The San Diego Declaration on Climate Change and Fire Management

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Abstract

The 'San Diego Declaration on Climate Change and Fire Management' was presented by the Association for Fire Ecology at the Third International Fire Ecology and Management Congress, held in November 2006 in San Diego, California, USA. The Declaration is intended to raise awareness of the effects that climate change may have on wildland fire, and to provide considerations for planning and management to enhance ecosystem resilience to fire. The Declaration discusses linkages between climate, fire and vegetation; factors that have altered fire regimes; and how climate change may further disrupt fire regimes, ecosystems, and our ability to manage wildland fire. This paper provides information on fire ecology, fire occurrence, and climate change effects that influenced the decision to develop and seek endorsement for this Declaration, and outlines considerations for management, research and education that are included in the Declaration. The full text of the Declaration is appended to this paper. The Declaration represents the position of the Association for Fire Ecology and other signatories.

Introduction

The Association for Fire Ecology (AFE) is an organization of professionals dedicated to improving the knowledge and use of fire in land management (http://www.fireecology.net). Our mission is to promote the application of fire ecology through science and education. Our long-term goal is to ensure that fire management actions are informed by sound science and the most innovative ecological thinking. Our membership includes research scientists, land managers, technical specialists, university faculty, and students. AFE currently has two sections, the Association for Fire Ecology of the Tropics, and the Student Association for Fire Ecology, with 15 chapters at university campuses. Sections are being organized in the southeast United States and California. Our activities include organizing scientific conferences, and hosting an online journal, "Fire Ecology." A book coordinated and edited by AFE members has recently been published, "Fire in the ecosystems of California"

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(Sugihara and others 2006), and a fire ecology text for arid and semi-arid ecosystems of North America is being prepared.

The Association hosted the Third International Fire Ecology and Management Congress, in San Diego, California, in November of 2006. The initial concept for 'The San Diego Declaration on Climate Change and Fire Management' was conceived in 2005. Members of the Congress Steering Group and AFE Board wrote the Declaration, and obtained peer review from technical experts. The Declaration was distributed at the Fire Congress. It was endorsed by individual Congress participants who signed the Declaration, and by the AFE membership at our annual meeting. There are many declarations addressing climate change, and several about wildland fire, including the Freiburg Declaration on Tropical Fire; the Helsinki Declaration on Cooperation in Wildland Fire Management in the Baltic Region; Nelspruit Declaration on Cooperation in Wildland Fire Management in Sub-Sahara Africa; Antalya Declaration on Cooperation in Wildland Fire Management in the Balkans, Eastern Mediterranean, Near East and Central Asia; and the San Jose Declaration on Pan-American Cooperation on Wildland Fire Management. Although climate change has been mentioned in these Declarations, AFE believes that this is the first declaration to focus entirely on climate change and fire management.

Fire seasons are becoming longer, and large and severe wildfires are becoming more common in many parts of the world. While these trends have been attributed to changes in fuels, and to increased ignitions caused by human activities, recent research suggests that in the United States, these trends are in part related to climate change (Westerling and Swetnam 2006; Morgan and others 2006). The mission of Federal and State wildland management agencies in the United States does not include regulation of human factors that may be influencing climate change. However, agencies can manage ecosystems to increase their resilience to wildland fire in a changing global climate.

The 'San Diego Declaration on Climate Change and Fire Management' outlines actions that could help managers anticipate and mitigate potential negative effects of fires that occur in variable and changing future environments. It represents the opinion of the Board of the Association for Fire Ecology, and members and other concerned parties who have endorsed it. The collective experience of the AFE Board is largely within the United States, a perspective that influenced the content of the Declaration. This paper provides information on fire ecology, fire occurrence, and climate change effects that influenced the AFE decision to develop and seek endorsement for this Declaration, and outlines considerations for management, research and education that are included in the Declaration. The full text of the Declaration is contained in an Appendix to this paper.

Fire regimes and fire exclusion

The U.S. Federal government manages 2.5 million km^2 (623 million acres) (*fig. 1*). Agencies with the largest responsibilities for these lands include the Bureau of Land Management, National Park Service, and Fish and Wildlife Service of the U.S. Department of the Interior, and the U.S. Forest Service of the Department of Agriculture. There are large tracts of contiguous Federal lands, particularly in the western continental United States and Alaska, that are essentially unpopulated, including 429,000 km^2 (106 million acres) of Federally designated Wilderness Areas. Wildland fires are a common occurrence. In the last 6 years, lightning accounted for 16 percent of all wildfire ignitions in the United States. However, these fires resulted in 67 percent of burned area.[2] Lightning will continue to be a significant cause of fire. Because of the extensive areas that are unsettled wildlands, there are tremendous opportunities to proactively manage wildland fire, vegetation and fuels in the face of climate change.

