# The Wildland Fire Challenge

## Focus on Reliable Data, Community Protection, and Ecological Restoration

Ecological Analysis

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The Wilderness Society

# The Wildland Fire Challenge

## Focus on Reliable Data, Community Protection, and Ecological Restoration

By
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and
Bo Wilmer

The Wilderness Society

## Acknowledgments

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This science report is one of a series that stems from conservation research studies conducted by The Wilderness Society's Ecology and Economics Research Department. Other recent reports in the series include:

- **Energy & Western Wildlands:** A GIS Analysis of Economically Recoverable Oil and Gas
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## Preface

Over the past several summers, we have read the headlines, heard the newscasts, and seen the film footage: wildland fire! From Glacier National Park straddling the Canadian border to the foothills of the Colorado Rockies to the affluent suburbs that hug the desert's edges in Arizona and California, fires have raged through the forests and grasslands of the drought-stricken West. Flames have destroyed — or threatened to destroy — homes and other structures and placed thousands of residents and firefighters in harm's way.

Understandably, citizens and elected officials alike are calling for a national fire policy that will reduce the threat of wildland fire to our communities. A number of "answers" have surfaced, including several high-profile proposals that would increase the rate of logging and thinning on America's national forests. These actions are needed, proponents say, to reduce forest fuel loads and to pay for fuel treatments.

In The Wildland Fire Challenge: Focus on Reliable Data, Community Protection, and Ecological Restoration, forest ecologist Dr. Greg Aplet, from The Wilderness Society's Four Corners regional office in Denver, and landscape ecologist Bo Wilmer, of our Seattle-based Center for Landscape Analysis, analyze the information now feeding these plans to log the national forests. Their careful assessment reveals that the supporting data are not only unreliable, but the plans fail to address community protection — a priority for any viable wildland fire policy. In addition, their work pinpoints non-federal lands as the source of the greatest danger to the communities most at risk. The report also outlines the first steps toward developing a national wildland fire policy that will truly succeed in reducing the menace of wildland fires and will allow land managers to rank landscapes for fuel reduction and ecological restoration.

The wildland fire challenge is serious. We must meet it through the implementation of responsible policies that incorporate both sound information and reasoned actions. This report provides the rationale and guidelines to move our nation forward in achieving that goal.

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## Report Highlights

In recent summers, large forest fires have burned millions of acres and hundreds of homes across western states where drought conditions prevail. Alarmed elected officials agree that fuel loads in forests must be reduced to protect communities and restore ecosystems, but they disagree over where and how much.

In part, disagreement stems from available information that exaggerates the amount of forested land at risk from high-intensity wildland fire. Conventional wisdom holds that the greater the perceived risk, the more treatment (logging and thinning) should take place. However, the information used to make these determinations in some proposed wildland fire policies is erroneous.

In this report, we evaluate the quality of information that feeds wildland fire policy, assess the fire management challenge with a focus on community protection, and outline the first steps in a comprehensive strategy to prioritize where fuel reduction and ecosystem restoration measures are needed.

Among our key findings:

- The condition class map prepared by the Forest Service, which is the basis for proposed high-profile wildland fire policy, is not reliable.
  - ✓ It depended heavily on unrepeatable "expert opinion," which led to inconsistent classification of vegetation across regional boundaries.
  - ✓ Low resolution and scale incompatibilities in the underlying data led to overestimation of degraded conditions.
  - ✓ The use of forest-density data as a surrogate for canopy closure was inherently flawed; forest density and canopy closure are separate, unrelated measures.
- Most important, the condition class map fails to address wildland fire policy's top priority — community protection.
- Despite widespread media attention on large fires on federal land in the West, most communities at risk from wildland fire are in the eastern United States, particularly the Southeast.
- Most threats to communities at risk from wildland fire arise on state, local, and tribal lands, not on federal land.
- The majority of forests that are good candidates for restoration are on private land in the East; only a small portion of candidate sites are likely to contain byproducts that can be sold to help offset the costs of restoration.

### Recommendations

For this report, we used government data and state-of-the-art technology to map protection zones around communities at greatest risk from wildland fire. There is little doubt that fuel treatments on the 11 million acres of community protection zones we identify will be costly. That will also be the case for any lands located outside community protection zones that may require treatment for ecological restoration. It is therefore important to prioritize fuel treatments and restoration goals.

A successful, comprehensive wildland fire policy will incorporate principles of prioritization, based on reliable information; distinguish between fuel treatment for community protection and for ecological restoration; fight fires only where they have to be fought; use prescribed fire to manage fuels where it is not safe to use wildland fire; invest in local collaboration and better information and tools for wildland fire management; and monitor conditions over time.

▼

The condition class map prepared by the Forest Service fails to address what should be the top priority of wildland fire policy — community protection.

▲

We recommend the following:

**Condition Class Map**

- Until data are compiled to produce a reliable condition class map, the existing map should not be used to prioritize fuel treatments across the country.

**Community Protection Zones**

- Individual homeowners must take action to protect themselves. Information is readily available through resources such as the FIREWISE website (www.firewise.org). Installation of metal roofs, moving firewood away from homes, and keeping yards clear of fine fuels can dramatically lower the probability of home ignition.
- Funding must be channeled to communities for the design and implementation of community-based wildland fire plans. The 10-year Comprehensive Strategy, facilitated by the Western Governors' Association, relies on community-based wildland fire planning to identify critical needs. In some cases, money will be needed only for homeowner education; in other cases, the less affluent will need assistance to do their part.
- Better information at the local scale must be developed to help set priorities, and funding is needed to gather that information. Rigorous application of risk-evaluation criteria would help, but often information is not available on potential behavior of wildland fire, the values at risk, and community infrastructure. In some cases, gaps can be filled with census data and geographic information system or remote sensing data. Some states are moving in this direction.

Until data are compiled to produce a reliable condition class map, the existing Forest Service map should not be used to prioritize fuel treatments across the country.

**Ecological Restoration**

Our analysis suggests that as many as 350 million acres may benefit from restoration planning in what is known as "fire regime 1" alone. Other fire regimes also merit eventual attention. Over such a vast area, restoration cannot be successful unless approached rationally and efficiently. There is simply not enough money available to treat every acre.

On the bright side, much of this area does not need treatment. Instead, it would benefit from additional protection from logging, road construction, and other ecologically disruptive activities.

We recommend incorporation of the following three principles into a comprehensive wildland fire policy. The principles were developed during a two-year collaborative process involving forest scientists, rural community advocates, and forest activists from across the nation.

1. Ecological Forest Restoration: Enhance ecological integrity by restoring natural processes and resiliency. Restoration should focus not on individual species or the structure of ecosystems, but on ecological processes, thereby enhancing the ability of ecosystems to rebound from natural and human-caused disturbances.
2. Ecological Economics: Provide economic incentives to encourage ecologically sound restoration.
3. Communities and Work Force: Restoration, if done right, should lead to revitalized rural economies.

## 1. Background

### Fire in Ecosystems

Virtually every North American ecosystem has experienced fire over its evolutionary history. Predictably, in regions such as subalpine forests where precipitation is high and temperatures low, fire was an infrequent visitor; periodic drought and hot weather were required to dry vegetation enough to burn. Between the infrequent fires, fuels built up naturally to high levels, ensuring that when fire did return, it was big and hot. In other regions such as southwestern ponderosa pine forests where "fire weather" is common, fire was also common. It burned frequently enough to keep fuels from amassing and consumed mostly grass and other surface vegetation. Plant communities in these places are adapted to these different "fire regimes."

A fire regime is a description of the way fire behaves in an ecosystem. It includes all of the complex characteristics of a fire — size, severity, frequency, and seasonality (Agee 1993). Generally, though, fire regimes can be characterized based on just their frequency (the number of years between fires in one place) and their severity (their tendency to kill vegetation). Many fire scientists now use a simplified classification scheme that assigns all fire behavior to one of five fire regimes (Table 1).

A low-severity fire does not consume the dominant vegetation, whereas a stand-replacing fire kills or consumes most of the vegetation. Under fire regime I, fires are frequent, burning across the forest floor but leaving trees intact. Fires under regime II behave similarly, but they occur in grasslands or low shrublands where there are no trees; they


JOHN CARR

Underburn fires, characteristic of natural conditions in fire regime I, burn grasses and forbs at ground level; overstory trees remain intact. If allowed to burn freely, frequent underburn fires maintain an open understory and prevent the build-up of fuel that feeds wildland fires.

**TABLE 1.**

**Characteristics of Fire Regimes**

This table summarizes important characteristics of the five wildland fire regimes and presents examples of vegetation that are typically found in each regime. Fire regime I occurs in open forests with grassy understories. Fire regime II occurs in grasslands or low shrublands. Fire regimes IV and V kill large patches of forest, while fire regime III produces a patchwork of light surface fire and intense crown fire.

| | Severity | Frequency | Vegetation | Examples |
|---|---|---|---|---|
| Fire Regime I | Low | 0-35 years | Open forests | Longleaf pine, southwestern ponderosa pine |
| Fire Regime II | Stand replacing | 0-35 years | Grasslands | Prairie, Everglades |
| Fire Regime III | Mixed | 35-200 years | Forests and shrublands | Redwood, sagebrush, interior Douglas-fir, Rocky Mountain ponderosa pine |
| Fire Regime IV | Stand replacing | 35-200 years | Dense forests and shrublands | Chaparral, lodgepole pine, pitch pine |
| Fire Regime V | Stand replacing | >200 years | Dense forests | Spruce-fir, coastal Douglas-fir |

*Source: Schmidt et al. 2002*

are considered as stand replacing. Fire regimes IV and V consume large patches of vegetation infrequently, and fire regime III is intermediate in effect, behaving as a surface fire in some places and burning small- to medium-sized patches more severely elsewhere.

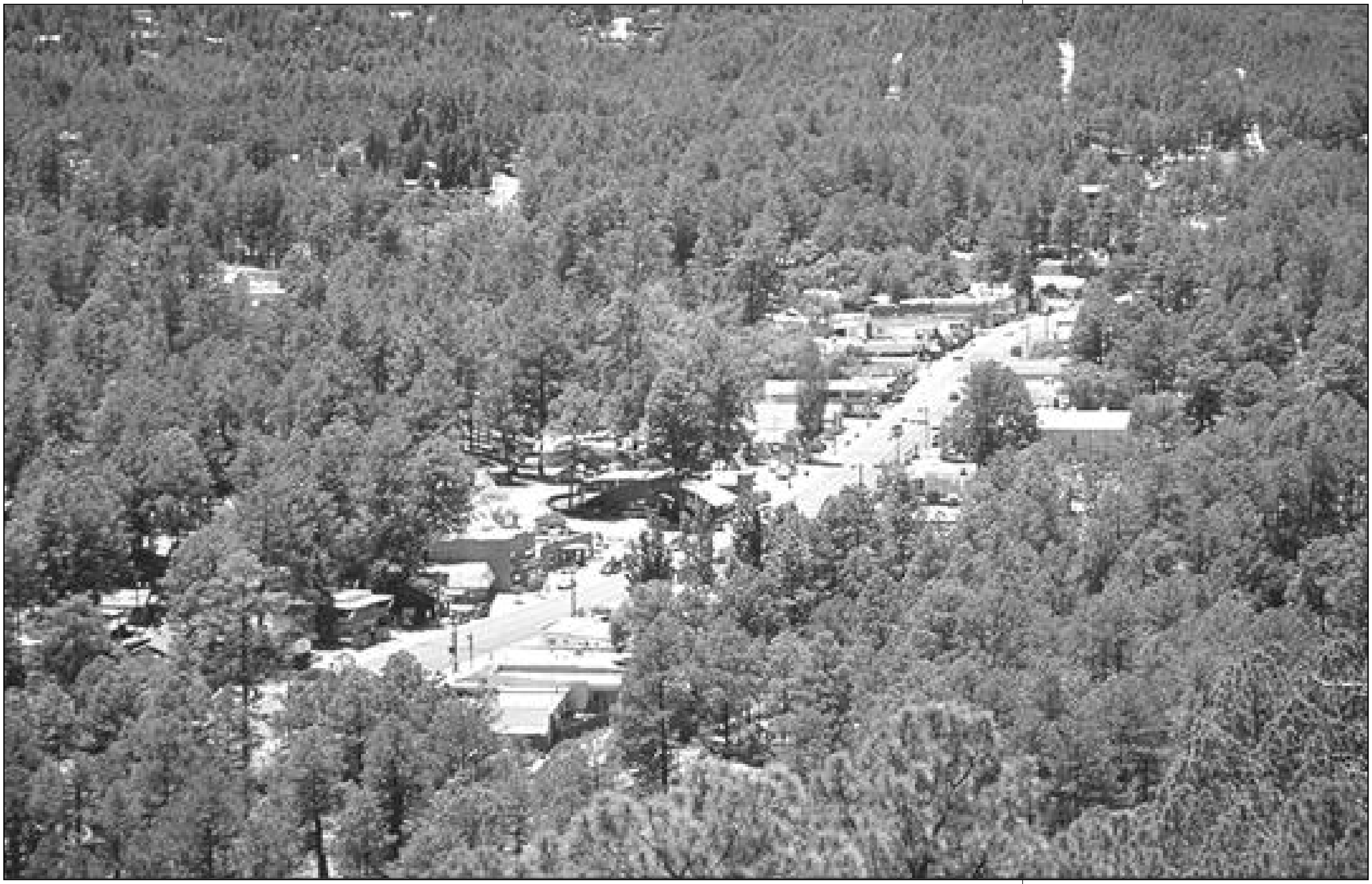
Under natural conditions, ecosystems recover quickly following fire and develop characteristics such as continuous grass, shrub, or tree cover that ensure perpetuation of the fire regime. In many parts of North America, the vitality of historical ecosystems depended on characteristic fire regimes that, in some cases, were abetted through intentional fires set by American Indians, who used fire extensively to clear ground around their settlements, favor certain plants, drive game, and refresh wildlife habitat (Pyne 1982, Cronon 1983, Whitney 1994). But it is not clear how much of an impact this burning had on fire regimes. Several authors suggest that Indians set most of their fires locally, and the impact faded with distance from their settlements (Vale 1998, Hammett 2000, Baker 2002). Others write that while Indian burning may have been common, it added only marginally to the effects of lightning-caused fires (Allen 2002). Still others contend that Indian burning pervasively affected vegetation character (Denevan 1992, Anderson and Moratto 1996, Krech 2000). For purposes of this report, it does not matter. Fire regimes are defined by the history of burning, not by the source.

