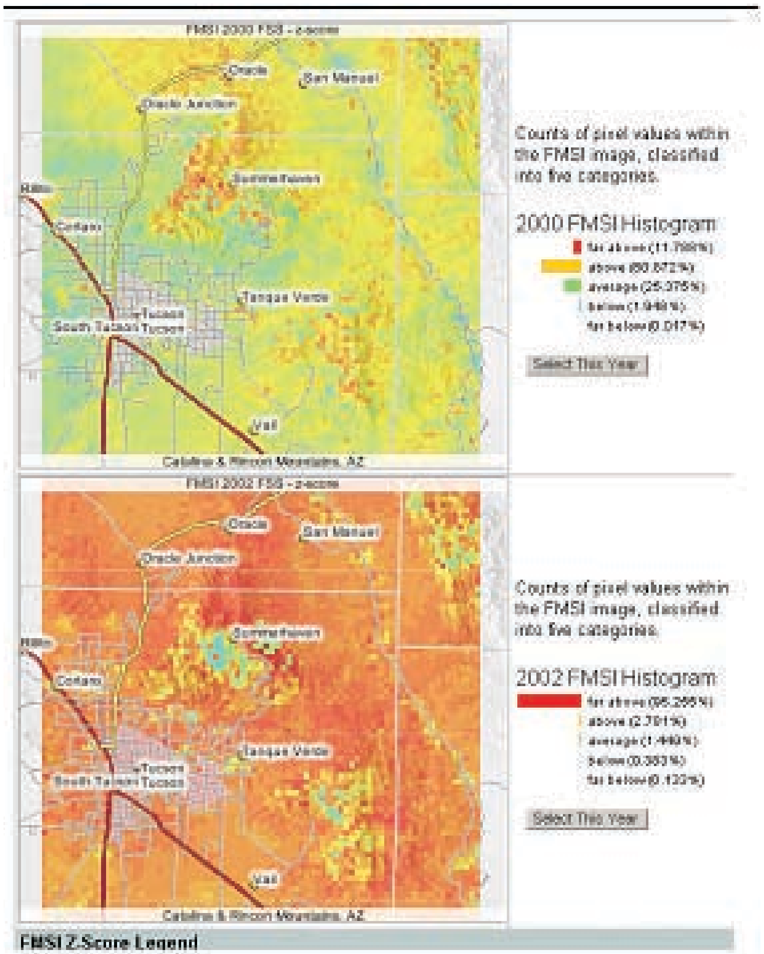

Figure 27. WALTER analysis of fuel moisture as an index of fire hazard, for climate conditions during the fire seasons of 2000 and 2000.

Wildfire Alternatives: Fire, Land Use, and Climate Analysis. The wildfire alternatives ("WALTER") project at the University of Arizona is another source of valuable information for communities and planners (www.walter.arizona.edu) WALTER provides a tool for integrating information in a "Fire-Climate-Society" analysis, which can be used on-line, in stakeholder workshops, or planning venues (Figure 26). WALTER allows users to assess two broad categories central to land-use planning, fire probability and values at risk. The user selects climate conditions from pre-loaded data (for example, the user can choose a severe drought year or a "normal" climate year). The "fire probability" module then generates spatial maps of fuel moisture, fire return interval departure, probability of a large fire, and ignition probability by lightning and human agents. The "values at risk" module uses a method termed Analytical Hierarchy Process (AHP) to allow the user to identify areas of high recreational and aesthetic value, property value, and ecological significance. The user weights these criteria according to their importance through a series of pairwise comparisons. WALTER then returns a map of areas ranked by the probability of fire and values at risk (Figure 27), allowing communities and planners to explore various scenarios for development and fire management (Morehouse, Christopherson et al. 2006).

Governing Land Use

Reducing long-term conflicts between fire and society first requires understanding where on the landscape fires are most likely to occur, and integrating this understanding into land use, fire management and restoration planning (Moore 1981; Sisk et al. 2005; Dickson et al. 2006). In this respect, planning for long-term forest and community health is consistent with other goals, such as reducing the pervasive effects of urban and exurban sprawl (Ewing et al. 2005). In many cases these conflicts are recognized only after the fact, sometimes tragically. Land-use planning tools offer Arizona a proactive model to encourage communities to undertake landscape planning and zoning with regard to fire threat before a catastrophic event takes place.