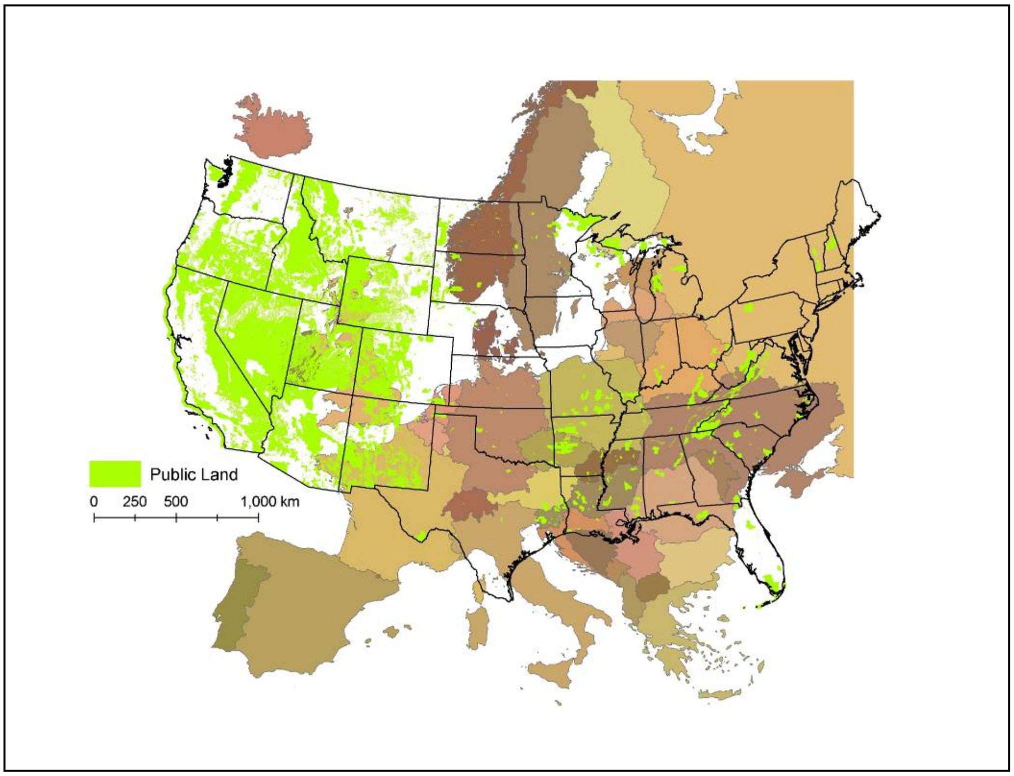

Figure 1. Federal land in the continental United States relative to the size of Europe.

Fire is a significant ecological factor in ecosystems of the United States. In most regions of the country, vegetation production exceeds decomposition rates, and biomass accumulates in the absence of fire. This is true for forests, rangelands, and

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[2] Wildland fire occurrence and acreage statistics used in this paper were obtained from the web page of the National Interagency Fire Center, Boise, Idaho. http://www.nifc.gov/stats

grasslands. The natural vegetation of a significant percentage of the continental United States experienced recurrent fire (*fig. 2*), with frequencies of less than 35 years. Many variations of fire regimes were the historic norm, including frequent, low intensity surface fires in western ponderosa pine (*Pinus ponderosa*) and southeastern pine that maintained low density forests; frequent stand replacement fires in the central plains grasslands that caused renewal of all aboveground biomass; infrequent fires in Alaska black spruce (*Picea mariana*) that enhanced productivity for many wildlife species; and long interval stand replacement fire in the temperate rain forests of the Pacific Northwest that initiated long-term sequences of successional change.