With the arrival of Euro-American settlers, the situation changed dramatically. Indians were forcibly removed from large parts of North America, forests were cleared for agriculture, and fires were intentionally excluded. During the late nineteenth century in the western United States, vast herds of livestock brought an end to the grasses that served as the basis of fire regime I. With the competing grass gone, tree seedlings flourished, and under the protection of efficient fire suppression forces, the seedlings grew into dense forests capable of carrying roaring, crown fires on lands where surface fire once prevailed. In essence, fire regime I has been eliminated, and the ecosystem composition, structure, and function that depended on it have changed — dramatically in some cases.

Outside of fire regime I, the story is different. Where fire typically was infrequent in the West, its recent absence because of fire suppression has had little effect; vegetation and fire regimes remain essentially unchanged.

In addition to fuel build-up, the past few decades have witnessed another important phenomenon. Many parts of the West are experiencing a record drought. According to the American Meteorological Society and the National Oceanic and Atmospheric Administration (NOAA), the 1990s were the warmest decade on record — 1997 and 1998 saw sequential record global annual mean surface temperatures (Bell et al. 1999). Regions of North America also experienced record drought and heat waves in 2000, 2001, and 2002 (Waple and Lawrimore 2003, Waple et al. 2002, Lawrimore et al. 2001, Bell et al. 2000).

These extreme temperatures and drought arrived on the heels of the relatively wet 1970s and early 1980s, a result of the periodic fluctuation in sea temperatures known as El Niño (Swetnam and Betancourt 1998). More trees and rapid vegetation growth during this time contributed to increased fuel loads as summers in western states entered an increasingly hot and dry climate cycle. Despite the periodic fluctuations of El Niño, temperatures continue to rise at an unprecedented rate. According to NOAA's National Climatic Data



KARI K. BROWN

Interface communities such as in Ruidoso, New Mexico, may be particularly susceptible to wildland fire during drought conditions. Municipal fire departments can be quickly overwhelmed by fire that advances rapidly through the forest crown.

Center, "The average temperature increase in the Northern Hemisphere over the 20th century is likely to have been the largest of any century during the past 1,000 years" (Karl 2001). Climate change will likely influence both the frequency and severity of future wildland fires.

## Fire in Communities

Changes in ecosystems are not alone in affecting the fire situation. People are a big part of the story. According to the U.S. Census Bureau, the population of the eleven western states increased by 12.5 million people (26.5 percent) from 1990 to 2000. Settlement continues to encroach on surrounding forests and shrublands as cities expand and people seek supposed serenity in suburbs and even more distant country (Duane 1993). The affluence of recent decades and tax breaks for second homes have made it possible for more people to own vacation homes in forests. Those homes are often located in the midst of some of the West's most fire-prone, low-elevation forest lands such as the ponderosa pine forests along Colorado's Front Range and the pinyon-juniper woodlands around St. George, Utah.[1]

Whether the homes are primary or secondary residences, the "mountain aesthetic" — wooden buildings and decks, stacks of firewood, and nearby trees — is often important to the people who live

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[1] U.S. Census Bureau data show that 19 of the 50 fastest-growing U.S. counties from 1990 to 2000 are in the fire-prone western states of Colorado (11), Utah (3), Nevada (3), and Idaho (2). The fastest growing (191 percent) was Douglas County in Colorado. Part of Douglas County burned in the 2002 Hayman Fire.

in them. But this mix of flammable homes and low-elevation, fire-prone vegetation creates an explosive fuel. Wildland firefighters increasingly find themselves in dangerous situations, defending buildings instead of engaging in more traditional indirect attack techniques. What to do about the wildland-urban interface problem is the most pressing question in wildland fire management.

## Crisis and Attempts at Resolution

Changes in fuel loads, drier weather, and flammable communities have combined to create a sense of crisis. In 2002, Colorado, Arizona, and Oregon witnessed the largest fires in more than a century. In ponderosa pine forests, scientists believe recent fires are more severe than at any time in the historical record (Betancourt et al. 2003). Many of these fires are burning adjacent to, and sometimes in, communities, resulting in the tragic loss of homes and lives. National media featured the 1991 Oakland Hills fire, 2000 Cerro Grande fire adjacent to Los Alamos, 2002 Hayman fire near Denver, and 2003 Glacier National Park fire on a daily basis, contributing to the sense of crisis.

Organizations and governments at all levels have produced a number of policy initiatives to try to reverse the trend. One of the most high profile was the National Fire Plan (Glickman and Babbitt 2000), developed during the Clinton administration in response to the 2000 fire season. That plan contained five key recommendations, among them the need to reduce fire risks, work with local communities, and be accountable. Congress appropriated more than $2 billion to fund the National Fire Plan, more than twice the typical amount appropriated for wildland fire in a given year (Gorte 2000).

State governments also organized. As a result of a meeting between western governors and the secretaries of Agriculture and the Department of the Interior in August 2000 at Salt Lake City, Congress inserted language into the committee report for the appropriations bill that funded the National Fire Plan, directing the two secretaries to work with states and other interested parties in devising a long-term plan for managing fire.

During 2001 and 2002, in a process facilitated by the Western Governors' Association, a broad-based group of stakeholders produced the 10-year Comprehensive Strategy (Western Governors' Association 2001, 2002). That initiative sought the same goals as the National Fire Plan, but opened the fire planning process to all stakeholders through a collaborative structure, set priorities on community protection and at-risk watersheds, and recommended accountability through monitoring. In May 2002, governors, the National Association of Counties, National Association of State Foresters, and the secretaries of Agriculture and the Department of the Interior agreed to the approach and signed the document. A critical point of consensus was that the strategy could be implemented without changes to existing law.[2]

In August 2002, the Bush administration announced a new fire plan, called the Healthy Forests Initiative. Despite the earlier federal commitment to the Comprehensive Strategy, the new plan called for changes in law through a series of regulatory revisions and congressional

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[2] Both the Comprehensive Strategy (August 2001) and its Implementation Plan (May 2002) included the following language: "This strategy should enhance collaboration among all levels and all parties for planning, decision-making, implementation, monitoring, and learning *without altering the responsibilities or statutory authorities of participating Federal and State agencies*" (emphasis added)

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Making a house fire safe does not necessarily mean the removal of all trees. Eliminating brush from around a house, ensuring an accessible water source, installing a metal roof — all can go a long way toward reducing the harm of wildland fire. Such measures were taken for this residence in West Glacier, Montana.

actions. In essence, the plan sought to address the fire situation by making it easier for federal land management agencies to take action without regard for environmental protections embedded in law and without regard for public participation in decision-making. A number of proposals followed, some designed to implement the Healthy Forests Initiative, some to counter it.

## Need for Fuel Load Reduction

While the debate over approaches continues, wildland fires continue to burn throughout the West. There is clearly a need to prioritize areas for treatment, as virtually all parties to the debate agree. Because all of North America evolved with fire, it can be said that all vegetation is fire adapted to some extent. Given that, how can the areas most worthy of attention be identified? And how can scarce resources be allocated to achieve the goals of community protection, collaboration, and accountability?

In an attempt to help set priorities, scientists at the USDA Forest Service's Rocky Mountain Research Station have worked on an approach to identify which lands have been most affected by changes in fire regimes. Their initial results were published in a 2002 report called "Development of Coarse-Scale Spatial Data for Wildland Fire and Fuel Management" (Schmidt et al. 2002). This study represented the first national look at fire from an ecological standpoint, examining how ecosystems have changed as a result of alterations in fire regimes on a continental scale. The report identified approximately 200 million acres of federal land that are at risk in the event of fire. Such numbers caught the attention of politicians, who proposed dramatic changes in federal

MICHELE CRIST

ESTATE OF VIRGINIA KLINE (UW-MADISON IMAGE COLLECTION)

MICHELE CRIST

Fire-dependent plant communities, when deprived of fire, can quickly grow shade tolerant understory trees. In drier climates, these densely grouped sub-canopy trees greatly increase fuel loads. The ponderosa pine stand in Colorado, shown immediately above, is overgrown with Douglas-fir and white fir, while the red oak forest in Wisconsin, shown at upper right, is intermixed with thick, mid-story sugar maples. In contrast, because of episodic ground-level fires, the old-growth ponderosa pine forest in Idaho shown in the lower photo maintains an open understory typical of natural conditions in fire regime I.

wildland fire management policy (for example, the administration's Healthy Forests Initiative) to address the threat.[3]

While a worthwhile scientific endeavor, the study has major shortcomings that diminish its usefulness. First, the report's ecological approach did not include the threat of fire to communities, which is widely recognized as the highest priority of wildland fire management.[4] Second, limitations of data used for the assessment made it impossible to accurately determine actual on-the-ground conditions. In recognition of this factor, the authors cautioned against inappropriate use of the maps: "The end products were not intended to be used at scales other than a coarse scale" (Schmidt et al. 2002).

In this paper, we reveal why the scientists insisted that their maps not be misused. We then investigate the extent of the community protection challenge and conclude with an examination of where forest restoration planning should be focused.

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[3] The most frequently cited number is "190 million acres of federal land at high risk of catastrophic fire," which has been used by President Bush, Secretary of the Interior Gale Norton, Council of Environmental Quality Chairman James Connaughton, and Congressman Scott McInnis, among others. This number does not stem from the Schmidt et al. report. It comes from extrapolation of figures in an unpublished Forest Service report available at http://fire.org/frcc/HannEtAl2003CohesStratOutcomes.pdf (Wendell Hann, pers. comm.) in which the authors averaged the percentage of federal land at significant risk based on four site-specific analyses. Schmidt et al. (2002) provides a more comprehensive analysis.

[4] The report included a supplementary analysis titled "Wildland Fire Risk to Flammable Structures," but this was not the focus of the report. Thus, the supplementary analysis has received little attention.

## 2. Prioritizing Fuel Treatment: Limitations of Existing Data

A century of ecological research has revealed the important role of fire in the development of virtually every type of vegetation on lands in the United States that have not been converted to agricultural and urban uses (Kozlowski and Ahlgren 1974, Brown and Kapler Smith 2000), including the negative consequences to some ecosystems that have resulted from a century of successful fire exclusion (Covington and Moore 1994, Mutch et al. 1994). Forests have often encroached on openings and now shade out rare plants and wildlife habitat (see Hessl and Spackman 1995, Greenlee 1997), and some forests have increased in density to the point that inevitable fires, which once burned harmlessly through the understory, now grow into raging crown fires that threaten ecosystems and people and their property (Covington et al. 1994).

Before these threats can be addressed and healthy ecosystem structures restored, it is essential to understand the distribution of the problem. Not all vegetation has been equally affected by fire exclusion, and restorative treatments are not equally appropriate everywhere. To address the information gap, Forest Service scientists produced a map of the current condition of U.S. vegetation with respect to fire ecology (Schmidt et al. 2002). That map, "Fire Regime Current Condition Classes," has been widely cited by policy-makers in their efforts to focus attention on the fire situation (Bush 2002, Norton 2002).

Because of the important role this research has played in recent debates, it deserves close scrutiny. What does the research really show? What are its limitations?

### What the Scientists Did

Methods used in the preparation of the condition class map are complex, involving a combination of expert opinion, existing maps, and map-based data analyzed in a geographic information system. Schmidt et al. (2002) describe the complicated process in some detail, but it can be summarized as follows.

Teams of experts on vegetation ecology were assembled for each of the Forest Service's eight regions in the conterminous 48 states. Each team was asked to describe the stages of normal vegetation development for various vegetation types in each region.[5] They were then asked to use three condition classes to rate whether current conditions, described as combinations of existing vegetation types and forest density, were (1) consistent with normal vegetation development, (2) moderately departed from normal because of natural fire disruption, or (3) significantly departed from normal.[6] The ratings, or condition classes, were then mapped as shown in Figure 1 (page 13).

Under this classification scheme, lands in condition class 1 are still in good condition with regard to fire ecology; forests

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[5] Vegetation can be said to develop through several stages. For example, foresters often use the stages of seedling, sapling, pole, sawlog, and old growth to describe forest development. Often, the species composition of vegetation changes over time in the process of succession. In the report prepared by Schmidt et al. (2002), Forest Service scientists described vegetation change using stages defined by different combinations of vegetation type (for example, shrub, aspen, spruce-fir forest) and density (for example, open forest, moderately closed canopy, closed canopy).

[6] This method appears to be conceptually sound for forest types such as longleaf pine, ponderosa pine, and oak woodlands that were historically kept open by frequent fire. It is less clear how it applies to the health of eastern deciduous forests that have experienced changes in species composition, not canopy closure, as a result of fire exclusion.

that historically burned with severe crown fire will still burn with a severe crown fire, and forests that historically were maintained in an open condition by fire remain in an open condition. Under condition class 2, ecosystems are at moderate risk from fire, having undergone increased densities of trees and moderately increased fuel loads. Ecosystems in condition class 3 would be significantly harmed in the event of fire as a result of dramatically increased fuel loads. The precise definitions used by the scientists are included in Table 2.