In a recent publication of the American Planning Association, Cohen and colleagues (2001) observed that an increased commitment to rational land use is a more effective—and cost-effective—way to approach the national fire risk problem. They note that the siting of new developments represents a particularly important opportunity to minimize fire risk, as each new development in fire-prone forests exacerbates an already huge challenge. Zoning tools, such as overlay zones, development reviews, and subdivision regulations are already widely used for similar situations, such as controlling development in floodplains, coastal dunes, barrier islands, and other unstable areas.

Minimizing tensions between development and wildland fire needs will require careful planning of the location and type of development in relation to specific factors that govern wildland fire risk and behavior.

Communities around the U.S. are beginning to undertake pre-fire land use initiatives, and interesting lessons can be learned from those examples. For example, San Diego County, California is considering zoning that would assess where homes are located as part of a design review process (Jacob 2003). Their recommendations suggest that structures should be “built away from ridge tops, canyons, and steep slopes” and that the location of roads, homes, parks and recreation sites within a subdivision should be reviewed relative to fire danger”. The San Diego Fire Recovery Network (SDFRN) was founded in October 2003 as a response to the large firestorms that year (see http://www.sdfirerecovery.net/). Among the SDFRN’s recommendations are to “Avoid building in fire-prone locations, such as in or near chaparral, on ridgetops or steep slopes, or on topography subject to strong Santa Ana winds. Where we cannot totally avoid such conditions, minimize risks by configuring developments to reduce the total amount of urban-wildland edge: cluster and condense development and avoid creating convoluted urban-wildland edges. Avoid “estate” style housing, with residences scattered within a matrix of highly flammable vegetation.” This is typical of the kind of thoughtful land-use policy that could be implemented in Arizona within existing regulatory frameworks.

Ventura County, California, the site of large fires in 2005 and 2006, has also addressed living in the WUI, including recommendations related to vegetation management, weed abatement, creation of defensible space, etc. High hazard fire codes were adopted for planned developments, with consideration of emergency access, availability of water for fire fighting, greenbelt setbacks, and types of construction noted as important planning elements (Roper 2003). The state of Montana is considering broad legislation that would give counties authority to regulate new subdivisions relative to fire risk and related public expenses (Lemon 2006).

Zoning can take into account potential fire probability and hazard as a means of preventing or reducing potential land use conflicts. For instance, a Forest Service General Technical Report (Moore 1981) recommends that a community should “zone, for its relative fire hazard severity, all land, whether in a city or unincorporated area, that is not already developed for residential, commercial, industrial, or cultivated agricultural use, in addition to land-use or other zoning.” An important lesson is that the location of development may have as much of an impact on the health of fire-adapted ecosystems as any other variable.

Hazard avoidance is the first rule of hazard mitigation. Minimizing tensions between development and wildland fire will require careful planning of the location and type of development in relation to specific factors that govern wildland fire risk and behavior. Areas with frequent ignitions, fire-prone vegetation, or areas upslope of fire-prone geographic features, such as canyons or steep slopes, may warrant careful consideration of potential fire hazards, reduction of losses of life and property, and costs and risks associated with fire suppression. For example, many large fires in the past 20 years in northern Arizona have been strongly associated with "topographic roughness" (Dickson et al. 2006), a factor that can be taken into account by planners in siting new developments.

Public expectations and institutional duties will probably continue to lead public land-managing agencies to devote resources to protecting private property located in fire prone landscapes. Thus, in the long-term, in addition to enhancing community preparedness, careful consideration of where development should occur could save local, state, and federal governments billions of dollars in fire prevention, suppression, and liability costs. Chi (2004) notes that after the Southern California fires of 2003, public debate began to shift toward "closer monitoring of urban developments extending into the backcountry, with any such expansion governed by stringent building codes."

Resolving the tension between potentially catastrophic wildfire and community development will not be easy. On the other hand, the potential for devastating loss is sufficiently high that new ideas must be explored and tested soon. As a first step, we offer the following ideas for implementing a land-use approach in Arizona.

Recommendations for implementing a land-use approach in Arizona

1. *Classify undeveloped lands based on relative fire hazard (analogous to other existing recognitions of risk and public expense from natural hazards);*
2. *Require new development plans to contain an evaluation of fire probability based on surrounding vegetation types, topography, and known weather patterns;*
3. *Review land-use ordinances and building codes, and adopt or revise as necessary to minimize communities' exposure to fire danger;*
4. *Incorporate perimeter protection ("buffer zones") into the design of new developments to allow for maintaining natural fire in adjacent forests;*
5. *Revise planning requirements under Growing Smarter legislation to encourage communities and counties to deal with fire risk proactively at the landscape scale; and*
6. *Create programs to educate residents of forest communities and developers about steps that they can take to reduce exposure to fire hazard and improve forest health.*

With adequate preparation, existing communities can greatly increase the probability that fires will be able exist nearby or even enter developed areas without loss of life or significant property damage.