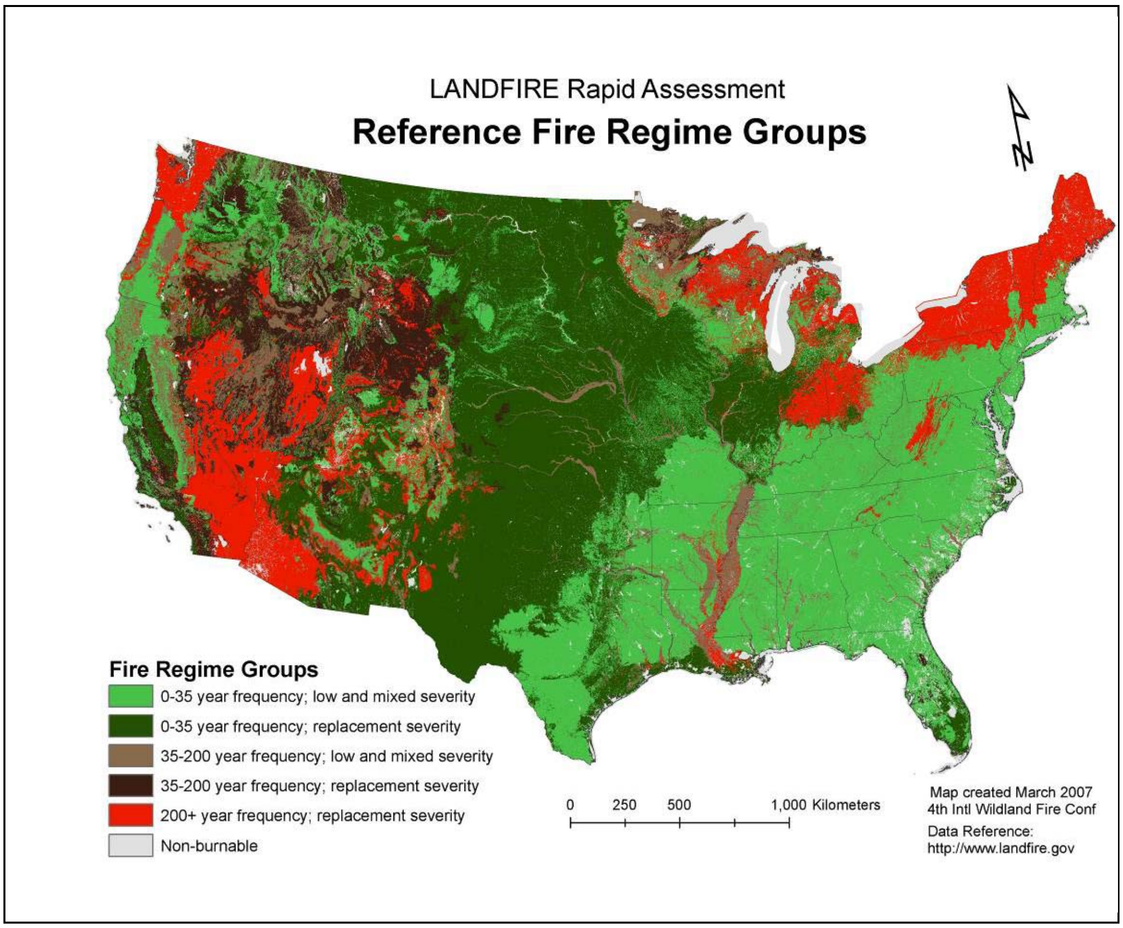


Figure 2. Frequency and severity of fire associated with potential natural vegetation groups, under the natural range of variability, including the influence of aboriginal burning (http://www.landfire.gov/ra1.php).

Fires have been excluded from many systems by active fire suppression, landscape fragmentation, and the removal of fine fuels by livestock grazing. The exclusion of fire can be associated with significant changes in structure and composition of dry forests, such as those dominated by ponderosa pine, making them more susceptible to extensive stand replacing fire. Crown fires are becoming more common because fire exclusion has allowed the development of an understory layer of trees that can carry fire into the overstory, and an increase in stand density that makes it easier for fire to remain in the forest canopy. Trees are also dying from root mortality caused by smoldering combustion of basal accumulations of litter and duff.

The removal of fire has allowed coniferous trees to establish in semi-arid rangelands of the United States. Eastern redcedar (*Juniperus virginiana*) is rapidly expanding in the grasslands of the southern Great Plains. Pinyon (*Pinus monophylla* and *P. edulis*) and juniper (*J. occidentalis*, *J. osteosperma*, and *J. monosperma*) have moved into areas that were formerly dominated by shrub-steppe and aspen (*Populus tremuloides*) communities in the intermountain west. Pinyon-juniper currently occupies about 30 million hectares (74 million acres), a ten-fold increase from the time of pre-European settlement (Miller and Tausch 2002). Juniper trees can exclude understory vegetation because of moisture competition. These sites can burn in a crown fire under windy conditions, and exotic weedy species gain dominance.

The effects of excluding fire are much less apparent in systems with very long fire return intervals, such as the rain forests of the Pacific Northwest, and the lodgepole pine (*Pinus contorta*) and spruce-fir (*Picea Engelmanni* and *Abies lasiocarpa*) forests of Yellowstone National Park. The 526,000 hectares (1.3 million acres) that burned in that Park in 1988 were likely not outside of the range of variability of fires historically experienced by these plant communities.

Fire occurrence and fuels management

The success of fire suppression efforts in the United States increased significantly after World War II. Currently, about 98 percent of all fires are controlled and suppressed during initial attack on U.S. Forest Service lands (U.S. Department of Agriculture 2006), and success rates on lands managed by other agencies are similar. Acres burned in the United States have been increasing (*fig. 3*) in recent decades. 2006 had the highest burned acreage since 1960, almost 4 million hectares (9.87 million acres). These increases are not due to higher numbers of wildfires (*fig. 4*). Despite the increase in burned acres in recent years, there is evidence that less acreage is burning than before the era of effective fire suppression (*fig. 5*). The large burned area in the early 1900s could be attributed both to limited fire suppression, and human caused fires. Leenhouts (1998) substantiates that there was a greater amount of annual burned area in the pre-industrial United States. He estimates that 200 to 500 years ago, in the conterminous United States (excluding Alaska and Hawaii), about ten times more area burned annually than is currently burning, and that if "historic fire return intervals were restored to contemporary non-urban and non-agricultural lands," 7 to 17 million hectares (18 to 43 million acres) would burn annually. Although more acres have been burning in recent years than in the earlier years of the fire suppression era, fewer acres may be burning than in pre-industrial times. It is likely that large fires that burned for long periods of time were common before European settlement of the continental United States. These statistics suggest that there is a large potential for increases in annual burned acreage.

