Forest Ecology and Management 294 (2013) 4–10

Contents lists available at SciVerse ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Exploring the onset of high-impact mega-fires through a forest land management prism

Jerry Williams *

Former National Director of Fire & Aviation Management, United States Forest Service, Retired, 1604 Jackson Street, Missoula, MT 59802, United States

ARTICLE INFO

Article history:
Available online 22 August 2012

Keywords:
Mega-fires
Wildland fire protection
Drought effects

ABSTRACT

In the modern era, high-impact mega-fires are unprecedented for the suppression costs, property losses, natural resource damages, and loss of life often involved. For a number of years, these extraordinary wildfires have been increasing in number and in severity. They affect countries around the world, including those with enormous firefighting capabilities. High-impact mega-fires are frustrating efforts to provide for public safety, slow rates of deforestation, sequester carbon and reduce black carbon emissions.

Despite more determined bidding, attempts to match increasing wildfire threats with greater suppression force have not stemmed climbing mega-fire trends. Yet, the majority of after-action reviews, reports, and commissions continue to weight recommendations to correcting emergency response deficiencies, generally through a fire operations lens.

This paper explores the mega-fire phenomenon through a forest land management prism. It is an early attempt to focus on the contributory factors that may set the stage for high-impact mega-fires. The paper draws on the results from two coarse-filter overviews of high-impact mega-fires from around the world and the authors' firsthand experiences dealing with others in the United States.

Drought and fire exclusion policies have been implicated in the large fire problem. However, several high-impact mega-fires can be further traced to land management decisions that resulted in dense forest conditions with high biomass and fuel build-ups over extensive areas. As droughts have intensified, more of these accumulated fuels have become available to burn at intensities that exceed suppression capabilities.

In contrast, some places have managed to largely avoid high-impact mega-fires. State and federal lands in Florida and Crown lands in Western Australia have better aligned policies and practices with the disturbance regimes that define the forested landscapes that they protect. They use prescribed fire at appropriate intensities, intervals, and scales to reduce fuels as the means to protect people, maintain forest resilience, ensure biodiversity, and increase margins of suppression effectiveness.

Forest land management policies and practices that, by design or by default, result in greater volumes of fuel and rely on suppression capabilities to maintain these conditions may no longer be sustainable as droughts deepen and become more widespread. This paper suggests that adapting wildland fire management programs, forest land management policies, and the current regulatory framework to the reality of warmer, drier climate patterns will be essential in reducing mega-fire risks. Protecting fire-prone landscapes can no longer rely on suppression alone; protection will become more dependent on the management of forests where high-impact mega-fires incubate.

© 2012 Elsevier B.V. All rights reserved.

1. Introduction

Over the past several years, an alarming new kind of wildfire has emerged; the so-called "mega-fire." Their onset may arguably represent one of the most important topics in forest management today. Against the backdrop of 2011, the United Nations' declared International Year of Forests – exploring the mega-fire phenomenon is timely. These high-impact wildfires adversely affect forested ecosystems already under strain in many places around the world. They are a global phenomenon, tied to internationally significant issues including public safety, deforestation, forest degradation, black carbon emissions, and carbon sequestration.

Most after-action reviews, reports, and commissions weight their recommendations to correcting emergency response deficiencies, generally through a wildfire operations lens. A few have attempted to increase fuel reduction efforts, but only within the confines of prevailing forest land management direction and in the context of the existing regulatory framework.

High-impact mega-fires are a new reality. They have been discussed in the context of climate change, but less is known about their relationship to the forest conditions and forest land

* Tel.: +1 406 544 2709.
E-mail address: jtwilliams50@msn.com

0378-1127/$ - see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.foreco.2012.06.030

management policies and practices that may make fire-prone forests more susceptible to mega-fire risks. In the spirit of the conference's theme, this paper sets out to explore these possible linkages through a forest land management prism and a regulatory prism. The paper argues that, as suppression capabilities are more often overwhelmed, land managers and policy-makers will be forced closer toward a critical crossroads. Do decision-makers attempt to further boost suppression capacity, or do they attempt to mitigate the predisposing risks that may be fueling high-impact mega-fires?

