The Restoring Healthy Forests for Healthy Communities Act: An Environmental Assessment

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Executive Summary

Catastrophic wildfires have increased in severity and federal timber revenues sent to rural counties to support local services have declined in recent decades. These problems have prompted attention from congressional representatives, particularly those from Western states with extensive federal forest land. In response to the issues associated with wildfires, Congressman Doc Hastings (R-Washington) introduced House Bill 1526, the Restoring Healthy Forests for Healthy Communities Act, in April 2013, which the House subsequently passed five months later. The proposed legislation is designed to reduce fuel loads in federal forests, decrease the risks from catastrophic wildfires, and increase timber harvests and revenue payments to rural counties.

This report provides an analysis of the issues surrounding catastrophic wildfires and how the proposed Restoring Healthy Forests for Healthy Communities Act would address these issues through fuel reduction treatments. We discuss the direct and indirect effects of American forest fire policies, the scientific and technical aspects of both the environmental problem and the proposed solution, the controversies associated with the bill, its expected outcomes, and methods for measuring its success.

We conclude that the Restoring Health Forests for Healthy Communities Act has the potential to reduce fuel loads and increase revenues in local communities provided that the actions detailed in the bill are performed in moderation. If the fuel reduction treatments proposed by the bill are undertaken successfully, then forest health can improve, local communities can better support their infrastructure and schools, and catastrophic wildfires can decrease. Other actions proposed by the bill, such as transferring forest management authority away from the federal government, not requiring state governors to consult with all affected parties when implementing projects, and reducing environmental oversight by limiting project requirements under the National Environmental Policy Act would allow for projects to potentially be implemented more quickly and more efficiently. However, these elements of the bill also leave room for potentially harmful environmental projects to move forward with few checks. The bill also reduces the ability of citizens to participate in the forest management process by restricting judicial oversight, which could delay or stop projects. While there are negative and positive aspects to the solutions outlined in the bill, it would increase timber harvests on National Forest lands and thus payments to rural counties and schools, which are critical to many rural economies.

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Introduction

Across the nation, and particularly in the western United States, National Forest lands are experiencing an increasing risk of devastating wildfires and pest infestations. While fire is a critical part of natural ecosystems, historic U.S. policy regarding fire suppression and management has led to overly dense forests with high fuel loads. When these dense forests experience dry conditions due to low precipitation, low soil moisture, and high temperatures, they are more likely to burn, as seen in an increase in the number of acres burned by catastrophic wildfires in recent decades (Westerling, 2006). Catastrophic fires produce negative environmental and human health impacts in addition to extensive economic costs. A related forest health issue, infestations from bark beetles, cause as much tree mortality annually as do fires, and can have similar consequences (Western Bark Beetle Strategy, 2011).

A 1908 law required the U.S. Forest Service (USFS) to provide 25% of timber harvest revenues to rural schools and counties that contain National Forest land, ensuring a continuous stream of funding in counties with small populations and limited tax bases. As the federal government does not pay local taxes, sharing timber harvest revenues provides critical funding for public education and the maintenance of roads and other infrastructure (Restoring Healthy Forests for Healthy Communitites, n.d.). These payments declined dramatically in the 1990s when timber harvests dropped substantially on National Forest land. Economic conditions, combined with the effort of environmental organizations to protect habitat for endangered species, forced a drastic decline in timber harvests. Timber harvests in 1987, a peak year in the United States, reached over 12 million acres, but fell to around 2 million acres by 2000 (Fretwell, 2014). Annual American timber harvests have remained at this level since the turn of the century (Figure 1).