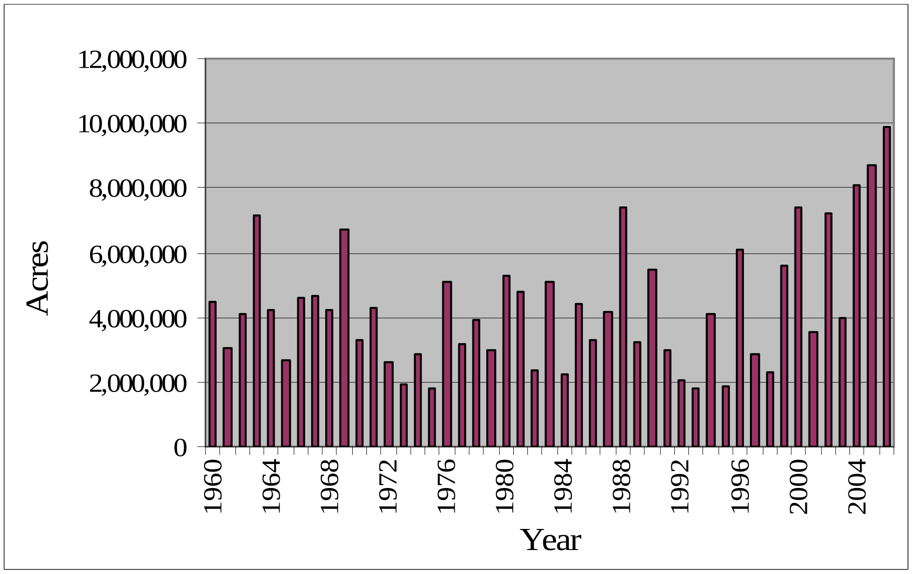


Figure 3. Acres burned by wildfires in the United States: 1960-2006.

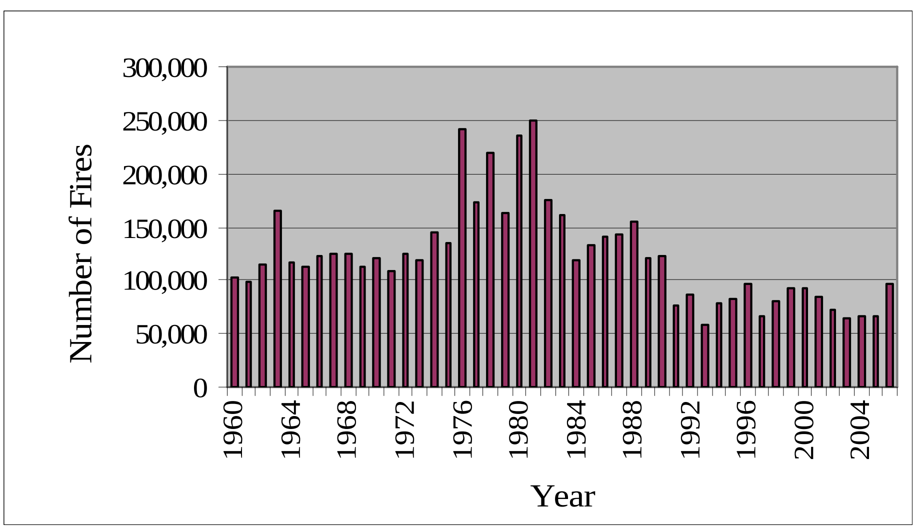
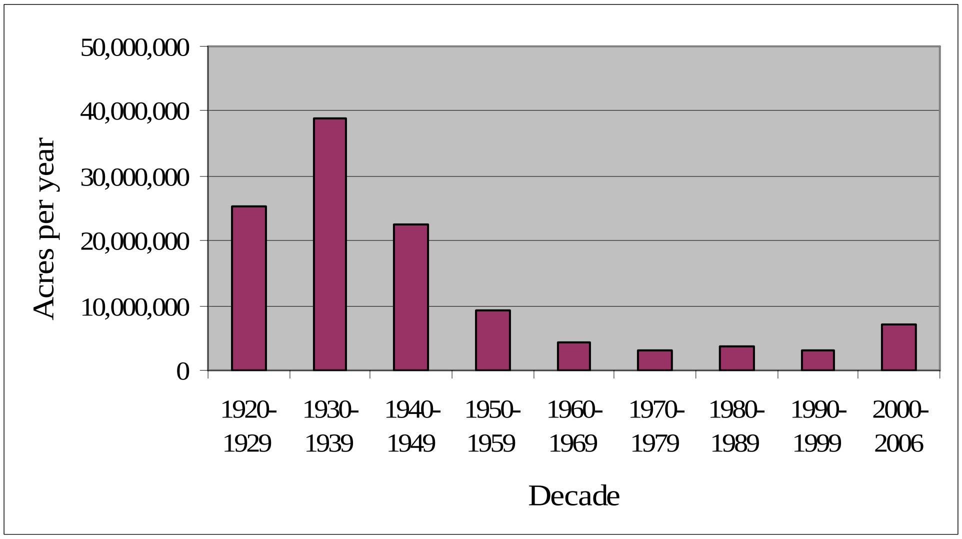