Analysis of the map (Figure 1) shows that 64.9 million acres (33 percent) of national forests and 128.4 million acres (56.4 percent) of Department of the Interior lands were in good condition with respect to fire ecology (Table 3). Some 230.7 million acres of federal land were at moderate to significant risk because of changes in fire regime, including 131.5 million acres of national forests and 98.2 million acres of Interior lands.

## Errors in the Condition Class Map

Scientists who developed the map warn of a number of weaknesses in their analysis that limit its usefulness. First, much of the process of constructing the map involved subjective judgment calls. For example, the succession diagrams that provided the basis for determining whether current conditions are normal or not were speculative and oversimplified. In reality, vegetation change can follow a number of very complex pathways not reflected in the diagrams. Because each regional team of scientists

**TABLE 2.**

**Fire Regime Current Condition Class[a] Descriptions**

These descriptions were prepared by Schmidt et al. (2002).

| Condition class | Fire regime | Management Options |
|---|---|---|
| 1 | Fire regimes are within an historical range, and the risk of losing key ecosystem components is low. Vegetation attributes (species composition and structure) are intact and functioning within an historical range. | Where appropriate, these areas can be maintained within the historical fire regime by treatments such as fire use. |
| 2 | Fire regimes have been moderately altered from their historical range. The risk of losing key ecosystem components is moderate. Fire frequencies have departed from historical frequencies by one or more return intervals (either increased or decreased). This results in moderate changes to one or more of the following: fire size, intensity and severity, and landscape patterns. Vegetation attributes have been moderately altered from their historical range. | Where appropriate, these areas may need moderate levels of restoration treatments such as fire use and hand or mechanical treatments to be restored to the historical fire regime. |
| 3 | Fire regimes have been significantly altered from their historical range. The risk of losing key ecosystem components is high. Fire frequencies have departed from historical frequencies by multiple return intervals. This results in dramatic changes to one or more of the following: fire size, intensity, severity, and landscape patterns. Vegetation attributes have been significantly altered from their historical range. | Where appropriate, these areas may need high levels of restoration treatments such as hand or mechanical treatments before fire can be used to restore the historical fire regime. |

[a] *Fire Regime Current Condition Classes are a qualitative measure describing the degree of departure from historical fire regimes, possibly resulting in alterations of key ecosystem components such as species composition, structural stage, stand age, canopy closure, and fuel loads. One or more of the following may have caused the departures: fire suppression, logging, livestock grazing, or other management practices; introduction and establishment of non-native plant species; introduced insects or disease.*

**TABLE 3.**

### Area of Federal and Non-federal Lands in the Three Condition Classes

The table includes lands (excluding agriculture, barren, water, and urban/development/agriculture cover types) in the conterminous 48 states as reported by Schmidt et al. (2002).

| Ownership | Condition Class 1 (good condition) | Condition Class 2 (moderately degraded) | Condition Class 3 (significantly degraded) | Total |
|---|---|---|---|---|
| | | MILLIONS OF ACRES | | |
| National forests | 64.9 | 80.4 | 51.1 | 196.5 |
| Department of the Interior Lands | 128.4 | 75.8 | 23.4 | 227.7 |
| Other lands | 404.7 | 313.3 | 107.3 | 825.1 |
| All lands (total) | 598.0 | 469.5 | 181.8 | 1249.3 |

made up their own succession diagrams and determined relative departure independently, identical vegetation types were assigned to different condition classes by different regional teams. Along regional borders, the same vegetation was assigned to different condition classes. These edge-matching problems were later resolved through negotiation among regional teams, but they strongly indicate the subjective nature of the classifications. As the authors state in the report, their methods cannot be repeated.

Second, most data used in the construction of the condition class map were collected at a scale that limits their usefulness. As well, inconsistencies in scale from map to map generated errors. The map used to represent historical vegetation (the potential natural vegetation map)[7] was drawn at a scale where one inch on the condition class map represents 50 miles on the ground, thus excluding the possibility of representing local variation in vegetation. The scientists further adjusted the vegetation boundaries from the historical map to match terrain features and combined 118 vegetation types from the historical map into 63 types. The result was a simplified depiction of historical vegetation that masked natural variability at the local scale.

Third, the succession diagrams that determine normal vegetation change were developed only for the simplified historical vegetation classes. Other naturally occurring vegetation was not considered part of a given successional sequence; it was wrongly considered a departure.

The scientists also used forest density data as a surrogate for structural stage,[8] warning that this was a weakness in the

### Limitations of the Condition Class Map

- The methods relied heavily on unrepeatable expert opinion and judgment calls, which make it impossible to determine exactly how condition classes were assigned.
- Regional teams of scientists used the unrepeatable methods differently in each region, leading to inconsistent classification across regional boundaries.
- Low resolution and scale incompatibilities in the underlying data led to overestimation of degraded conditions.
- The use of forest-density data as a surrogate for canopy closure is inherently flawed.

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[7] The potential natural vegetation map represents the vegetation that its author, A.W. Küchler, believed would exist in the absence of human disturbance. It is not an actual map of historical vegetation, but because it represents vegetation in the absence of major human modification, it is often used as a surrogate for historical vegetation.

[8] The Forest Service scientists considered that some types of vegetation, in the absence of fire, would progress from a healthy, open condition (or structural stage) to a dense, crowded, unhealthy condition. Thus, accurate information on forest canopy cover (structural stage) was crucial to the determination of condition class in some types of vegetation.

KAREN WATTENMAKER

Fires may burn harmlessly through the understory of an open canopy forest. Forest density data used to construct the Forest Service's condition class map (Figure 1) can show how much of a given area is forested, but those data cannot tell how dense the forest is. Therefore, large expanses of perfectly healthy open ponderosa pine forest, like that shown above, could be erroneously rated as most prone to catastrophic fire.

methodology (Schmidt et al. 2002). Structural stage was the key piece of information needed to determine if forests that once flourished in open stands of widely spaced trees had grown more dense and acquired a continuous canopy of explosive fuels. Such data are extremely difficult to develop because they require a close look at every acre, a monumentally expensive task to accomplish for the entire country. Instead, the scientists used readily available forest density data and thereby introduced irreconcilable errors into the analysis.

The forest density data were initially developed by the Forest Service's Forest Inventory and Analysis (FIA) program to produce a forest resources inventory (Zhu 1994). Of particular interest was the amount of wood available for harvest. Existing information on the location of forests was developed with a 1-kilometer$^2$ resolution — not high enough resolution for the FIA inventory. The information described which square kilometers were considered to be forest, but not how much forest existed on each square kilometer. To complete the FIA inventory, the Forest Service developed a method to determine how much of each square kilometer was forested.

Incorporating data with a resolution of 30 meters (30 x 30 meters) from 19 test sites around the country, the agency used regression equations to estimate how much of each 1-kilometer$^2$ pixel in the United States should be covered with forest. Briefly, the number of forested 30-meter pixels in each 1-kilometer pixel was determined at each test site, and a relationship was derived between the number of forested pixels and the "color" of the 1-kilometer pixel (measured from a satellite using multiple bands of limited wavelength). A 30-meter pixel was considered forested if more than 20 percent of it was covered with trees.

In the end, the Forest Service predicted forest density for the entire country based on the regression equations, one for each of 15 different regions (some of the 19 test sites were in the same regions). The resulting map was never tested on the ground. It was, however, believed to be accurate enough to produce useful numbers at a national scale; any over-predictions were matched by under-predictions when the data were aggregated nationally (Zhu 1994).

While these data are useful in assessing forest resources at the national scale, they cannot serve to estimate forest density accurately for the condition class map because that map requires data on canopy cover; that is, how tightly packed trees are in a given area of forest. Only canopy cover can reveal whether a ponderosa pine forest is open and "park-like" — and therefore deemed healthy — or whether it is overgrown with saplings and small trees.

The forest density data used to construct the condition class map, even if they had been verified on the ground as locally accurate, can only show how much of a given area is forest, not how dense the forest is. The two measures are not related and cannot be interchanged.

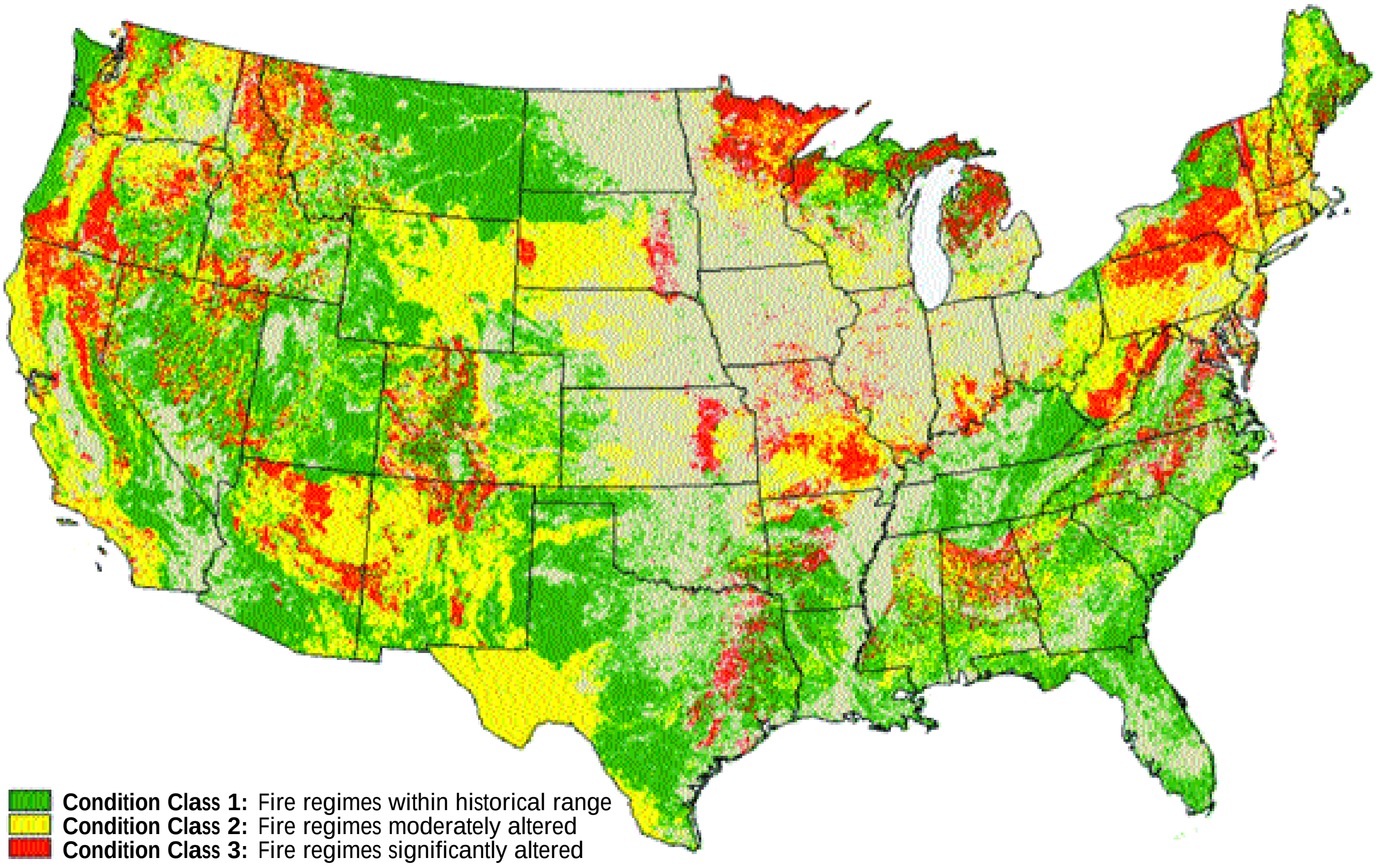
As examples, under the procedure followed by Forest Service scientists, a broad area of open ponderosa pine forest in perfectly healthy condition would be classified as 100 percent forested, assigned to the densest (least healthy) condition class, and thus considered at high risk from fire. But a patch of dense ponderosa pine forest covering 25 percent of an otherwise unforested square kilometer would be considered open and therefore relatively healthy. As these examples show, there is simply no relationship between the forest density map and forest structure.

Perhaps the most important reason why the Forest Service condition class map should not be used to guide policy is the fact that it fails to address what should be the top priority of fire policy — community protection. As an alternative to the condition class map, we developed a more comprehensive strategy for prioritizing fire protection at the national scale. In the following sections, we discuss the method we used to assess the scope of the two primary goals of fire policy — community protection and restoration of natural fire regimes — and the results of that method.

**FIGURE 1.**

**Fire Regime Current Condition Classes**

This condition class map, prepared by scientists from the U.S. Forest Service (Schmidt et al. 2002), classifies the conterminous 48 states into three categories: (1) unaltered fire regime, (2) moderately disrupted fire regime, and (3) significantly disrupted fire regime. The map erroneously suggests that more than half of the nation’s wildlands are at risk of long-term ecological damage from fire.



## 3. Protecting Communities: The Scope of the Challenge

On August 8, 2000, at the height of one of the worst fire years on record, President Clinton directed the secretaries of Agriculture and the Interior to prepare a report recommending how best to respond to the year's severe fires, reduce the impacts of those fires on rural communities, and ensure sufficient fire management resources in the future. The response, "Managing the Impacts of Wildfires on Communities and the Environment," gave rise to the National Fire Plan and set priorities for fire management at the federal level.