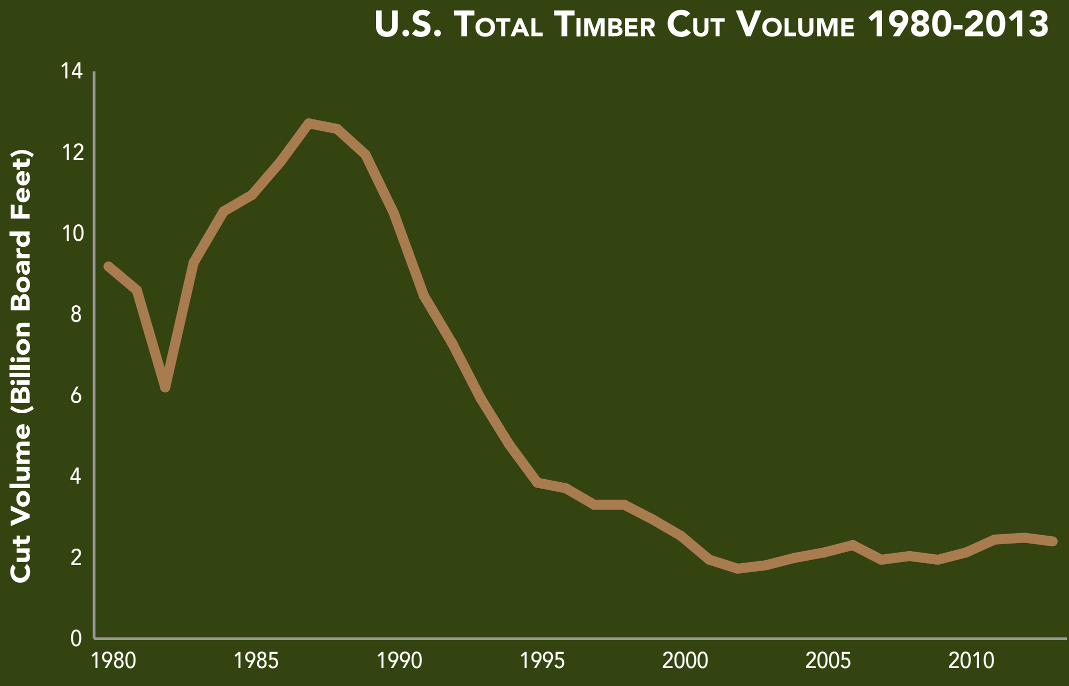

Figure 1. The total volume of timber harvested in the National Forest System from 1980-2013. Legislation enacted in the 1987 significantly reduced the volume of timber harvested to roughly 2 billion board feet per year since the early 2000s (Headwater Economics, 2014).

The Restoring Healthy Forests for Healthy Communities Act aims to address both the economic issue of reduced timber harvests and the environmental concerns regarding catastrophic wildfires and forest degradation due to pest infestations and disease. The proposed Act would provide a reliable source of income for rural communities and schools through revenue sharing from the sale of timber on National Forest lands. The bill would establish Forest Reserve Revenue Areas that would require minimum timber harvests based on calculated sustainable yield and would reduce environmental review and judicial involvement in the projects. This would potentially expedite management to improve forest health and reduce hazardous fuels throughout federal lands (H.R. 1526, 2013).

The proposed Act would require the Secretary of Agriculture to establish Forest Reserve Revenue Areas in each unit of the National Forest System. Each Reserve Area must be at least 50% of the National Forest System land with the ability to produce 20 cubic feet of timber per acre per year. A minimum of 50% of the sustained yield must be harvested annually from these Reserve Areas, and 25% of the payments from the timber sales returned to beneficiary states and counties. The Restoring Healthy Forests for Healthy Communities Act would also enable forest managers to expedite hazardous fuel reduction projects and improve forest health by allowing categorical exclusions for projects under the National Environmental Policy Act and placing the responsibility for implementing these projects with state governors. Governors can designate federal lands as "high-risk" and subsequently propose projects in order to address drought conditions, bark beetle epidemics, or lands that are or may become at risk for devastating wildfires or future bark beetle infestations. Catastrophic wildfires have become increasingly destructive throughout American forests, particularly those in the West; this bill's implementation could lead to declines in severity while still promoting wildfires' regenerative capabilities.