Figure 4. Number of wildfires in the United States: 1960 – 2006.



Fire suppression costs are escalating. The U.S. Forest Service spent $1.5 billion dollars on fire suppression in the 2006 fire season, and costs have exceeded $1 billion dollars in three of the last six years (U.S. Department of Agriculture 2006). The majority of U.S. Forest Service fire suppression costs are directly related to the protection of private property in the wildland/urban interface (U.S. Department of Agriculture 2006). Land managers continue to prioritize protection of private properties over natural resources (ibid.). Yet, large numbers of structures are still being lost to wildfires during extreme conditions, such as the 3600 homes burned in southern California in the fall of 2003, resulting from fires in chaparral and forest. And these fires caused 24 deaths.

To address the issue of increasingly large and severe fires, the Federal government has funded an extensive fuels management program, including prescribed fire and mechanical treatments. From 2000 through 2006, $2.7 billion dollars were budgeted for fuel treatment programs. This funding, new management tools and collaboration have greatly increasing the capability of Federal and State agencies to manage wildland fuels. Nearly 7.7 million hectares (19 million acres) were treated from 2001 to 2006, 4 million more hectares (10 million acres) than in the previous six years (U.S. Forest Service and Department of the Interior 2006). More than 60 percent of fuels treatment dollars have been focused in the wildland/urban interface. The goal is “to create landscape conditions that improve our effectiveness in suppressing unwanted fires and reducing risks to firefighters, communities, and the environment; and using desirable fires to help achieve natural resource management objectives” (U.S. Forest Service and Department of the Interior 2006). Tools and data are that are being developed in support of this fuels initiative, include LANDFIRE (http://www.landfire.gov), a five-year, multi-partner project producing consistent and comprehensive maps and data describing vegetation, wildland fuel, and fire regimes across the United States. Data can be used for fuels project prioritization, real time fire behavior prediction, and strategic project planning.

Fire and climate

Burned acres are increasing, suppression costs are rising, and there is a significant U.S. initiative to manage wildland fuels. What might happen to wildland fire occurrence and size in the event of climate change? A strong relationship between wildfire events and climate variation has been established (Kitzberger and others 2007). In the Pacific Northwest, the development of blocking high pressure ridges divert storm tracks around the region, leading to decreased soil and fuel moisture, and increased fire potential (Gedalof and others 2005). In the southwestern United States, northwest Mexico, and the south-central Rocky Mountains, warm El Nino-Southern Oscillation events cause wet years, which results in increased growth of herbaceous fuels that carry fire. In a subsequent dry La Nina year, large fires often occur [Swetnam and Betancourt (1990) and Veblen et al (2000) in Kitzberger et al 2007]. The Atlantic Multidecadal Oscillation, a measure of North Atlantic sea surface temperatures, affects precipitation in the western United States. We are trending toward the warming phase of its 60 year cycle, which has been associated with widespread fire in the western United States in the past (Kitzberger et al 2007).

If climatic patterns have a strong relationship to wildland fire (McKenzie and others 2004), one can assume that any alterations of these patterns under the influence of global climate change can affect wildland fire occurrence, size and severity. Eleven of the last twelve years are among the 12 warmest years since global surface temperatures have been instrumented (Alley and others 2007). The persistence of these warm temperatures into the future is ‘virtually certain’ (ibid.). Forecasted warmer temperatures will likely increase the length of the fire season in the western United States (McKenzie and others 2004). More winter precipitation in this region now falls as rain and not snow, leading to reduced spring snowpack, and earlier melting (Knowles and others 2006). Temperature and snowpack changes are already having an effect according to Westerling and others (2006), who analyzed fire and climatic data from forests of the western United States, and concluded that since the late 1980s, there has been a higher frequency of large wildfires, longer wildfire durations, and longer wildfire seasons. The greatest increases have occurred in mid-elevation forests of the Northern Rocky Mountains, strongly associated with increased spring and summer temperatures and an earlier spring snowmelt. Morgan and others (2006) support this interpretation: “We suggest that the late twentiethcentury increase in regional fire years in this region resulted from a combination of climate variation, climate change and land use. Given projections of future climate, the region is likely to experience larger and more severe fires in the future." There has been a misconception that fuels and restoration treatments will prevent the occurrence of large fires. While fuels treatment alone will not reverse current trends in wildfire occurrence (Westerling et al 2006), the severity of fires will be reduced where effective treatments have occurred on lands affected by past management and use. These fires could have increased ecological benefit, and enhance, rather than reduce the provision of ecosystem services.