Drought represents a changed circumstance. Coupled with high fuel loads in many places, it is changing the calculus of wildland fire protection programs and the land management policies upon which they hinge.

The term "mega-fire" seems to have become popularized during the 2002 fire season in the Western United States. In that year, five states suffered their worst wildfires on record. It became clear that the scale and scope of impacts resulting from these incidents were extraordinary and altogether distinct from other large wildfires.

Omi (2005) defined mega-fires as "large project fires that require more people, more equipment, and greater commitment of financial resources." While they are commonly very large, a few are quite small. Some are actually a complex of multiple large fires burning in close proximity to one another over a wide geographic area. Regardless of size, though, some mega-fires carry enormous and often lasting un-wanted human, economic, and environmental consequences. Politically, the fallout from these high-impact mega-fires often reach to the highest levels of government. At a fundamental level, they can call into question governments' ability to protect its citizens at the most extreme levels of threat. In any country, they are deeply shocking to survivors, and to those charged with protection.

China's 1987 Great Black Dragon Fire perhaps marks the beginning of the high-impact mega-fire phenomenon in the modern era (since the advent of organized wildfire protection). This wildfire claimed the lives of over 200 people and burned approximately 1.2 million hectares (Salisbury, 1989). That same year, beginning on the last day of August, multiple large wildfires in northern California prompted one of the United States' largest firefighting mobilizations up to that time. The next year, Yellowstone and Canyon Creek joined the list of 'never-before-seen' massive wildfires.

In the United States and elsewhere around the world, large wildfires represent only a small fraction of total wildfires and high-impact mega-fires only a small fraction of those. However, these wildfires account for a disproportionately high percentage of total suppression costs, private property losses, natural resource damages, and fatalities. Among all wildfires, high-impact mega-fires are the most dangerous, most destructive, and most costly wildfires that a region or a nation will suffer. Some have become their country's worst civil disasters on record (e.g. Australia's 2009 Black Saturday Bushfire with 173 fatalities).

High-impact mega-fires challenge the most able suppression-centric protection programs. Despite growing wildfire protection budgets, improved coordination, and better technology, these extraordinary incidents exceed all efforts at control until there is a break in fuels or relief in weather. Here, fire behavior characteristics go well beyond the most determined firefighting capabilities. At the highest level of wildfire threat – where protection often matters the most – high-impact mega-fires defeat protection aims. Their onset suggests the need to evaluate alternatives.

2. Methods

Most post-fire inquiries and reports have tended to concentrate on operational issues and response actions taken (or opportunities missed) between time of detection and time of containment. This paper attempts to draw attention to the factors that may set the stage for high impact mega-fires; factors that may begin to incubate many years before the incident starts.

The results of this paper draw from two coarse-filter overviews of eight record-setting wildfires in the United States and four more from elsewhere around the world (Williams and Hyde, 2009; Williams et al., 2011).[1] The author puts forward observations based on firsthand experience with several of these incidents in the United States. In many cases, there were significant differences between the ecological, social, economic, legal, and historical complexities involved. Land tenures and demographics were also different. The overviews relied on subject matter experts familiar with each incident to provide information on response issues, impacts, and causal and contributory factors. Most respondents answered with first-hand knowledge of the incidents, basing their input on their experience and their observations. Without benefit of common data bases and incomplete information, some responses were less detailed than others. This paper attempts to use the information at hand and explore its meaning.

The findings discussed in this paper were developed from the following high-impact mega-fire samples:

United States:

- *Volusia-Flagler Complex* (Florida, 1998); 83,278 hectares.
- *Valley Complex* (Montana, 2000); 85,805 hectares.
- *Rodeo-Chediski Fire* (Arizona, 2002); 189,651 hectares.
- *Hayman Fire* (Colorado, 2002); 55,749 hectares.
- *Ponil Complex* (New Mexico, 2002); 37,442 hectares.
- *Biscuit Fire* (Oregon, 2002); 202,329 hectares.
- *Georgia Bay Complex/Bugaboo* (Georgia and Florida, 2007); 227,029 hectares.
- *Cascade Complex* (Idaho, 2007); 122,367 hectares.