Among the priorities were to increase investments to reduce fire risk and to work with local communities to reduce fire hazards close to homes and communities. The report specifically directed federal officials to "prioritize projects targeted at communities most at risk." A year later, the 10-year Comprehensive Strategy, facilitated by the Western Governors' Association, placed similar emphasis on "the protection of communities, municipal, and other high priority watersheds at risk."

The focus on community protection is sound. Preventing the loss of life and property must be the highest priority of fire management. But there is considerable difference between placing a priority on community protection and the actual identification of the communities most at risk and the actions necessary to protect them.

### Identification of Communities at Risk

Locating the communities at risk from wildland fire is a complex task that requires knowledge of fire behavior potential, the values at risk, and the infrastructure that could potentially affect firefighting. In January 2001, the secretaries of Agriculture and the Interior posted a notice in the *Federal Register* that outlined the challenge and included a preliminary list of more than 4000 "communities at risk," compiled from information received from some states.[9] The notice provided guidance on how to recognize a community at risk so that the states could "refine and narrow" their lists, and it solicited a second round of names from the states. The result was a list of 22,127 communities. It is likely that some states anticipated federal funding based on the number of communities at risk, and they elected to submit extensive lists. Other states were more circumspect, submitting only those few communities in obvious peril.

Unable to resolve the differences between states, the secretaries applied a screen to include only those communities that states and tribes identified as near federal land, the communities most likely to be affected by federal policies.[10] The result was a list of 11,376 communities, still almost three times the size of the original list that the secretaries hoped to narrow. To display the locations of these communities, the U.S. Geological Survey matched the names with places in the Geographic Names

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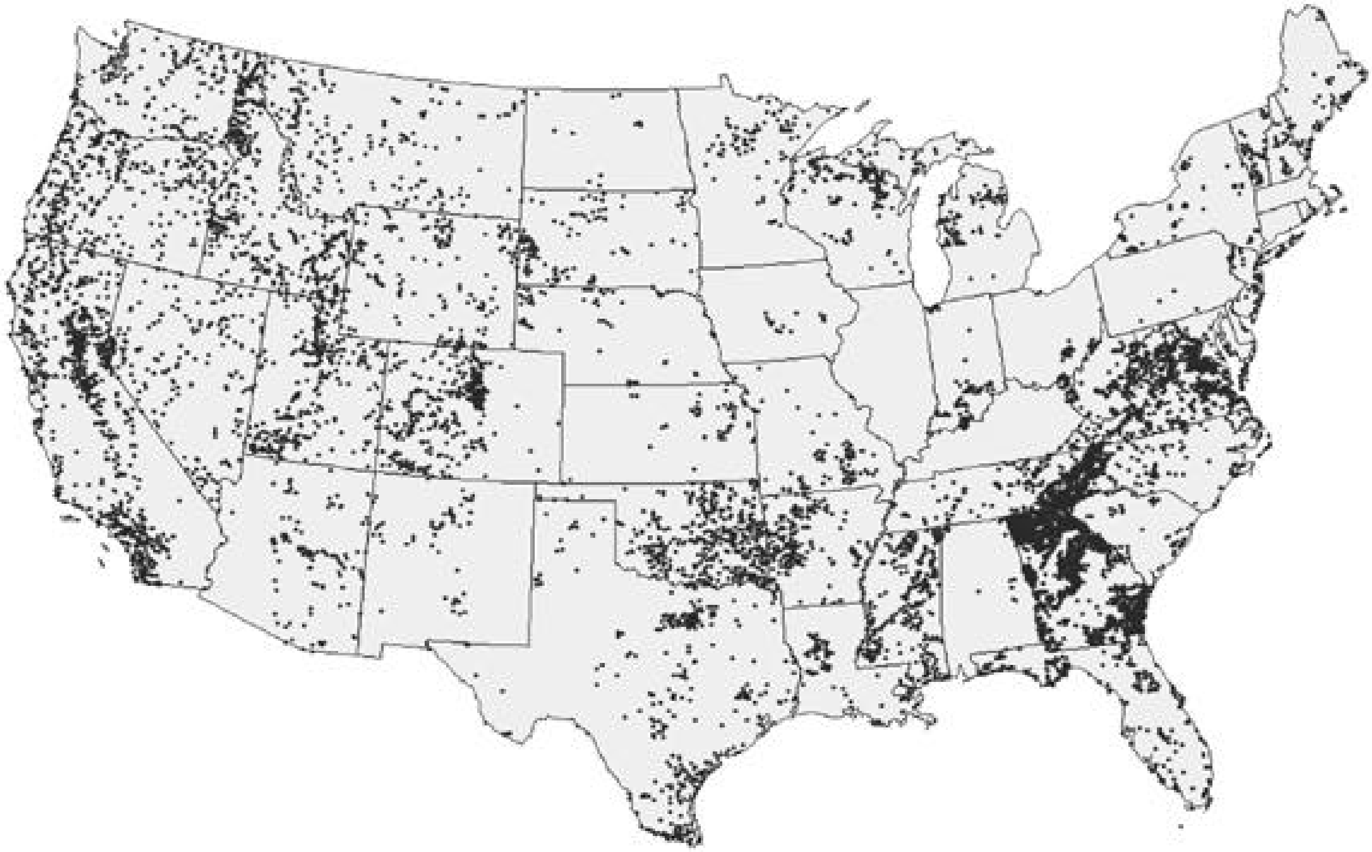
[9] "Urban wildland interface communities within the vicinity of Federal lands that are at high risk from wildfire" (*Federal Register* 66(3): 751-777, January 4, 2001).

[10] "Urban wildland interface communities within the vicinity of Federal lands that are at high risk from wildfire" (*Federal Register* 66(160): 43383-43435, August 17, 2001).

**FIGURE 2.**

### Designated Communities at Risk from Wildland Fire

This map of designated communities at risk from wildland fire was prepared by the U.S. Geological Survey from lists submitted by states and refined by the federal government to include communities near federal lands. The Geological Survey matched the lists with the Geographic Names Information System.



Information System, a federal database listing known places across the country (cities, towns, lakes, streams, etc.).[11] Of the 11,376 communities, 9,339 could be matched with place names in the system to create a national map of communities at risk (Figure 2).[12]

Figure 2 clearly depicts disparities across state boundaries. Georgia, for example, is heavily represented, while neighboring Alabama has almost no representation, and Oklahoma and Kansas, similar both ecologically and demographically, also show large disparities.[13] Inclusion of a community on the list appeared to be arbitrary. In Arizona, the town of Summerhaven, which burned during the Aspen fire in 2003, was not on the list.

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[11] For more information, see http://geonames.usgs.gov

[12] The map resulted in the loss of about one-fifth of the "communities" on the list, most of which were obscure subdivisions, ranches, and other very small locales. Virginia lost half of its submitted list, Colorado 42 percent, and North Carolina almost 30 percent. Still, these states were among the top seven in the number of communities mapped. Texas, Utah, and Wyoming lost more than 20 percent of their lists. Combined, these six states accounted for 75 percent of the 2,037 communities at risk that were not included on the map.

[13] On the other hand, 10 of the 50 fastest-growing counties in the United States from 1990 to 2000 were in Georgia; none was in Alabama or South Carolina. This suggests that the wildland-urban interface may indeed be growing in Georgia and not in neighboring states.

**TABLE 4.**

**Categories of Urban-Wildland Interface Communities**

| Interface Community | Intermix Community | Occluded Community |
|---|---|---|
| Interface communities exist where structures directly abut wildland fuels. There is a clear line of demarcation between residential, business, and public structures and wildland fuels. Wildland fuels do not generally continue into the developed area. The development density for an interface community is usually three or more structures per acre, with shared municipal services. Fire protection is generally provided by local fire departments with the responsibility to protect the structure from both interior fires and advancing wildland fires. An alternative definition of the interface community emphasizes a population density of 250 or more people per mile$^2$. | Intermix communities exist where structures are scattered throughout a wildland area. There is no clear line of demarcation; wildland fuels are continuous outside of and within the developed area. The development density in the intermix ranges from structures very close together to one structure per 40 acres. Fire protection districts funded by various taxing authorities normally provide fire protection for life and property and may also have wildland fire protection responsibilities. An alternative definition of intermix community emphasizes a population density of between 28 and 250 people per mile$^2$. | Occluded communities generally exist in situations, often within cities, where structures abut an island of wildland fuels (as examples, parks or open spaces). There is a clear line of demarcation between structures and wildland fuels. The development density for an occluded community is usually similar to those found in the interface community, but the occluded area is usually less than 1,000 acres in size. Fire protection is normally provided by local fire departments. |

The secretaries might have been wiser to apply uniform standards across the nation, rather than soliciting input from each state. Still, Figure 2 shows those communities that each state considers to be at risk (except for submissions that could not be mapped) and that, in aggregate, represent a first approximation of the location of communities at risk from fire in the vicinity of federal land.

## Defining the Community Protection Zone

In addition to identifying the communities at risk, it is important to determine how much land around each community must be treated to reduce the risk of fire. This is a function of both the size of the community and the width of the fuel treatment "buffer zone" around each community.

The January 2001 *Federal Register* notice described a class of communities at risk of wildland fire as "urban wildland interface communities," which, according to their definition, "exist where humans and their development meet or intermix with wildland fuel."[14] The notice defines three categories of such communities (Table 4), but the salient point is that interface communities exist where structures occur at densities greater than one structure per 40 acres adjacent to wildland fuels (intermix community). A structure is either a residence or a business facility, including federal, state, and local government facilities. Structures do not include small improvements such as fences and wildlife watering devices.

An understanding of the density limits of a community is important, but it does not answer the question of where to apply treatment. Protecting the communities requires treating fuels some distance from structures, but how far should community protection zones extend?

The first step in answering this question requires examination of the defini-

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[14] The *Federal Register* notice modified a definition taken from "A Report to the Council of Western State Foresters: Fire in the West — The Wildland/Urban Interface Fire Problem" (September 18, 2000).

tion of interface communities. One structure per 40 acres translates to one structure in a quarter-mile square parcel. In other words, the interface community consists of contiguous parcels containing structures no more than one-quarter mile apart (parcels roughly one-eighth of a mile in radius). Applying the *Federal Register* definition in this manner, one-eighth of a mile defines the dividing line between the wildland urban interface and wildlands. Thus, the definition of intermix community suggests that the community protection zone should extend a maximum of about one-eighth of a mile from structures.

One-eighth of a mile (about 190 meters) is substantially more than the approximately 60 meters that fire physicists have determined must be treated to reduce the probability of home ignition (Cohen and Butler 1998, Cohen 2000). If the only concern is to protect homes, then a protection zone of 60 meters may be adequate.

However, there are reasons to extend the protection zone beyond 60 meters. Nowicki (2002), in the most extensive inquiry to date into the appropriate width of community protection zones, applied rules of thumb developed by fire physicists and fire safety personnel. The study concluded that community protection zones of 400 meters, if treated to reduce surface fuels and the probability of crown fire, could provide an area that would allow firefighters to work safely to protect structures. The calculations assumed that an adequate safety zone would be four times the maximum sustained flame length of a crown fire, where the length of a crown fire flame may be twice the height of the forest canopy. Since few communities are surrounded by forests with trees exceeding 50 meters (165 feet) in height, the study arrived at the estimate of 400 meters, or approximately one-quarter mile.

Other theories contend that the zone must be wider, at least 20 miles from communities, because fires can travel many miles in a day and rain firebrands down on communities from five or more miles away. But extending the community protection zones that far renders the concept virtually meaningless. Community protection requires strategic fuel

**FIGURE 3.**

**Sample Community Protection Zones in Montana**

This magnified view of our national analysis of community protection zones displays and labels two designated communities at risk from wildland fire and their half-mile buffer zones in the Bitterroot Valley of Montana.