Declaration Content

AFE believes that climate change concepts should be integrated into fire management planning and operational decisions. The Declaration is intended to raise awareness of the effects that climate change may have on wildland fire, and to provide ideas for planning and management that may help land managers anticipate and mitigate potential negative effects of fire in variable and changing future environments. The Declaration introduces the issue and describes six premises about fire and climate that are a basis for our concerns. It provides specific considerations for fire management planning, fuels management, and research, education, and outreach, including:

Fire and ecosystem management

- The need to incorporate knowledge of potentially more severe fire weather, lengthened wildfire season, and larger fires into:
  - The fire budgeting and allocation process;
  - Strategic allocation of fire fighting and fire use resources during the fire season;
  - The development of fire and land management plans; and reassessment of the underlying assumptions for current plans;
  - Planning for postfire vegetation management, particularly when selecting species for reseeding and planting.

Fuels Management

- The expansion of prescribed burning, mechanical fuels treatments, and wildland fire use programs
- Strategic location of burning and thinning treatments where they are more likely to influence fire spread
- The integration of expected vegetation response to climate change into site specific project design and implementation
- Control of flammable invasive, non-native plant species in ecosystems that are threatened by their continued spread and persistence

- Use of woody materials from mechanical treatments for forest products and biomass energy

Research, Education and Outreach

- Implementation of long-term biodiversity and fuels monitoring programs in fire-adapted ecosystems expected to be most affected by climate change
- Improvement of our ability to forecast fire season severity
- Integration of information on climate change and its relationship to disturbance into primary and secondary school and university curricula
- Dissemination of information to the general public and government agencies that manage natural resources
- Organization of conferences and symposia in order to enhance discussion on how to adapt public land management to changing fire regimes
- Identification and implementation of research in emerging areas of fire and climate science

Current Status

Uncharacteristic wildland fire may cause a more rapid rate of vegetation transformation than any other climate induced change. AFE hopes that this Declaration will raise awareness of this potential among Federal, State and private land managers in the United States, and in other parts of the world. The Director of the U.S. National Park Service has distributed copies of the Declaration to all Park Superintendents. It has been endorsed by the Global Fire Initiative and Global Change Initiative of The Nature Conservancy. This is the third conference at which AFE has made presentations on the Declaration since it was released last November. The Association for Fire Ecology welcomes any input on future direction for and enhancement of the Declaration. We would be pleased to obtain your endorsement.

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APPENDIX I.

The San Diego Declaration on Climate Change and Fire Management

The Association for Fire Ecology

Presented at:

Third International Fire Ecology and Management Congress, San Diego, California, U.S.A.[3, 4]

November 13-17, 2006

Preamble

As scientists and land managers who focus on fire and its effects on natural ecosystems, we recognize that climate plays a central role in shaping fire regimes over long time scales and in generating short-term weather that drives fire events. The science surrounding human-caused climate change continues to strengthen and the weather patterns that shape the ecosystems where we live and work may be altered dramatically over the coming decades. In anticipation of such changes it is important to consider how fire management strategies may enable us to respond to a changing global climate and thereby reduce potential disruptions to plant communities, fire regimes and, ultimately, ecosystem processes and services.

Currently, we are observing serious wildland fire conditions, such as increasing numbers of large and severe wildfires, lengthened wildfire seasons, increased area burned, and increasing numbers of large wildfires in fire-sensitive ecosystems (e.g. tropical rain forests and arid deserts). Recent research suggests that these trends are, in part, related to shifts in climate.

As temperatures increase, fire will become the primary agent of vegetation change and habitat conversion in many natural ecosystems. For example, temperate dry forests could be converted to grasslands or moist tropical forests could be converted to dry woodlands. Following uncharacteristic high-severity fires, seedling reestablishment could be hindered by new and unsuitable climates. Plant and animal species already vulnerable due to human activities may be put at greater risk of extinction as their traditional habitats become irreversibly modified by severe fire. Streams and fisheries could be impacted by changing climates and fire regimes with earlier peak flows, lower summer flows, and warmer water even if ecosystems don't burn. Finally, extreme wildfire events and a lengthened fire season may greatly

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[3] This declaration represents the position of the Association for Fire Ecology and other signatories and may not represent the position of other organizations or agencies sponsoring the Congress.

[4] During the Congress, the Association for Fire Ecology will provide this declaration to all Congress attendees for their individual and collective endorsement.

increase the risk to human lives and infrastructures, particularly within the wildland urban interface.

We acknowledge that there are uncertainties in projecting local impacts of climate change, however, without taking action to manage fire-dependent ecosystems today and in the absence of thoughtful preparation and planning for the future, wildland fires are likely to become increasingly difficult to manage.