International:

- *Paleochori-Sekoulas Fire* (Greece, 2007); 40,000 hectares.
- *Black Saturday Fire* (Australia, 2009); 430,000 hectares.
- *Central Russia Complex* (Russia, 2010); 67,000 hectares.
- *Mount Carmel Fire* (Israel, 2010); 3000 hectares.

Although the two assessments that have been conducted to date included a chaparral example (*Cedar Fire*, California 2003; 110,578 ha), two tropical examples (*Kalimantan Complex*, Indonesia 1997/98; 9,700,000 ha and the *Roraima Fire*, Brazil 1998; 11,000 ha), and one grassland-savannah example (*Ghanzi Fire*, Botswana 2008; 3,600,000 ha), this paper is confined to temperate forest examples in an effort to narrow focus by fire regime and climatic influence.

In the United States, each incident's large fire package, land management plan, and other supporting documentation are archived on the unit where the fire occurred. Information on the international assessments is being compiled into an FAO Working Paper. This information is housed at the Food and Agriculture Organization Headquarters, Rome Italy.

Note: In 2011, Arizona's *Bear Wallow Fire* (189,798 ha) and New Mexico's *Las Conchas Fire* (41,958 ha) eclipsed those states' worst

[1] The US assessment was commissioned by the United States Forest Service, under contract with The Brookings Institution and co-authored with Dr. Albert C. Hyde. The findings from that assessment were presented at the 90th Annual Society of American Foresters Convention in Orlando, Florida (September 30–October 4, 2009). The international assessment was commissioned under volunteer agreement with the Food and Agriculture Organization of the United Nations. Nine subject-matter experts co-authored the report. The assessment's findings were presented at the 5th International Wildland Fire Conference in South Africa (May 9–13, 2011). The findings and observations resulting from these assessments are not necessarily the views of the United States Forest Service, The Brookings Institution, or the United Nations' Food and Agriculture Organization.

wildfires on record, both established only 9 years earlier. Also in 2011, in Texas, some 21,000 wildfires destroyed 1500 homes and burned approximately 1.6 million hectares, marking the state's worst wildfire season on record. In the meantime, Mexico's *Serranias del Burro Fires* burned for over 3 months, consuming over 200,000 hectares.

3. Results

3.1. Background findings

- Mega-fires occurred in both undeveloped and developed countries. Even units with enormous firefighting capacity suffered high-impact mega-fires.
- Virtually all occurred during periods of record-setting drought and under extreme fire weather conditions.
- Several mega-fires started during wildfire emergencies, when multiple large fires and new starts were stretching firefighting capabilities.
- Mega-fires typically exceeded all efforts at control until firefighters got a break in fuels or relief in extreme fire weather.
- Rates of fire spread far out-paced fireline production rates. Firefighting was often impeded by long-distance spotting and heavy fuels. Firefighters frequently reported very high resistance-to-control problems.

3.2. Causal factors

- One-half of all mega-fires studied here were believed to have been human-caused. Most human-caused starts were attributed to carelessness, but some were the result of malicious arson. Lightning accounted for the remaining starts.

3.3. Contributory factors

- Forest land management practices (by design or by default; both active and passive) were implicated as contributory factors leading up to high impact mega-fires.
- High-impact mega-fires occurred in forests where biomass and fuel accumulations dominated the landscape. Relatively dense forest conditions, with high volumes of fuel contributed to extreme fire behavior.
- Within the perimeters of some mega-fires, relatively small previously treated areas with less biomass and less fuel survived overall mega-fire impacts.
- On the perimeters of some mega-fires, extreme fire behavior dropped and high rates of spread slowed as a result of previous fuel reduction efforts.

3.4. Summary of overview

No two mega-fires were the same, but the findings drawn from these assessments indicate that large increases in biomass at landscape scales was a common significant contributing factor in fueling the mega-fire threat. The observation was particularly pronounced in drier forest types where long-term fire exclusion, limited fuel reduction work, and slow rates of decomposition, have combined to result in steady fuel build-ups. Mega-fire risks were also elevated where vegetative mosaics have diminished and melded into more continuous high hazard landscapes.