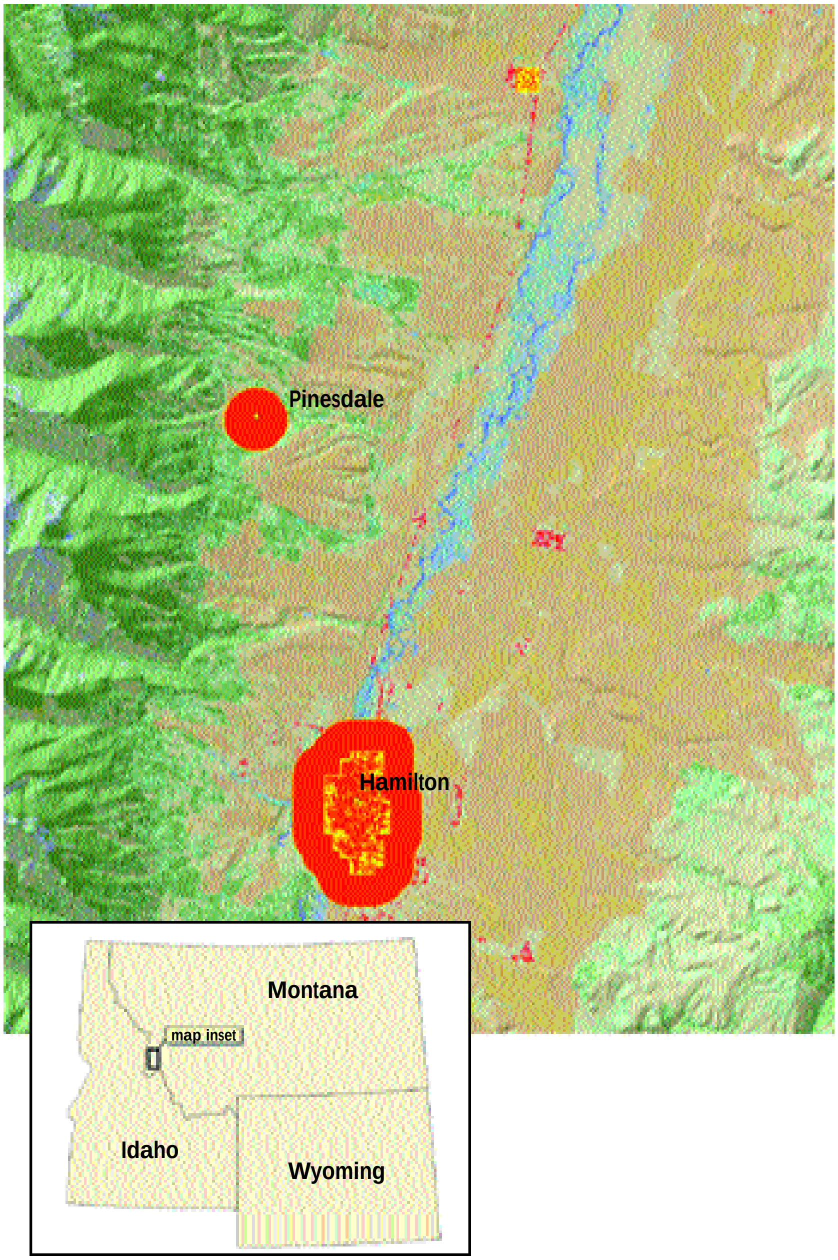

TABLE 5.
**States Ranked by Acreage of Community Protection Zones**

| State | Acres | % of Total |
|---|---|---|
| California | 1,474,110 | 12.95 |
| Georgia | 1,364,218 | 11.99 |
| Texas | 868,129 | 7.63 |
| Virginia | 758,114 | 6.66 |
| Florida | 698,133 | 6.13 |
| North Carolina | 519,985 | 4.57 |
| Oklahoma | 488,392 | 4.29 |
| Idaho | 382,414 | 3.36 |
| Washington | 356,849 | 3.14 |
| Colorado | 328,757 | 2.89 |
| Oregon | 319,846 | 2.81 |
| Mississippi | 316,860 | 2.78 |
| New York | 284,166 | 2.50 |
| Utah | 281,999 | 2.48 |
| Nevada | 231,300 | 2.03 |
| Minnesota | 202,679 | 1.78 |
| Tennessee | 194,100 | 1.71 |
| Indiana | 185,778 | 1.63 |
| Montana | 172,414 | 1.51 |
| Illinois | 161,156 | 1.42 |
| Arkansas | 155,582 | 1.37 |
| Louisiana | 143,784 | 1.26 |
| New Jersey | 122,042 | 1.07 |
| Wisconsin | 118,650 | 1.04 |
| West Virginia | 115,494 | 1.01 |
| Wyoming | 114,860 | 1.01 |
| Missouri | 98,875 | 0.87 |
| Michigan | 98,801 | 0.87 |
| Arizona | 98,774 | 0.87 |
| Maryland | 87,796 | 0.77 |
| South Dakota | 82,263 | 0.72 |
| Kansas | 75,706 | 0.67 |
| South Carolina | 62,435 | 0.55 |
| Maine | 60,790 | 0.53 |
| New Mexico | 51,253 | 0.45 |
| Nebraska | 50,119 | 0.44 |
| Vermont | 38,806 | 0.34 |
| New Hampshire | 38,180 | 0.34 |
| Ohio | 37,274 | 0.33 |
| Iowa | 36,631 | 0.32 |
| Massachusetts | 34,290 | 0.30 |
| Alabama | 32,516 | 0.29 |
| District of Columbia | 10,171 | 0.09 |
| North Dakota | 9,816 | 0.09 |
| Rhode Island | 6,283 | 0.06 |
| Kentucky | 5,683 | 0.05 |
| Pennsylvania | 4,161 | 0.04 |
| Delaware | 1,391 | 0.01 |
| Connecticut | 0 | 0.00 |
| Total | 11,381,821 | 100.00 |

treatment in the vicinity of communities, not in the backcountry. A more reasonable alternative is to modify the width of community protection zones to fit the terrain, taking advantage of natural fuel breaks such as cliffs and rock outcrops. While the one-quarter-mile zone recommended by Nowicki incorporates a sufficient margin for safety, a zone of one-half mile should provide the latitude needed to adjust community protection zones to terrain. Beyond that distance, work should focus on ecological restoration, not the protection of structures.

It is important to note here that this logic does not argue for a half-mile buffer around every home. First, community protection zones are intended to protect communities, which by definition must exceed a density of one structure per 40 acres; an individual home more than a quarter mile from the next is not a community. The protection of individual homes scattered throughout fire-prone wildlands is the responsibility of the individual homeowner.

Second, there are some vegetation types for which a half-mile community protection zone is unnecessary or inappropriate. Homes surrounded by grassland or agriculture need only a narrow swath cleared. In other vegetation types, fire behavior cannot be significantly altered by fuel treatment. Chaparral and subalpine forests will burn when the weather is right, regardless of whether the crowns are touching or ladder fuels have been removed. In these vegetation types, it makes little sense to treat beyond the 60-meter zone that influences home ignitability.

Third, there will be cases where communities decide they do not want treatment for protection. Aesthetics and sense of place are more important to some people than fire safety. Communities should be free to make that decision, but they should not later expect firefighters to risk their lives to protect structures.

## The Scope of the Community Protection Challenge

Just how much treatment is necessary to protect communities? We computed the amount of land within a half mile of the communities on the federal list. Because the communities-at-risk map represented communities only as points, the methods required a more sophisticated analysis than simply applying a half-mile buffer around each point.

Briefly, we relied on a national database that assigns every 30-meter pixel to a land cover class. From this dataset, we extracted all of the pixels assigned to urban land classes (low-density residential, high-density residential, and commercial/industrial). Next, we identified "urban footprints" of towns by selecting clusters of urban pixels and matching them to communities on the list if a cluster fell within one mile of a named community. This gave us the approximate outlines (or footprint) of the larger communities on the list. Where the location of a listed community was more than one mile from an urban footprint, we assumed the town was too small to produce a footprint, and we mapped it as a point.[15] To determine the national extent of community protection zones, we applied a half-mile buffer to the outside of the urban footprints and remaining points representing the communities at risk and added up the area within the buffers.

Figure 3 (page 17) illustrates the results of our methodology for two communities in Montana's Bitterroot Valley. See Appendix A for a detailed description of our methods.

The results revealed that across the 48 conterminous states, community protection zones around the 9,339 mapped federal communities at risk equal 11,381,821 acres, an area approximately the size of Vermont and New Hampshire combined.[16] Forty percent of this total is agricultural or agricultural/developed land.

California ranks first among the states, with 13 percent of community protection zone acreage nationwide (Table 5). Georgia, Texas, Virginia, Florida, and North Carolina rank next; combined, they account for nearly 37 percent of the total. Fire-prone western states — Idaho, Montana, Wyoming, Nevada, Utah, Colorado, Arizona, and New Mexico — account for less than 15 percent of the total. Overwhelmingly, community protection zones are where people are, not where forests are.

By overlaying a public land ownership geographic information system database (DellaSala et al. 2001) on our community protection zone data, we determined that the vast majority of land in the community protection zones — even for this list of communities in the vicinity of federal land — is non-federal land (Table 6). Just 9.3 percent of community protection zone acreage is on national forests; only five percent is found on other federal lands.

**TABLE 6.**

### Community Protection Zone Acreage by Land Ownership

Eighty-five percent of community protection zone acreage is on non-federal land and would not be addressed by federal land management policy.

| Land Ownership of Community Protection Zone Acreage | Acres | % of total acreage |
|---|---|---|
| Private/State/Tribal | 9,688,977 | 85.13 |
| Bureau of Land Management | 160,594 | 1.41 |
| Department of Defense | 229,741 | 2.02 |
| U.S. Fish and Wildlife Service | 54,273 | 0.48 |
| U.S. Forest Service | 1,097,544 | 9.64 |
| National Park Service | 112,775 | 0.99 |
| Other Federal Lands | 37,917 | 0.33 |
| Total | 11,381,821 | 100.00 |

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[15] Even the smallest developed area produces some footprint. However, where we had no evidence of a footprint, we had no choice but to represent it as a point. The 0.785-mile$^2$ community protection zone calculated for these communities therefore likely underestimates the true size of the area that must be addressed. Also, where we did identify a footprint, that footprint probably represented only the dense inter*face* community. Our methods likely failed to represent scattered inter*mix* communities.

[16] If we had been able to map as points the 2,116 communities that we believe were left off the Geological Survey map in the conterminous 48 states, an estimated 1,063,078 acres would be added to the total.

## 4. Restoring Fire-adapted Ecosystems: Where Are the Priorities?

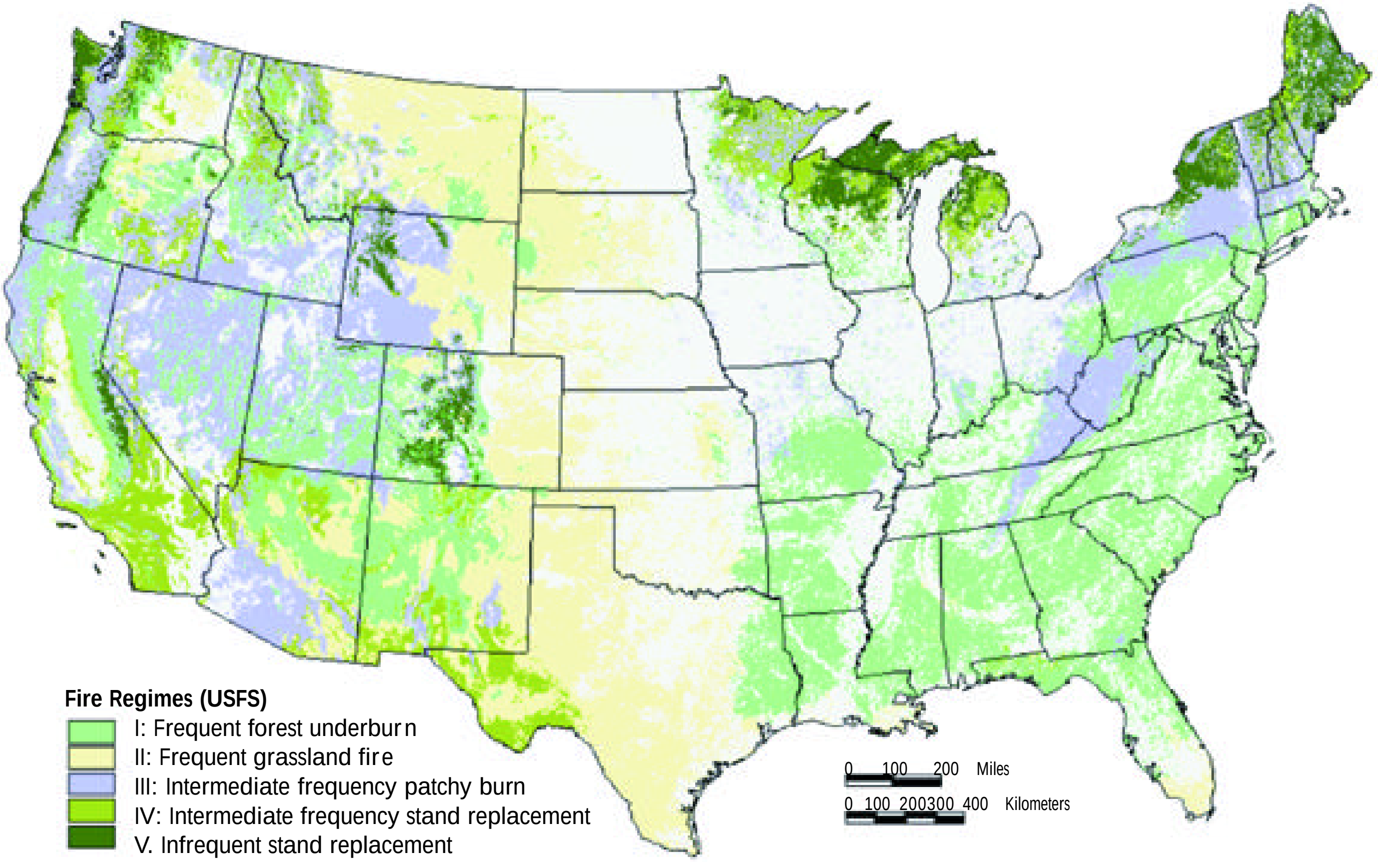
Without a doubt, the protection of homes and lives must be the highest priority of fire management. But it is not the only priority. Centuries of post-Colonial land use have disrupted North America's ecological rhythms and left many ecosystems in poor shape. Eastern forests, many of them fire dependent, have been almost entirely logged at least once, and many have been converted to food or fiber farms. In the West, most of the largest trees have been cut, livestock grazing has removed grass cover from formerly productive rangeland, and fire, successfully excluded for most of the twentieth century, has returned with a ferocity unknown to many western ecosystems.