We, the members of the Association for Fire Ecology that endorsed this document at the Third International Fire Ecology and Management Congress, support the following considerations for planning and management to enhance ecosystem resiliency to wildland fire in a changing global climate.

Background

1. Both fire and climate regimes interact with other natural processes to direct the formation of vegetation in ecosystems. Given that climate and fire regimes are linked through vegetation, changes in climate can lead to large or small changes in fire regimes. Climate and fire regimes are also directly connected through the climate drivers of ignitions and fire weather. Climate influences both where and how vegetation grows and thereby creates the fuel conditions that drive fire frequency, intensity, severity, and seasonality. Precipitation and temperature patterns regulate the accumulation of fuels. In some ecosystems, wet years may promote “boom” vegetative (fuels) conditions, while drought years promote “bust” and the burning of the “boom” vegetation. Further, we know that the inevitable dry years, particularly when warm, are associated with larger fires, both in size and number, especially where fuel is abundant. Fire can also contribute to the problem of increasing green house gas emissions because it is a source of CO2 and particulate emissions, which may affect local and regional air quality and worldwide climate.

2. Historical fire regimes have been disrupted in many ecosystems. Factors such as human activities and land development, loss of indigenous burning practices, and fire suppression have all led to changes in some plant communities historically shaped by particular fire regimes. Human activities have significantly increased the number of ignitions in many temperate, boreal, and tropical regions. Fuel loads have increased in some temperate forests where low intensity fires were historically the norm. In some rangelands, shrubs have been replaced by annual grasses or colonizing trees. Human caused burning has increased fire frequency in some tropical regions where fire-sensitive ecosystems dominate.

It should be noted that not all vegetation types in have been significantly altered by fire suppression. Many shrubland ecosystems, such as California chaparral, burn with high severity under extreme weather conditions and fire management in the 20th and 21st centuries has not appreciably changed their burning patterns. Coastal, mesic coniferous forests in the Northwestern US have not been modified to a great extent by fire suppression policies because fire rotations in this area are much longer than the period of fire suppression. In other forests such as Rocky Mountain lodgepole pine, high severity fires every 100-300 years are ecologically appropriate and fire suppression has probably not affected these ecosystems to a great extent. The ecosystems most impacted by fire suppression are forests that once experienced regimes of frequent, low-moderate intensity fires; these ecosystems are probably the most vulnerable to altered fire regimes from changing climates.

Approaches to restore fire-adapted ecosystems often require treatment or removal of excess fuels (e.g. through mechanical thinning, prescribed fire, or mechanical - fire combinations), reducing tree densities in uncharacteristically crowded forests, and application of fire to promote the growth of native plants and reestablish desired vegetation and fuel conditions. Excess fuels are those that support higher intensity and severity fires than those under which the particular ecosystem evolved or are desired to meet management objectives. For example, in dry western US forests that once burned frequently, a high density of trees and a large surface fuel load often promotes crown fires that burn over very large areas. Some of these same forests once flourished under a fire regime where frequent, non-lethal low-intensity surface fires were the norm, and large-scale crown fires were rare. Managers should determine if forests can be restored to what they once were or if another desired condition is more appropriate. If it is not appropriate to restore ecosystems to a previous condition because of expected novel climate conditions, then managers should develop new conservation and management strategies and tactics aimed at mitigating and minimizing uncharacteristic fire behavior and effects.

3. Climate change may interact with other human activities to further change fire regimes. For example, in much of the western US, since the 1980s, large fires have become more common than they were earlier in the century. This has often been attributed to increased fuel loads as a result of fire exclusion. However, a number of research studies suggest that climate change is also playing a significant role in some regions, elevations, and ecosystem types. In the western US, researchers recently identified an increase in fire season duration in mid-elevational forests. These changes were correlated with earlier spring snowmelt dates. With global temperatures projected to rise throughout this century, increases in fire season length and fire size can be expected to continue.

4. Climate change can lead to rapid and continuous changes that disrupt natural processes and plant communities. Are managers safe in assuming that tomorrow's climate will mimic that of the last several decades? Increased temperatures are projected to lead to broad-scale alteration of storm tracks, thereby changing precipitation patterns. Historical data show that such changes in past millennia were often accompanied by disruption of fire regimes with major migration and reorganization of vegetation at regional and continental scales. Exercises in modeling of possible ecological responses have illustrated the potential complex responses of fire regimes and vegetative communities. These exercises indicate that dramatic changes in fire regimes and other natural disturbance processes are likely. Indeed, some believe that the impacts of climate change may already be emerging as documented in widespread insect infestations and tree die-offs across some areas in the western U.S. and British Columbia, and more rapid and earlier melting of snow packs. Developing both short- and long-term fire and fuels management responses that improve the resilience of appropriate ecosystems while reducing undesired impacts to society will be critical.