Mega-fire risks were amplified by land management practices that aimed for dense, largely undisturbed conditions over very large, un-broken landscapes.

4. Discussion

4.1. Examples of forest land management practices resulting in fuel build-up

During the course of the assessments, several forest land management objectives or practices were linked to increased biomass and/or fuel build-ups. Some were expressed in land management allocations; others were expressed less formally or simply occurred over broad landscapes:

- Maximizing basal area growth for wood fiber production (e.g. pulp).
- Maintaining dense forest conditions for homeowner seclusion or screening (some with protective covenants against thinning or biomass removal).
- Preserving multi-storied, or late successional stand conditions for wildlife habitat, visual quality, recreation values, and others by restricting active management entries.
- Maintaining high levels of filtration to protect watersheds and water quality by minimizing ground disturbances or removal of debris.
- Maintaining high air quality for nearby communities, tourism values, and crop production by minimizing smoke impacts.
- Draining peat bogs for use and development.
- Abandoning the land and traditional uses that keep biomass accumulations in check (e.g. grazing, fuelwood gathering, resin tapping) for better economic opportunities elsewhere.

Many of today's high-impact mega-fires are not being fueled by logging debris, as they were a century ago; they are being fueled by over-accumulated biomass and dead fuel build-ups in undisturbed forests. Society's values, behaviors, and actions have always intersected wildland fire outcomes in many ways, but, today, vast landscapes have become more combustible as a result of being left unattended (Pyne, 2008).

4.2. Linking increases in biomass and fuel build-ups to potential fire behavior in drier forest types

The following examples, drawn from the inland northwestern United States, are used to illustrate changes in potential fire behavior as a result of biomass and fuel accumulations.

Before organized fire suppression, ponderosa pine forests were characterized by frequent low-intensity burning regimes. Biomass and fuel build-ups were checked by these surface burns. Species adaptations made these forests resilient to lower intensity burning, with most of the forest left intact following passage of the fire (Fig. 1).

Today, these same forests are choked with understory biomass and over-accumulated dead fuels. Fire behavior characteristics have changed dramatically from frequent, low-intensity burning to severe, high-intensity burning with consequent effects to people living in these zones, as well as to soil, water, air, and other values (Fig. 2).

4.3. Changes in fire regime characteristics over time

In a 100 year period, fire regimes have largely reversed from low-intensity understory burning to high-intensity stand replacement burning in the ponderosa pine forests of the West (Fig. 3).

Similar fire behavior patterns are evidenced in dry forest types elsewhere, including in longleaf pine (and associated) ecosystems in the Southeastern United States, the dry eucalypt forests of Australia, and pine dominated (or co-dominant) forests in the

Fig. 1. Typical fire behavior characteristics in a late 1800 – early 1900 ponderosa pine forest in the Western United States (low-severity fire behavior characteristics).

Fig. 2. Typical fire behavior characteristics in a late 1900 – early 2000 ponderosa pine forest in the Western United States (stand replacement burning characteristics).

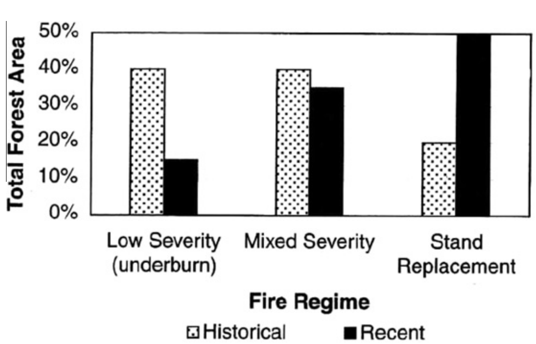

Fig. 3. The proportion of understory fire, mixed-severity fire, and stand-replacement burning in the pre-1900 period and in recent times in the inland northwestern United States (Arno and Allison-Bunnell, 2002).