Numerous studies document the ecological harm that has resulted from the removal of fire from ecosystems across the nation (see as examples Wright and Heinselman 1973, Covington and Moore 1994, Mutch et al. 1994). The relatively new field of ecological restoration addresses the poor condition of many ecosystems, and restoration of fire has been at the center of discussion among scientists and land managers. But which ecosystems are most in need of attention? What are the priorities, given limited financial resources and personnel, for restoration? Answers to

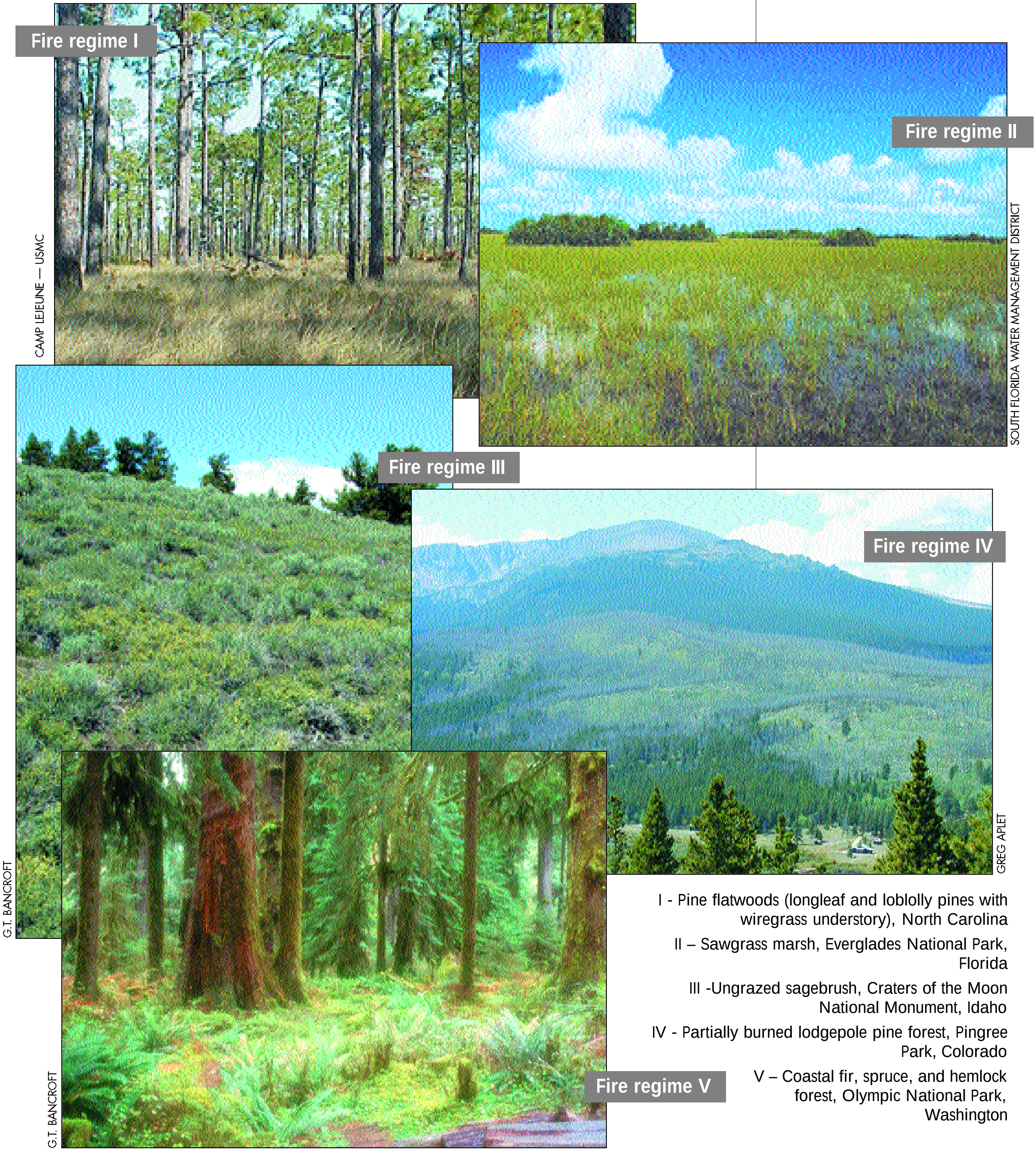
**FIGURE 4.**

**Wildland Fire Regimes in the Conterminous 48 States**

We removed agricultural and developed areas from the fire regime map produced by Schmidt et al. (2002) to achieve a more realistic picture of the actual distribution of fire regimes and the potential for restoration of ecosystems.



## Representative Vegetation Communities for Each Fire Regime



CAMP LEJEUNE — USMC

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

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I - Pine flatwoods (longleaf and loblolly pines with wiregrass understory), North Carolina

II – Sawgrass marsh, Everglades National Park, Florida

III -Ungrazed sagebrush, Craters of the Moon National Monument, Idaho

IV - Partially burned lodgepole pine forest, Pingree Park, Colorado

V – Coastal fir, spruce, and hemlock forest, Olympic National Park, Washington these questions are a function of both the degree of alteration and the potential for restoration. In this chapter, we review the effects of fire exclusion on ecosystems and examine the distribution of ecosystems with the greatest potential for restoration. In the next chapter, we propose principles to guide future restoration activities.

## Fire Regimes

The timing and pattern of fire has a tremendous effect on vegetation, and species and ecosystems can be said to be adapted to particular fire regimes (Table 1, page 3 of this report). Thick bark is a good defense against frequent, low-intensity fire, and low-intensity fire is a product of open forest with abundant fine fuels such as grass or low shrubs. Hence, trees with thick bark do well in open forests where fire is frequent. In other ecosystems, where conditions for burning are infrequent and long intervals between fires lead to more intense conflagrations, trees are adapted not to survive fire but to regenerate quickly afterward. Those trees tend to have thin bark, but light, easily dispersed seeds that regenerate on burned-over sites. The various species, ecosystems, and fire regimes respond quite differently to changes in fire frequency.

To aid in this discussion, we modified a map from Schmidt et al. (2002) that displays the distribution of historical fire regimes. We removed the areas of altered vegetation (agriculture and urban) that Schmidt et al. included in their map because of the low potential for restoration in those areas. We wished to achieve a more realistic depiction of the distribution of fire regimes and the potential for restoration of ecosystems. Our analysis (see Figure 4, page 20) shows fire regime I to be the most common, accounting for 34.3 percent of wildland vegetation in the conterminous 48 states. Fire regimes II and III account for 27.2 and 23.4 percent, while fire regimes IV (9.8 percent) and V (5.34 percent) are decidedly less common.

For the following discussion, it is important to note that the type of vegetation is critical to the definition of a fire regime.

**Fire regime I** (high-frequency, low-intensity forest fire) occurs only in forests and woodlands where frequent fire (occurring at least once every 35 years) consumes grass, pine needles, and other fuels of the forest floor without killing the trees. Understory species often resprout quickly from live, underground structures, and trees possess traits such as thick bark and have relatively large seeds that are capable of growing quickly above the resprouting grass.

Fire regime I occurs in forests that occupy sites where hot, dry weather is frequent but that support grass growth. Examples of such vegetation include the longleaf pine-wiregrass ecosystem of the southeastern coastal plain, shortleaf pine and pine-oak systems in the interior Southeast, ponderosa pine forests in the Southwest, and extensive oak woodlands rimming California's Central Valley (Figure 4). For each of these systems, studies show that fire exclusion results in dramatic changes in vegetation, including increased forest density and the failure of some species, especially grasses and oaks, to regenerate. Some of the earliest and most extensive experiments in ecological restoration focused on ecosystems in fire regime I.[17]

**Fire regime II** behaves similar to fire regime I, except that no trees are pre-

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[17] Some of the earliest experiments in prescribed burning were conducted in longleaf pine (Pyne 1982). Researchers with the USDA Forest Service and with Northern Arizona University's Ecological Restoration Institute have worked on restoration of ponderosa pine since the 1970s (Friederici 2003).

sent. Therefore, fire is considered to be stand replacing, even though plants sprout very quickly from live, underground roots, rhizomes, and tubers. Fire regime II dominates the great grasslands of North America, including the Great Plains, Washington State's Palouse Prairie, and the sawgrass wetlands of Florida's Everglades (Figure 4). Most of these once vast ecosystems have been converted to agriculture, dramatically reducing the potential for restoration of functional ecosystems. Nevertheless, some of the most intensive research on ecological restoration has focused in these ecosystems, including the artificial restoration of Curtis Prairie at the University of Wisconsin's arboretum and the maintenance of fire at the Konza Prairie Biological Station, part of Kansas State University.

**Fire regime III** is a mixture of lethal and non-lethal fire. Fires can be either low-intensity surface fires or high-intensity crown fires and sometimes both in the same fire event. The result is a mosaic of burned and unburned (or lightly burned) patches across the landscape. Classic vegetation in fire regime III includes interior Douglas-fir and larch forests. These species have thick bark that allows trees to survive even moderate fire intensities, while patches elsewhere on the landscape are opened by lethal crown fires.

Although lodgepole pine is often associated with crown fires (fire regimes IV and V) in places like Yellowstone and the central Rockies, this vegetation type can also exhibit a mixed, patchy fire behavior (Kilgore 1981, Agee 1993, Arno and Allison-Bunnell 2002). Even fog-shrouded redwood forests have been shown to dry out frequently enough to support a mixed-severity fire regime (Kilgore 1981, Agee 1993). Sagebrush is often considered to be in fire regime III, but invasion of exotic cheatgrass has increased fire frequencies in sagebrush cover, leading to the eradication of sagebrush (Whisenant 1990). Fire regime III produces some of the most complex and least understood vegetation patterns, providing what Agee (1993) describes as "the most significant fire management challenges of all the Northwest forests."

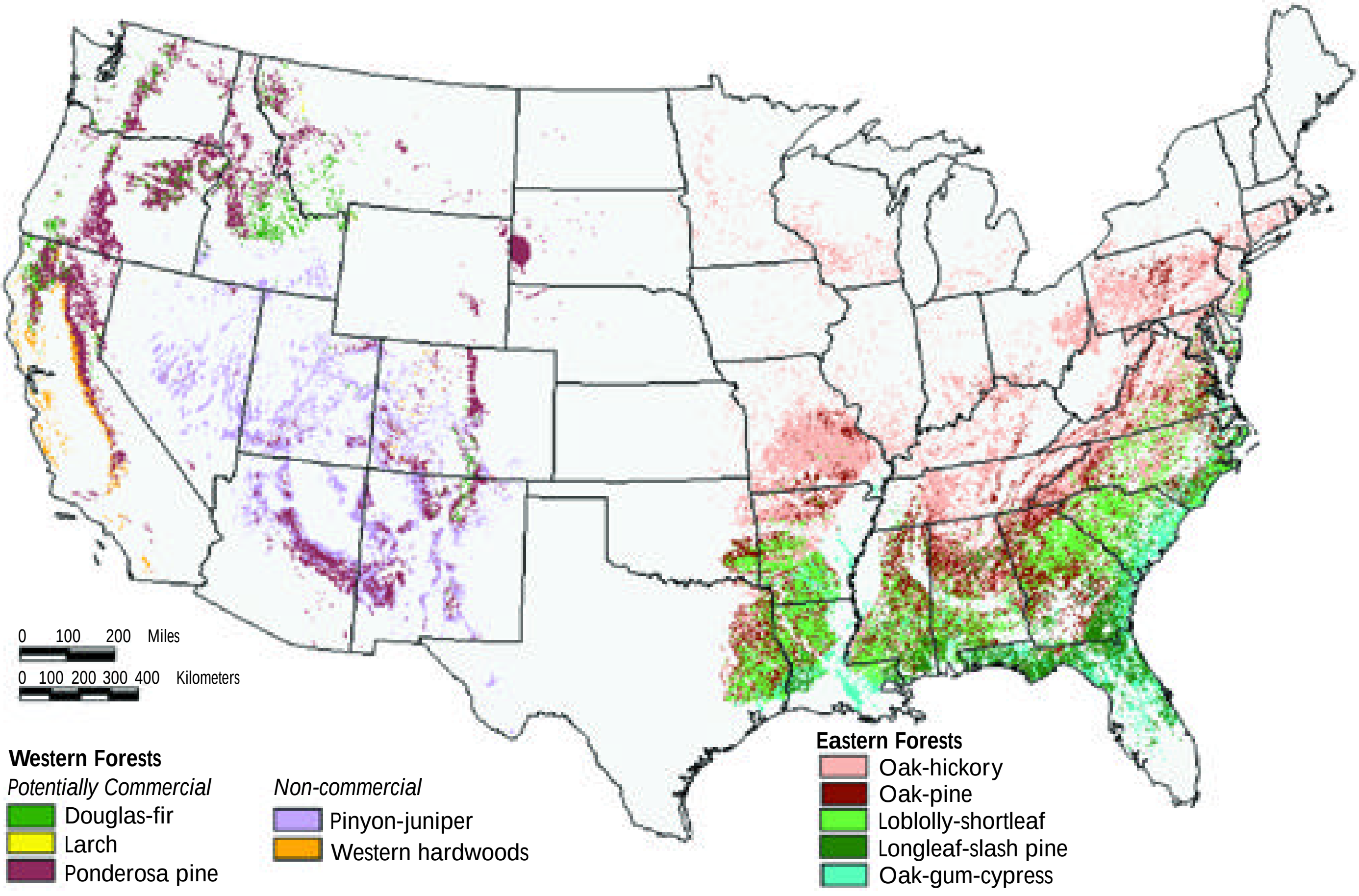
**Fire regimes IV and V** consist of infrequent, large crown fires. Vegetation in fire regime IV experiences fire every 35 to 200 years; in fire regime V, fire is very rare, occurring every 200 or more years. In both cases, large patches of vegetation are consumed, but not necessarily killed. For example, aspen forests and chaparral shrublands are considered fire regime IV, although they resprout vigorously from underground structures. Other vegetation types, like eastern spruce-fir forests and red, white, and jack pine forests in the Great Lakes states, as well as most lodgepole forests, are killed outright, but recover quickly from seed. Fire regime V is generally limited to cool, moist locations such as high-elevation forests and alpine tundra or coastal Douglas-fir, spruce, and hemlock forests (Agee 1993, Arno and Allison-Bunnell 2002). Fire is not thought to be a frequent disturbance in northern hardwood forests, although Heinselman (1981) suggested that the presence of some short-lived, shade-intolerant species such as yellow birch, black cherry, and basswood argue for more of a mixed fire regime there. Except for places where the patchiness of vegetation appears to have been reduced by a century of fire exclusion (Hessburg et al. 1999), it is generally agreed that vegetation in fire regimes IV and V has been the least altered of all fire regimes (Christensen 2003).