5. Changes in climate may limit the ability to manage wildland fire and apply prescribed fire across the landscape. Under future drought and high temperature scenarios, fires may become larger more quickly and could be more difficult to manage. Fire suppression costs may continue to increase, with decreasing effectiveness under extreme fire weather and fuel conditions. In some temperate and boreal regions, it is expected that more acres will burn and at higher severities than historically observed. In humid tropical regions exposed to severe droughts, vast forests could burn making it difficult for forest managers to prevent farmers from entering destroyed forests and establishing new farms. Globally, new fire regimes would be associated with shifts in ecosystem structure and function and likely, changes in biodiversity.

6. Approaches to fire management that recognize the potential for greater variability and directional change in future climates may help to reduce ecological and societal vulnerability to changing fire regimes. Such approaches are likely to improve fire management and ecosystem health. A goal could be to reduce the vulnerability, both ecologically and socially, to the uncertainties that accompany a changing climate. For example, if managers restore some forests as a means to increase ecosystem resiliency to climate change, they will also be improving

biodiversity and protecting important forest resources. In the humid tropics, if managers make a concerted effort to prevent fire from entering rain forests during drought years, then they would be reducing the risk of future fires and illegal logging, even if droughts did not become more frequent and severe with a changing climate.

Considerations for Management, Research and Education

Recent changes in climate and fire patterns have been observed in many areas of the world, and current projections are that ongoing and long-term changes are likely. We believe that the actions outlined below could help managers to be better prepared to anticipate and mitigate potential negative effects of variable and changing future environments.

Fire and Ecosystem Management

- Incorporate the likelihood of more severe fire weather, lengthened wildfire seasons, and larger-sized fires in some ecosystems when planning and allocating budgets, which traditionally are based on historical fire occurrence.
- Make use of both short-term fire weather products AND season-to-season and year-to-year climate and fire outlooks that are increasingly available from "predictive services" groups in federal agencies, and particularly the sub-regional variations in anticipated fire hazards that enable strategic allocation of fire fighting and fire use resources nationally.
- Continually assess current land management assumptions against the changing reality of future climates and local weather events.
- Develop site-specific scenarios for potential weather events linked to climate change and redesign fire management strategies to make room for rapid response to these events.
- Consider climate change and variability when developing long-range wildland fire and land management plans and strategies across all ownerships.
- Consider probable alternate climate scenarios when planning post-fire vegetation management, particularly when reseeding and planting.

Fuels Management

- Prepare for extreme fire events by restoring some ecosystems and reducing uncharacteristic fuel levels through expanded programs of prescribed burning, mechanical treatments, and wildland fire use to meet resource objectives. Burning under the relatively mild weather conditions of a prescribed fire produces lower intensity burns and, generally, less carbon emissions than would a fire burning under wildfire conditions. Burning and thinning treatments should be strategically placed on the landscape in locations where they are more likely to influence fire spread. Some ecosystems will continue to burn in high severity stand replacement fires and this is appropriate for their sustainability.
- Incorporate emerging scientific information on the impact of changing temperature and precipitation on plant communities into fuels management project design and implementation at the local level.
- Expand wildland fire use at the landscape scale in fire-adapted ecosystems to restore fire regimes and reduce fuel loads. Be more aggressive in promoting fire use during lower hazard fire seasons, and fire use in landscapes that offer particular opportunities for relatively low-risk, large-scale burning. This will allow more

acres to be burned under less extreme fire weather conditions than fires that might occur in the future under extreme heat or drought conditions.

- Control highly flammable non-native plant species and develop management options to address their increased spread and persistence. In some ecosystems appropriately timed prescribed fires can be used to reduce non-native species, while in others, continued fire exclusion may be the best management strategy. In some areas, reseeding and active restoration may be the best option.
- In some cases the removal and use of small diameter forest products (engineered lumber, pulp and paper, biofuels) and chipped fuels (for electrical energy generation) could be used to reduce fire hazards in appropriate vegetation types. Burning excess fuels in a co-generation plant has the additional advantage of producing lower emissions when compared to prescribed fires.

Research, Education, and Outreach

- Implement long-term biodiversity and fuels monitoring programs in the fire-adapted ecosystems that are expected to undergo the widest range of change and variability linked to climate change, such as those that once experienced frequent, low-moderate intensity fire regimes.
- Expand inter-disciplinary research to forecast potential fire season severity and improve seasonal weather forecasts under future climate change scenarios.
- Integrate the subject of climate change and its influence on ecosystem disturbance into curricula within natural resource management programs at the university and continuing education levels, and in science programs within primary schools.
- Disseminate information to the general public and government agencies regarding the potential impacts of changing climate on local natural resources and disturbance regimes, particularly those that interact with fire.
- Hold conferences or symposia to enhance communication among researchers and managers and to engage the general public in discussion on how best to adapt public land management to cope with fire in a changing environment.
- Form inter-disciplinary teams of researchers that include fire ecologists and climate scientists to identify and pursue emerging areas of climate and fire research.