Mediterranean region. The paper wishes to make clear that these dynamics are not the same, but they are similar with respect to the relationship between fuel accumulations and resultant fire behavior.

4.4. Linking increases in biomass and fuel build-ups at landscape scales to potential fire spread

The size, arrangement, and distribution of vegetative mosaics are an important determinant of wildfire potential (Agee, 1993). Particularly in a cooler/wetter climate cycle, past wildland fires probably did not start actively burning until later in the season (Westerling et al., 2003). Burn patterns were likely also influenced by moisture differentials in elevation, aspect, slope, and riparian areas. Cultivation and other disturbances further influenced patch dynamics (Xanthopoulos, 2008). Owing to differences in fuel loading among these patches, flammability potential was probably highly variable across more heterogeneous, more richly patterned landscapes.

More homogeneous landscapes have developed as the number of relatively small stand replacement fires have declined. As droughts have spread and deepened, moisture differentials have also begun to shrink and disappear. Mega-fire potential seems greatest where diverse landscape mosaics have been lost and biomass has dried out over very large homogeneous areas (Fig. 4).

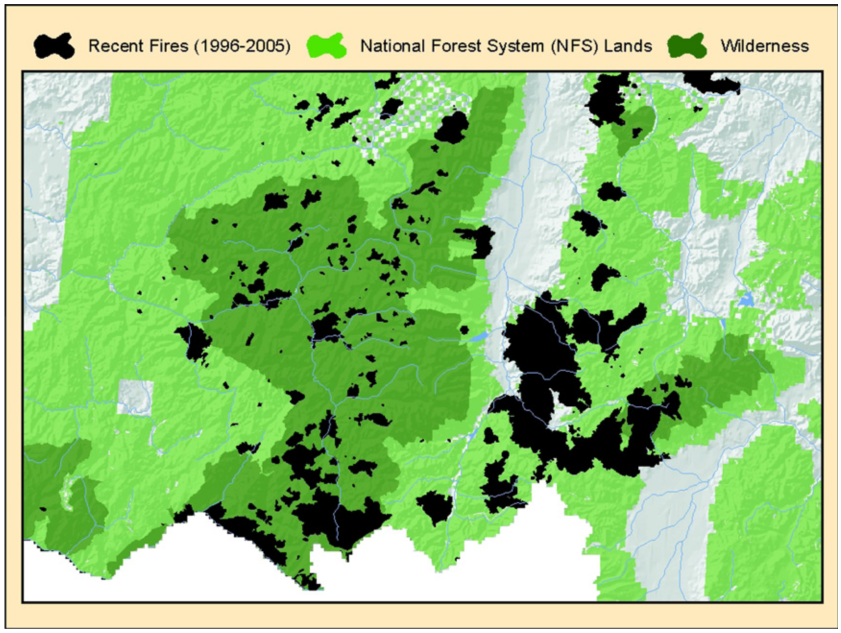

Fig. 4. Size, arrangement, and distribution contrasts between recent wildland fires (1996–2005) in wilderness (prescribed natural fire-use emphasis) and general National Forest System lands (suppression emphasis) in the Selway-Bitterroot area of Western Montana.

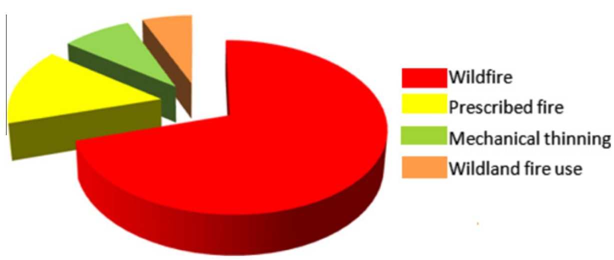

Fig. 5. The relationship between wildfire, prescribed fire, mechanical thinning and wildland fire use for the eleven western United States for all federal wildland agencies (2002–2010). *Compiled from National Interagency Fire Center data.*

In the illustration above, ignitions in the Selway-Bitterroot Wilderness (darker green[2] background, left of center in frame) were often allowed to burn in order to maintain wilderness characteristics. The fire plan for this area had its genesis in the 1970s. In the intervening years, several fires have burned, but most were limited by the length of season, natural barriers, and moisture differentials across the landscape. Similar patterns are evidenced in the Bob Marshall Wilderness, the Gila Wilderness, Yosemite National Park, and in other places where long-term fire-use programs have been in place.