Overall, fire has had a varied effect on most, if not all, North American vegetation. In some places such as sparsely vegetated deserts and wet coastal or cove

FIGURE 5.

**Forests Potentially in Need of Fire Restoration**

Forests identified on this map represent a subset of forest types that may have suffered from fire exclusion. Further analyses, relying on more accurate data, are required to determine if specific fuel treatments are required. These forests do not represent stands that necessarily require treatment.



forests, fire may be so infrequent that it plays only a minor role in the ecosystem. Elsewhere, fire has had a major role in shaping the vegetation.

It is also evident fire exclusion has had a varying effect on forest vegetation, but despite fire exclusion efforts, fire regimes IV and V are still considered largely within their range of historical fire behavior. Grasslands that comprise much of fire regime II have been largely converted to other uses. Where grasslands still exist, however, the role of fire is not well understood (Sims 1988). Although it is known that fire exclusion has resulted in the loss of some prairie species, restoration of fire has met with some success in revitalizing other species (Greenlee 1997).

Least understood is fire regime III, where fire exclusion has likely produced some changes in vegetation, but where the complexity of fire and vegetation dynamics obscures obvious solutions. Only in fire regime I, the high-frequency, low-severity forest types, has there emerged a consensus that fire exclusion has resulted in dramatic changes and that those changes must be addressed (Christensen 2003). It is in fire regime I that the solutions are most clearly understood.

## Understory Fire: A National Priority

More than 50 years ago, Weaver (1951) published his landmark paper “Fire as an ecological factor in the southwestern pine forests.” Prior to that time, foresters debated the value of “light burning” as part of forest and range management policy. Proponents argued that intentional burning promoted grass growth and kept fire danger low. Opponents, including most professional foresters, denigrated the practice as primitive and unscientific, destroying saplings and reducing forest productivity. Weaver, for the first time, placed fire in an ecological context, showing its importance to the function of the forest. The opponents of fire prevailed, and conditions worsened. Today, the exclusion of fire is recognized to have affected the entire southwestern region, causing degraded ecosystems and increased fire danger (Covington and Moore 1994).

The Southwest is not the only region to have suffered. Changes are apparent throughout fire regime I. From the interior oak woodlands of the Pacific Northwest to the pine forests and wetlands of the Southeast, vegetation that evolved with fire has been starved of a key process, and

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Natural fire regimes create a diverse mosaic of patches across landscapes and thus have significant influence on ecosystem heterogeneity — from a vast forest ecosystem such as the 1988 Yellowstone fires (top photo) to smaller landscapes where topography and fuel moisture play a larger role (center photos) to fine scales where localized burns creep across forest floors to rejuvenate understory vegetation (lower photo).

ecosystems have been altered — their composition, structure, and function. It is now evident that the future health of forests in fire regime I depends on the return of fire as an ecological process. In some places, this will require only the restoration of fire, either naturally or through intentional ignition, but in other places, trees need to be thinned (and fuels otherwise manipulated) to facilitate the reintroduction of fire.

Thinning is the most controversial aspect of forest restoration. Nearly all experts agree that restoration of fire to fire regime I will require breaking the continuity of the fuel ladder from the ground to the canopy and that this will mean thinning of some small trees (Agee et al. 2000). The controversy arises from uncertainty over how big those trees should be. Some argue that large trees (more than 14 inches in diameter) must be thinned to break up the continuity of canopy fuels, while others insist that only surface fuels, consisting of shrubs and trees less than six inches in diameter, need to be cut.

Many conservationists point out that large trees are already a seriously depleted element of many forest ecosystems (Anderson et al. 1996) and should be protected. They view with skepticism any suggestion that large trees should be cut in the name of restoration. The controversy was exacerbated in 2002 when the Bush administration announced its Healthy Forests Initiative, recommending that trees be cut from national forests to pay for fuel treatments. Partly because taxpayers have paid the bill for logging on national forests over many years (General Accounting Office 1998, USDA Forest Service 2001), the initiative met with considerable resistance. Why, critics ask, should taxpayers be responsible for yet another giveaway to the timber industry — this time under the guise of fire protection?

Regardless of whether or not trees are sold, fuel reduction as part of fire restoration is sure to be an enormously expensive undertaking. It may be possible to recover some of the costs of restoration through the sale of by-products, but it will also require substantial investment of public funds to restore healthy conditions to national forests and other forest lands.

To gain a better understanding of which areas might be in need of fuel treatment and thus to help prioritize treatment activity and save costs, we subjected the fire regime map in Figure 6 to additional analysis. We first examined the current vegetation types found within the area identified by Schmidt et al. (2002) as fire regime I in Figure 4. This area contains a number of vegetation types that are clearly not in fire regime I (for example, maple-beech-birch and grassland), so we eliminated them from display.

Bold entries in Table 7 show the vegetation types we included in fire regime I; those we eliminated from the Schmidt et al. classification (which accounted for 18.6 percent of the wildland area that Schmidt et al. assigned to fire regime I) are shown in normal typeface. All eastern vegetation types in bold in Table 7 are well understood to be in fire regime I. In the West, ponderosa pine and western hardwoods (oak woodlands) are also clearly in fire regime I. In addition to these types, we included the pinyon-juniper, Douglas-fir, and larch vegetation types that Schmidt et al. count in fire regime I. Although these types may be

**TABLE 7.**

### Current Wildland Cover Types

This table presents current wildland cover types on lands identified as fire regime I by Schmidt et al. (2002). In Figure 5, we mapped the cover types shown below in bold as fire regime I. Figure 5 does not include the cover types shown below in non-bold typeface because they do not belong in fire regime I (see text).

| Current Vegetation | Acres |
|---|---|
| **Oak-hickory** | **102,946,988** |
| **Loblolly-shortleaf** | **57,479,052** |
| **Oak-pine** | **43,837,325** |
| **Ponderosa pine** | **43,053,174** |
| **Pinyon-juniper** | **39,429,245** |
| Other Shrub | 26,523,916 |
| **Oak-gum-cypress** | **26,484,904** |
| **Longleaf-slash pine** | **19,961,533** |
| Maple-beech-birch | 14,456,430 |
| Grassland | 13,694,368 |
| Desert Shrub | 10,742,784 |
| **Douglas-fir** | **9,866,802** |
| **Western hardwoods** | **4,923,633** |
| Fir-spruce | 3,264,263 |
| Lodgepole pine | 2,976,681 |
| White-red-jack pine | 2,200,098 |
| Aspen-birch | 1,961,780 |
| Elm-ash-cottonwood | 1,776,321 |
| Wetlands | 1,310,044 |
| **Larch** | **196,073** |
| Alpine tundra | 162,648 |
| Spruce-fir (east) | 133,827 |
| Hemlock-Sitka spruce | 69,902 |
| Redwood | 59,971 |
| Western white pine | 48,052 |
| Barren | 40,079 |
| Total | 427,599,893 |

more appropriately classified as fire regime III in other parts of their range, the well-established history of frequent fire in some places led us to include them.

We then mapped the locations of these vegetation types to produce Figure 5 (page 24). To facilitate interpretation, we distinguish between western woodlands, which are not likely to produce usable timber, and western forest types that may yield commercial by-products.

Several conclusions are immediately apparent from Figure 5. First, fire exclusion is not a problem only in western forests. More than 250 million acres of fire regime I are in the Southeast where fires historically burned with frequency. In many of these forest types, fire exclusion has led to the build-up of a shrubby understory that degrades wildlife habitat and increases fire severity. The association of longleaf pine and shortleaf pine forests with fire is well known (Christensen 1988, Foti and Glenn 1991), but oak-hickory and oak-pine forests also used to depend on frequent fire to maintain species composition. Abrams (1992) described the invasion of oak-hickory forest by red maple as a result of fire exclusion in Pennsylvania and New York. Unlike fire in open pine forests, which is typically carried in grass, understory fire in closed deciduous forests is carried in fallen leaves (Christensen 1981). Concerns about resulting fire-induced wounds and complex ownership and land-use patterns complicate efforts to restore fire in the East.

Figure 5 also suggests that much of fire regime I in the West is in open woodlands, not forests. Almost 40 million acres of pinyon-juniper and 5 million acres of hardwoods are mapped by Schmidt et al. (2002) as fire regime I. A century of grazing and fire exclusion in pinyon-juniper woodlands has resulted in higher tree densities than occurred historically (Jacobs and Gatewood 1999). In some places, those densities appear to be inhibiting grass growth and increasing both erosion and fire severity. Research points to a need for restoration thinning before fire can be reintroduced (Sydoriak et al. 2000). Pinyon-juniper is the most widespread forest type in the West, but wood values are low, suggesting that the sale of by-products will not offset restoration costs (Henderson and Baughman 1987). A similar story is told in the extensive non-commercial oak woodlands in California and the Willamette Valley of Oregon, where the invasion of non-native shrubs and tree saplings threatens to carry lethal fire to the oaks. As found by Agee (1993), “Without prescriptive treatment, up to 50 percent of the threatened oak woodlands could be beyond help by the year 2010.”

The remaining 53 million acres of vegetation mapped as fire regime I in Figure 5 consist of dry forest types, primarily ponderosa pine (43 million acres), interior Douglas-fir (10 million acres), and larch (200,000 acres). Ponderosa pine includes the pure (or nearly pure) ponderosa pine forests in the Southwest, Colorado Front Range,


RANGE COVER WEB PAGE, R.E. ROSIERE, TARLETON STATE UNIVERSITY

In contrast to wet, coastal Douglas-fir forests, which are included in fire regime V, interior Douglas-fir forests burn frequently and therefore are included in fire regimes I and III. This photo of a forest dominated by interior Douglas-fir in the Lolo National Forest, Montana, could maintain frequent understory fires.

Black Hills, and east side of the Cascade Mountains. It also includes much of the west side of the Sierra Nevada, where pure stands of pine grade into mixed-conifer forests with elevation and where fires historically burned frequently in the understory (Kilgore 1981). Interior Douglas-fir forest experiences a different fire regime from wet, coastal Douglas-fir forests, which historically burned infrequently. Interior Douglas-fir, like the larch forest type included in fire regime I, exhibits thick bark and fire scars as evidence of adaptation to frequent fire (Arno and Allison-Bunnell 2002).

As Figure 5 shows, much of the fire restoration challenge lies in the East, not in the western forest types that have been the focus of the debate over forest thinning. Even in the West, much of the area of concern is in woodland types that will not likely yield commercial by-products through restoration, although some thinning may be necessary. Out of the approximately 350 million acres of fire regime I in the conterminous 48 states that likely would benefit from the restoration of fire, only about 15 percent is in western forest types that may produce usable timber through thinning, and not all of those forests will need thinning.

## 5. Lessons Learned and Recommendations

### Condition Class Map

Our analysis of the Forest Service's condition class map shows that the data needed to assess the condition of America's forests are not available and that while the concepts behind the mapping effort are sound, at least for some forest types, they cannot be applied to existing data. Too little is known about historical and current forest conditions, especially forest structure, and the scale of available data is too coarse to produce accurate and meaningful results. In a telling recommendation, Schmidt et al. (2002) state, "In general, the quality of products could be improved by developing base layers in conjunction with one another and in developing layers required by the methodology, specifically forest structure."

#### Recommendation

Until the data "required by the methodology" are compiled, any results from applying that methodology should be viewed with skepticism. The condition class map should not be used to prioritize fuel treatments across the country.

### Community Protection Zone

Lessons from our community protection zone analysis are obvious. Protecting communities from fire is a big job. A simple half-mile zone around communities at risk exceeds 11 million acres, representing a daunting amount of work. As the results displayed in Table 6 (page 19) indicate, the responsibility lies largely with private, state, and tribal lands. Federal policy aimed at logging and thinning (treating fuel loads) on national forests will not protect the overwhelming majority of communities deemed at risk from wildland fire.

Citizens and elected officials must also learn to accept that fire will never be completely eliminated from the landscape, even in community protection zones. Insurance companies and zoning boards can provide incentives to landowners to help them adapt to life in fire-prone ecosystems, fire behavior can be changed, and homes can be saved. But as long as vegetation exists in fire-prone areas, fire will return.

#### Recommendations

Individual homeowners must take action to protect themselves. Information is readily available through resources such as the FIREWISE website (www.firewise.org). Simple steps, such as the installation of metal roofs, moving firewood away from the home, and keeping yards clear of fine fuels can dramatically lower the probability of home ignition.

Funding must be directed to communities for the design and implementation of community-based fire plans. The 10-year Comprehensive Strategy relies on community-based fire planning to identify critical needs. In some cases, money will be needed only for homeowner education; in other cases, the less affluent will need assistance to do their part.