6 The way forward

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"How to reduce fire risk is not a one-answer question. It involves multiple variables that can only be properly addressed by examining the entire fire environment. Fire risk reduction is a land-planning issue, not something that can be accomplished by grinding up native wildlands in a quixotic attempt to control nature…We can create communities that can safely coexist with large wildland fires if we have the courage and humility to objectively examine our own perceptions and listen to what science has to offer." (Halsey 2007)

In Arizona, the front line of forest health issues at landscape scales occurs where the developed human environment interfaces with the natural environment. All Arizonans want to reduce the risk of damage to lives and communities. At the same time they want healthy forests as a legacy for the future, and efficient expenditure of scarce public resources. The key to achieving this resolution is to understand both fire and development at the scale of whole landscapes, and then to use this understanding to promote and manage the coexistence of forests, fire, and people (Sisk et al. 2005). Action is needed urgently, due to the combination of altered to altered forest conditions, climate variability and change, and the increasing human presence in the landscape.

Fire is not the enemy; indeed, it is an essential component of healthy, multiple-use forests in Arizona. While the character of some fire-adapted ecosystems has been altered over the past century, the inevitable spatial coincidence of landscape-scale fires and development is fundamentally challenging to society and ecosystems. Resolving or minimizing current and future conflicts between wildland fire and development—including hazard avoidance and mitigation, costs and risks of suppression, smoke, and impacts of development-induced suppression on restoration and maintenance of fire-adapted ecosystems—will require new thinking and the use of new analytical tools ((Steinberg 2006).

The future for Arizona forests cannot consist only of expanded suppression, of which one legacy is the extreme and destructive fires of recent years. While suppression may be necessary for the immediate future in instances where the threat to communities is considerable, an accelerated use of prescribed and managed fires in WUI and wildland fire use in more remote areas must be continued, along with mechanical treatments when fuel accumulations are high and pose an unacceptable risk to life and property.

The Healthy Forest Initiatives (HFI) and the Healthy Forest Restoration Act (HFRA), have given forest land managers greater ability to restore fire-adapted ecosystems, especially in WUI areas. By regulation, HFI provides for some categorical exclusions from National Environmental Policy Act (NEPA) analysis in forest projects affecting forest health in fire-adapted ecosystems. HFRA gives priority for thinning projects to communities that have developed wildfire protection plans developed, and a budget level for Congressional appropriation of $750 million for forest fuels management on public and private lands. In Arizona, more than 27,000 acres were treated in 2004 by mechanical removal of trees or by prescribed burning on our six national forests, at a cost of $5.3 million. This was expanded to 85,000 acres in FY 05 at an estimated cost of $8 million.

Managing the growth of the WUI emerges as an important policy goal, an expression of an important public interest, and the beginning of a path to sustainability in Arizona's forests. This does not mean that development should stop, but rather it must be done carefully, intelligently, and only where it will not create new conflicts and hazards, so that wildfire risks and costs are minimized and forest sustainability is maximized. The state as a whole should consider the social, environmental, and financial costs of continued uncontrolled development into fire-prone areas carried out without due consideration for fire and forest sustainability.

This resolution is important not only to reduce risk to lives and communities, but also to offer a realistic chance of preserving healthy, functioning forests into the future. Land-use planning is a critical-path issue for the long-term health of fire-adapted ecosystems (ESA 2000). Restoration and maintenance of keystone fire processes are crucial for maintaining the health of fire-adapted ecosystems. Just as public expectations and institutional duties require land management agencies to assume some level of cost and risk protecting private property located in fire prone landscapes, so should development of private property reflect its effects on forest health, and management and restoration of fire-adapted ecosystems.

In many respects, these proposals to integrate development planning with forest health mirror larger trends in American society to recognize the importance of ecologically sustainability (Floyd and Peaser 2003). Maintaining safe communities in the West where fire is a natural part of the ecosystem will require education, commitment, and creative thinking. These steps are just the beginning, but the time for action is now.

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