More lately in this vicinity, larger wildfires now tend to burn outside the Selway-Bitterroot Wilderness, where fire exclusion and a lack of fuel reduction work has resulted in more continuous fuel build-ups over larger areas (lighter green background, lower right quadrant of frame).

5. Conclusions

There seems a growing awareness that suppression-centric wildfire protection programs have clear limits under severe burning conditions (Johnson, 2011), but the view is not yet fully acknowledged within the fire management community, nor widely believed among the public. Many units continue to attempt matching growing wildfire threats with greater suppression force when other, more comprehensive fire protection strategies – working in concert – might prove more effective.

5.1. Elements of more effective fire protection under a deepening drought scenario

5.1.1. Wildland fire management programs

High-impact mega-fires were not evidenced on lands where fire management programs have used large-scale fuel reduction programs to complement suppression capabilities. Western Australia, the State of Florida, and National Forest System lands in Florida orient fire protection around fuel reduction. They use prescribed fire at ecologically appropriate intensities and intervals over extensive areas to reduce fuel build-ups as the means to protect people, sustain biodiversity, and maintain a measure of resilience across fire-prone landscapes. These programs are not without risk, but they appear to have been successful in limiting overall suppression costs, private property losses, environmental damages, and wildfire fatalities over the long-term; even under severe drought conditions. These governments believe that prescribed burning is vital and "to not undertake prescribed burning is too great a risk to the community" (Barnett, 2012).

Both programs have reached a maintenance mode, where they treat up to 20% of their lands at regular intervals. In places where fuel build-ups are greater and restoration work is required, fire-use risks will likely be considerably higher. Starting and sustaining fire-use programs in high-hazard environments cannot overlook strong risk management precautions (Keelty, 2012).

The ecological foundations for integrating fire into wildland fire protection programs and forest land management policies are better understood in some forests types than in others (Bradstock et al., 2002; Keeley et al., 2009). Certainly, there remains the need for more research in many places, but, as the Florida and Australian examples demonstrate, it seems clear that integrating the ecologies of fire disturbance regimes into protection programs and land management strategies can be a key to reducing mega-fire threats under drought conditions.

[2] For interpretation of color in Figs. 1, 2, 4 and 5, the reader is referred to the web version of this article.

5.1.2. Forest land management policies

Although drought conditions dominated virtually all mega-fire landscapes, high-impact mega-fires also consistently traced to the susceptible condition of forested landscapes. Changes in forest structure, biomass, and landscape mosaics that abetted extreme fire intensities were commonly observed on pre-mega-fire sites. This finding was most striking in many of the dry forest types where, before organized fire suppression, potential fire behavior was relatively benign. Ironically, several high-impact mega-fires have occurred in altered dry forest types.

Where land management objectives aim for dense, fuel-laden forest conditions at landscape scales, mega-fire potential will become higher. Over long periods, mega-fire risks may also become self-perpetuating as larger burned-over areas establish even-aged forests. As these landscapes mature and become more flammable, subsequent generations will likely experience repeat mega-fires.

Managing for largely undisturbed conditions where live and dead fuels continue to accrue may inadvertently imperil the values that policy-makers are attempting to sustain as warmer, drier climate cycles take hold.

Forest land management objectives that aim for more diverse and more resilient conditions at the landscape level and constrain overall fuel build-ups to levels within suppression capabilities may prove the best hedge against future mega-fire threats. High fuel-hazard conditions – where managers are attempting to achieve many of the objectives outlined above (see Section 4.1) may be manageable where risks can be reduced by limiting exposure. The size, arrangement, and strategic placement of less flammable forest conditions, interposed across the landscape, may improve the odds of sustaining high values that require undisturbed, dense forest conditions.