Better information must be developed to help set priorities, and funding is needed to gather that information. The nationwide list of communities at risk is too long to set meaningful priorities. Rigorous application of risk-evaluation criteria such as those laid out in the January 2001 *Federal Register* notice would help, but often information on fire behavior potential, values at risk, and infrastructure in communities is unavailable. In some cases, gaps can be filled with geographic information system or remote sensing data. Some states are moving in this direction.[18]

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[18] The California Department of Forestry has developed a robust analysis to identify more precisely which communities are threatened in that state. Using locally specific census data, urbanized area boundaries, satellite imagery, and land ownership data, the department identified community protection zones more accurately than can be achieved through a national analysis. Colorado has developed a statewide hazard and risk map to help set priorities (see http://www.colostate.edu/Depts/CSFS/).

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In this intermix community, structures are scattered throughout the surrounding wildlands. There is no clear line of demarcation, thus creating perfect conditions for catastrophic loss of property during a wildland fire.

## Ecological Restoration

Our analysis suggests that as many as 350 million acres in fire regime I may benefit from restoration planning (see Figure 5). Other fire regimes also merit eventual attention. Over such a vast area, restoration cannot be successful unless approached rationally and efficiently. There are simply not enough resources available to treat every acre. In addition, much of this area does not need treatment and would benefit instead from additional protection to relieve ecological stressors. Successful restoration requires careful planning and implementation based on clear priorities.

To help provide a framework for planning, DellaSala et al. (2003) prepared a set of ecological forest restoration principles and criteria that stem from a two-year collaborative process involving forest scientists, rural community advocates, and forest activists from across the nation. Collectively, the principles and criteria provide a guide to restore ecosystems, sustain rural economies, and rebuild communities.

The restoration guidance is built on the three core principles outlined in Table 8. The basis of the Ecological Forest Restoration principle is that restoration should be focused not on individual species or the structure of ecosystems, but on restoration of ecological processes to enhance the ability of

**TABLE 8.**

### Ecological Restoration Principles

The following is adapted from DellaSala et al. 2003.

ECOLOGICAL FOREST RESTORATION

Enhance ecological integrity by restoring natural processes and resiliency

1. **Restoration Project Planning** — Document all restoration projects in the context of a restoration assessment and appropriate restoration approaches that restore ecological integrity.
2. **Forest Restoration Assessment** — Conduct a restoration assessment prior to restoration activities.
3. **Ecological Restoration Approaches** — Determine the appropriate use of protection and passive and active restoration based on restoration assessments.
4. **Community Protection Zone** — Distinguish between fuel-reduction treatments that restore ecological integrity and those that serve primarily to protect property and human life.
5. **Adaptive Management** — Monitoring and evaluation must be assured before restoration proceeds and incorporated into the project's budget.

ECOLOGICAL ECONOMICS

Develop positive incentives to encourage ecologically sound restoration.

1. **Economic Incentives** — Investments in restoring ecosystems should be applied across land ownerships in cooperation with willing landowners and should be tiered to regional and local ecological needs.
2. **Public Lands** — Successful restoration on public lands requires reforming federal agency funding mechanisms and contracting procedures to remove incentives for ecologically and socially damaging activities.
3. **Private Lands** — Restoration on private lands requires both outreach to landowners with information about the ecological importance of their lands in the context of the larger landscape and resources for technical and financial assistance to help landowners restore their lands.

COMMUNITIES AND WORK FORCE

Make use of or train a highly skilled, well-compensated work force to conduct restoration.

1. **Community / Work Force Sustainability** — Effective restoration depends on strong, healthy, and diverse communities and a skilled, committed work force.
2. **Participation** — Encourage involvement of a diversity of communities, interest groups, agencies, and other stakeholders at all levels.

ecosystems to rebound from natural and human-caused disturbances. The Ecological Economics principle argues for economic incentives to encourage ecologically sound restoration. The Communities and Work Force principle contends that restoration, if done right, should lead to revitalized rural economies and healthy, inclusive communities.

The foundation of the Ecological Forest Restoration principle rests on a commitment to employ a sound plan built on ecological assessments that are conducted at multiple scales, including the region, the watershed, and the site. The plan must include adequate protection for those areas that are still in good ecological condition and provide for the cessation of activities that cause degradation before engaging in active restoration. Otherwise, restoration is not likely to yield benefits over the long run.

A distinction must be made between ecological restoration and fuel treatment for community protection. Community protection treatments do not need to restore ecological integrity, but they should be concentrated on the Community Protection Zone. Successful restoration projects also include a monitoring and evaluation component and ensure that funding is available before work is begun.

The Ecological Economics principle recognizes that the need for restoration does not stop at ownership boundaries and encourages participation of all landowners. It also recognizes that restoration on public land will require consistent, adequate, multi-year funding from Congress. Contracting mechanisms must be revamped to ensure that they are driven by ecological objectives, not individual financial gain or growth in agency budgets. The award of contracts must take into account factors other than the lowest bid — factors such as skills, commitment, and location. Mechanisms such as tax incentives and revolving loan funds must be created to encourage private landowner participation in restoration.

The Communities and Work Force principle acknowledges that restoration requires work and therefore a work force, and that the workforce deserves to be treated fairly. Restoration workers should be trained to develop the technical and scientific skills required for their work. They should be fairly compensated, and they must be guaranteed the right to organize and bargain collectively. Citizens at all levels and from all perspectives should have the opportunity to be involved in the planning, implementation, monitoring, and evaluation of restoration programs, and those programs should be scaled to ensure the sustainability of both ecosystems and communities.

These are not trivial requirements. But restoration is not trivial. As the authors of the principles conclude, "We have decades of restoration work ahead. It is vital that we begin to make the long-term investment in the protection and restoration of our forests that is necessary to secure their lasting value for future generations."

We recommend that these principles form the basis for ecological restoration of lands in fire regime I and other fire regimes as appropriate.

### A Cautionary Note About Cost

Our analysis identifies almost 100 million acres of fire regime I in the West alone that may benefit from the restoration of surface fire. When added to the 11 million acres that we estimate need treatment in community protection zones, the workload is daunting. Recent research (Barbour et al. 2001) shows that the cost of such treatment generally runs from $500 to $1500 per acre for mechanical thinning and $100 to $500 per acre for prescribed burning. At $100 per acre, it will cost $10 billion dollars just to burn the backlog of fire regime I lands in the West. Mechanical treatments in community protection zones will cost another $10 billion. And every acre treated accrues a long-term maintenance need, as both thinned and burned areas must be regularly cleared of regrowth every 5 to 10 years.

There is clearly not enough money to treat every acre. Priorities must be set, and communities have to come first. It is also necessary to identify when the fighting of fire is unnecessary and which parts of the landscape should be the highest priority for fire restoration.

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# APPENDIX A

## Mapping the community protection zone

To map the extent of the community protection zone (CPZ) across the conterminous United States, we began with the point coverage of 9,339 communities at risk that the U.S. Geological Service (USGS) was able to match with places in the Geographic Names Information System (GNIS). To move beyond points, we relied on the National Land Cover Dataset (NLCD), a classification of Landsat Thematic Mapper 5 satellite imagery produced by the USGS EROS Data Center (http://edc.usgs.gov/products/landcover/nlcd.html), to represent the physical footprint of the communities. The resolution of the dataset is 30 meters. We extracted three urban categories of Low Density Residential, High Density Residential, and Commercial/Industrial to render a nationwide 30-meter resolution urban land cover map.

Two problems arose at this point. First, the high resolution of the urban data nationwide required more processing time than we could allow, and second, the urban dataset failed to distinguish urban/community clusters from wide interstate highways. Therefore, we engaged in a sequence of geographic information system (GIS) procedures to (1) efficiently resample the urban data to a coarser resolution to save processing time and (2) filter out the highways from the urban/community clusters. The following GIS commands accomplished these tasks. They were performed using the ARC/INFO software from Environmental Systems Research Institute (ESRI).

To prepare the urban data for resampling to a more practical resolution and to filter out long, unpopulated stretches of highway, we employed a 7 x 7 cell neighborhood analysis called FOCALSUM. This GIS command uses a roving window to count the number of urban cells within a specified neighborhood around each 30-meter cell. Because the neighborhood is calculated around a single central cell, the number of cells defining the neighborhood must be odd so that the roving window assigns the number of urban cells to the center cell of the neighborhood. The result is still a 30-meter resolution map, but rather than representing simply urban/non-urban for each cell, each cell now represents the density of urban cells within the surrounding 48 cells. We selected 7 cells for two reasons: (1) for practical purposes, a resampled 210-meter resolution can be processed within reasonable time frames (hours rather than days), and (2) a 210-meter neighborhood is large enough to estimate urban cell density such that long stretches of highway would occupy only a fraction of the neighborhood, thereby preparing the data for a filtering step that removes cells with low urban cell density.

Incorporating the result of the FOCALSUM command, we then used the SELECT command in GRID to select only those cells whose 49-cell neighborhood contained 10 urban cells or more (about 20 percent). This eliminates cells that represent a small percentage of urban cells such as long, linear stretches of highway within the neighborhood analysis.

Having filtered out the cells with very low urban densities (less than 20 percent), we then resampled the 30-meter image to 210-meter resolution. This made the resolution of the data coarser, thereby enabling quicker processing of subsequent steps. Because of our previous steps, each 210-meter cell represented a neighborhood within which at least 10 urban cells were detected at the 30-meter resolution, despite the coarser resolution.

At this point, some long, wide interstate highways were still present in the 210-meter urban data. Therefore, we employed GIS commands to “SHRINK” the dataset by one 210-meter cell, and then “EXPAND” the dataset by one 210-meter cell. The SHRINK command eliminated any remaining long, thin stretches of highway that are, at most, 2 cells across (420 meters). The EXPAND command operates on the output from the SHRINK command such that accurate area figures are restored, while the long, thin stretches of highway have been eliminated. This combination of commands effectively aggregates the communities and eliminates wide interstate highways.

To conduct an overlay with the communities at risk map, the urban dataset needed to be converted to a vector format using GRIDPOLY with a 210-meter weed tolerance.

Having the clustered and filtered urban dataset and the communities at risk map, we overlaid the two maps to identify those communities at risk for which a physical urban footprint was within a mile. We relied on a 1-mile proximity distance to assign urban footprints to communities because, in some cases, the community at risk” point fell just outside the urban footprint polygon. Also, we relied on the assumption that a physical urban footprint falling within a mile of a designated community at risk was, in fact, the intended urban area.

For those communities at risk within a mile of an urban footprint, the urban footprint data were buffered by a half mile. For those communities at risk that were farther than a mile from a physical urban footprint, the point itself was buffered by a half mile.

The resulting map represents our best estimate of a half-mile community protection zone around every officially designated and mapped community at risk. It should be noted that these methods apply only to the scale of a single national analysis. Interpreting this map at any scale finer than a national perspective is erroneous and misleading. To generate a more accurate map at a finer scale — an individual state, for example — the mapping should take advantage of more locally available datasets such as census data, land ownership maps, topography, and digital orthophotos. Some states, including California and Colorado, are pursuing just such an approach with positive results.

It is evident that practical constraints precluded processing the original 30-meter land cover data across the entire country. As a consequence of filtering out the low density clusters of urban pixels (using FOCALSUM and SELECT) and resampling the data to a 210-meter resolution, the acreage of the urban footprint grew from 36,718,254 acres in the original dataset to 53,904,581 acres after the resampling. However, after applying the SHRINK and EXPAND commands to the 210-meter data, the acreage fell to a more accurate 35,054,422 acres. Unfortunately, this step also eliminated many small towns and narrow strips of development that then had to be treated as individual points. Overall, we detected 2,307 footprint polygons that together contributed 75.5 percent of the nationwide community protection zone; 5,780 of 9,339 communities showed no detectable footprint and were treated as points.

## APPENDIX B

List of common and scientific names of species mentioned in this report

| COMMON NAME | SCIENTIFIC NAME |
|---|---|
| Ash | *Fraxinus* spp. |
| Aspen | *Populus* spp. |
| Basswood | *Tilia spp.* |
| Beech (American beech) | *Fagus grandifolia* |
| Birch | *Betula* spp. |
| Black cherry | *Prunus serotina* |
| Cheatgrass | *Bromus tectorum* |
| Cottonwood | *Populus* spp. |
| Cypress (bald cypress) | *Taxodium distichum* |
| Douglas-fir | *Pseudotsuga menziesii* |
| Elm | *Ulmus* spp. |
| Gum (sweetgum) | *Liquidambar styraciflua* |
| Hemlock | *Tsuga* spp. |
| Hickory | *Carya* spp. |
| Jack pine | *Pinus banksiana* |
| Juniper | *Juniperus* spp. |
| Larch | *Larix* spp. |
| Loblolly pine | *Pinus taeda* |
| Lodgepole pine | *Pinus contorta* |
| Longleaf pine | *Pinus palustris* |
| Maple | *Acer* spp. |
| Oak | *Quercus* spp. |
| Pinyon pine | *Pinus* spp. |
| Pitch pine | *Pinus rigida* |
| Ponderosa pine | *Pinus ponderosa* |
| Red pine | *Pinus resinosa* |
| Redwood | *Sequoia sempervirens* |
| Sagebrush | *Artemisia tridentata* |
| Shortleaf pine | *Pinus echinata* |
| Sitka spruce | *Picea sitchensis* |
| Slash pine | *Pinus elliottii* |
| Spruce | *Picea* spp. |
| Western white pine | *Pinus monticola* |
| White pine (Eastern white pine) | *Pinus strobus* |
| Wiregrass | *Aristida stricta* |
| Yellow birch | *Betula alleghaniensis* |