Re-aligning policies to optimize forest land management objectives in the context of fire disturbance regimes and ecological dynamics at the landscape scale, rather than maximizing outputs (and biomass production) and minimizing disturbances (allowing greater fuel build-ups) may be a better way to reduce high-impact mega-fire risks, protect people, improve margins of safety for firefighters, and sustain important values.

5.1.3. Regulatory framework

In many places, wildfires are viewed as ‘‘accidents of nature’’ or, at the magnitude of high-impact mega-fires, a ‘‘natural disaster.’’ When viewed through a land management prism, it is not clear that this may always be the case, particularly when wildfire outcomes can be linked to predisposing land management decisions or practices.

In some places, the means to effectively reduce fuel build-ups with prescribed fire is simply forbidden. In other places, it is more subtly discouraged. Fuel reduction work is costly and, often contentious, but prescribed burning can be particularly difficult owing to smoke impacts and the risk of escape. However, options with potentially worse long-term outcomes can often be masked.

Wildfires are largely free of regulatory oversight. On the other hand, planned management actions, including prescribed burning, are subject to rigorous analysis of social, economic, and environment effects, any one of which can discourage action. Compounding this regulatory bias, ‘‘no-action’’ options have been generally perceived as having no consequence. This distinction makes formal trade-off analysis un-even and obfuscates long-term consequences. Until the regulatory ‘‘playing field’’ is leveled and the long-term tradeoffs of no-action are better displayed, the risks of future wildfires will likely become greater as droughts deepen.

In the United State and elsewhere, many of the regulatory controls that influence fire-use, fuel reduction work, and land management activities were established in the 1960s and 1970s, in a cooler, wetter climate cycle. During this period, when fire disturbance regimes were noticeably less active, the consequences of managing high-hazard landscapes were less apparent. Looking back, it is not clear that disturbance ecologies, including fire regime dynamics, were widely understood nor well incorporated in the language, interpretation, and implementation of the law.

Given climate change projections and the high fuel hazards that dominate many fire-prone landscapes, it seems timely to consider a new regulatory framework that more evenly displays the long-term effects of all land management alternatives, including no-action. Certainly, until this is accomplished, wildfire losses will probably continue to eclipse mitigation treatments (Fig. 5).

5.2. Closing comments

Very large wildland fires are a part of the planet’s history (Pyne, 1995), but the onset of high-impact mega-fires signals a disturbing new reality. In many places, now, the rate of biomass accumulation has become far greater than the rate at which it is used, treated, or otherwise decomposes. In the presence of drought, more of these fuel accumulations become available to burn at ever-higher intensities, compounding wildfire risks. They defeat wildfire protection objectives when fireline intensities, fueled by these build-ups, cross control thresholds. Over very large landscapes, mega-fire risks go up and become especially serious when high values are involved.

Climate change represents a changed circumstance. Drought and extreme fire weather is changing the calculus of wildland fire protection programs and the forest management policies upon which they hinge. Policies and practices that may have been sustainable in a cooler, wetter climate cycle may no longer be feasible as droughts deepen and wildfire risks intensify.

This paper suggests that protecting people and sustaining natural resources can no longer rely on suppression capabilities, alone; protection will become more dependent on how we manage the forests where high-impact mega-fires incubate.

Acknowledgments

The author thanks Dr. Peter Attiwill (University of Melbourne, Melbourne, Australia) and Dr. Dan Binkley (Colorado State University) for organizing and leading this first international conference on the mega-fire phenomenon.

The author also wishes to thank the following for their support in exploring the mega-fire reality: Mr. Tom Harbour (USDA Forest Service, National Director of Fire & Aviation Management, Washington, DC), Mr. Gary Morgan (Chief Executive Officer, Bushfire Cooperative Research Centre, Melbourne, Australia), Mr. Jim Carle (Forest Management Team Leader, Food and Agriculture Organization, United Nations, retired), David L. Bunnell (USDA Forest Service, retired), Rex Mann (USDA Forest Service, retired), Dr. Herman (Dutch) Leonard (Kennedy School of Government, Harvard University), Dr. Albert C. Hyde (Independent Contractor, formerly with The Brookings Institution), Sandy Evenson (USDA Forest Service, retired), Chief Jack Ward Thomas (USDA Forest Service, retired), and Chief Dale Bosworth (USDA Forest Service, retired).

Sincere thanks also to the following for their contributions in the assessments that form the basis for this paper: Mr. Jim Karels (Florida State Forester), Rick Sneeuwjagt (Fire Program Leader Western Australia Department of Environment and Conservation, retired), Dorothy Albright (USDA Forest Service), Anja Hoffman (Independent Wildland Fire Specialist), Andrey Eritsov (Deputy Director of Aerial Forest Fire Centre, Russian Federation), Dr. Peter Moore (Independent Consultant in Natural Resources and Fire Management, Sydney Australia), Dr. Jose Carlos Mendes de Morais (Chief, Brazilian Center for Firefighting and Prevention), Michael Leonard (Strategic Advisor, Bushfire Cooperative Research Centre), Dr. Jesus San Miguel-Ayanz (Senior Researcher, Institute for Environment and Sustainability, European Commission), Dr. Gavriil Xanthopoulos (Research Forester, Fire Specialist, Institute of Mediterranean Forest Ecosystems), Ir. Pieter van Lierop (Forestry Officer, Fire Management, Food & Agriculture Organization of the United Nations).

References

Agee, J., 1993. Fire Ecology of Pacific Northwest Forests. Island Press, Washington, DC.

Arno, S., Allison-Bunnell, S., 2002. Flames in our Forest: Disaster or Renewal? Island Press, Washington, DC.

Barnett, C., 2012. Minister's Statement Accompanying the Report of the Special Inquiry into the November 2011 Margaret River Bushfire. Government of Western Australia, Perth.

Bradstock, R. et al., 2002. Flammable Australia, the Fire Regimes and Biodiversity of a Continent. Cambridge University Press, Cambridge, UK.

Johnson, L., 2011. President's Address in Austral-Asia (AFAC) Newsletter (November). Made Available Through the Bushfire Cooperative Research Centre, Melbourne, Victoria Australia.

Keeley, J. et al., 2009. Ecological Foundations for Fire Management in North American Forest and Shrubland Ecosystems. USDA Forest Service General Technical Report PNW-GTR-779, Pacific Northwest Research Station, Portland, OR.

Keelty, M., 2012. Appreciating the Risk – The Report of the Special Inquiry into the November 2011 Margaret River Bushfire. <http://www.publicsector.wa.gov.au>.

Omi, P., 2005. Forest Fires, a Reference Handbook. Contemporary World Series, ABC-CLIO, Santa Barbara, CA.

Pyne, Stephen J., 1995. World Fire, the Culture of Fire on Earth. University of Washington Press, Seattle, WA.

Pyne, S., 2008. Passing the Torch, why the Eons-Old Truce Between Humans and Fire has Burst into the Age of Megafires, and what can be done about it. American Scholar (Spring), Phi Beta Kappa Society, Washington DC.

Salisbury, H., 1989. The Great Black Dragon Fire, A Chinese Inferno. Little, Brown and Company, Boston, MA.

Westerling, A. et al., 2003. Climate and Wildfires in the Western United States. Bulletin of the American Meteorological Society (May). American Meteorological Society, Washington DC.

Williams, J., Hyde, A., 2009. The mega-fire phenomenon: observations from a coarse-scale assessment with implications for foresters, land managers, and policy-makers. In: Proceedings of the Society of American Foresters 89th National Convention, Orlando, FL (September 30–October 4, 2009). Society of American Foresters, Bethesda, MD.

Williams, J., et al., 2011. Findings and implications from a coarse-scale global assessment of recent selected mega-fires. In: Proceedings from the 5th International Wildland Fire Conference, Sun City, South, Africa (May 9–13, 2011).

Xanthopoulos, G., 2008. People and the mass media during the fire disaster days of 2007 in Greece. In: Proceedings of the International Bushfire Research Conference Fire, Environment and Society. Bushfire Cooperative Research Centre and the Australasian Fire Emergency Service Authorities Council (AFAC), September 1–3, 2008. Adelaide, Australia.