The Problem of Catastrophic Wildfires

Background

Research suggests that substantial wildfires have occurred naturally on Earth for roughly 350 million years, most often initiated by lightning strikes (Scott, 2000). Over these hundreds of millions of years, plant and animal species have evolved to cope with the effects of fire on the landscape, and in some cases have evolved to depend on the transformative ability of fire. Post-fire landscapes regenerate through a process known as "secondary succession" whereby a diverse assemblage of herbaceous plants and shrubs recover across the burned area after fire has eliminated competitors like larger shrubs and trees (Baldocchi, n.d.). A patchwork of sites with varying fire history results in a mosaic of different successional patches in one area, increasing both plant and animal biodiversity (US Department of Agriculture, n.d.).

After a series of severe woodland fires in the 1880s demonstrated the potential threat to the timber industry, the United States introduced a fire suppression policy designed to extinguish all fires ("U.S. Forest Service Fire", 2013). In response to another series of catastrophic blazes in 1910 that burned roughly 5 million acres of timberland, the newly formed U.S. Forest Service instituted an amended policy recommending precautionary measures to prevent future fires (Federal Emergency Management Agency, 2001). The Forest Service implemented a public information campaign to help prevent human activites that create fire risks (Figure 2). By the 1960s, scientists, forest managers, and policy makers began questioning the efficacy of this approach. This led to a 1968 review of fire policies and practices that prompted the National Park Service to conclude that fires are a natural and necessary ecological process. The United States Forest Service followed suit in 1974. Fires would therefore be allowed to burn so long as they could be contained (Van Wagtendonk, 2007). Subsequent policy changes by the U.S. Forest Service and National Park Service further relaxed the initial intolerance for natural wildfires, but the cumulative effect of 80 years of fire suppression has exacerbated current fire risk.

Figure 2. Smokey the Bear was developed by the U.S. Forest Service in 1944 as part of the campaign to increase wildfire prevention in U.S. forests (U.S. Forest Service, 2012).

Current Situation

The United States has experienced an alarming increase in the amount of land consumed by catastrophic wildfires over the past 25 years. Although the number of wildfire incidents annually has remained fairly constant, the average number of acres burned during a single wildfire has increased dramatically (Figures 3 and 4). For example, 1987 saw 75,000 wildfires consuming 2 million acres in comparison to 2012's 80,000 fires burning 8 million acres ("Total Wildland Fires and Acres", n.d.). The two main factors contributing to this change in wildfire intensity are the overgrowth of vegetation in federal forestland and dry and warm conditions exacerbated by climate change.

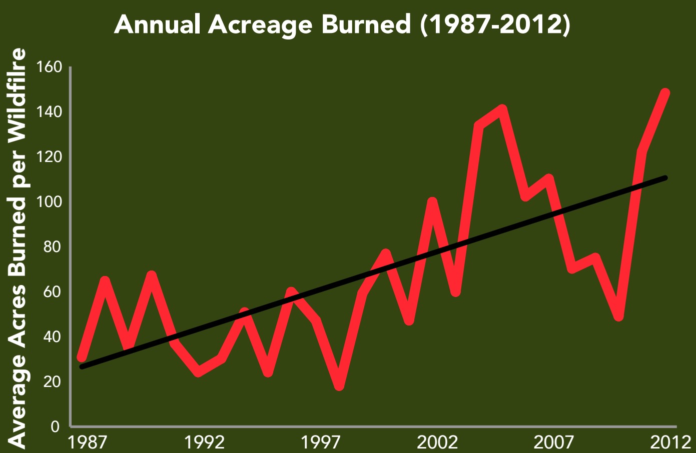

Figure 3. A time series of the annual average acreage burned per wildfire in the U.S. from 1987 to 2012. The trendline shows the acreage loss to wildfire has been increasing ("Total Wildland Fires and Acres.", n.d.).

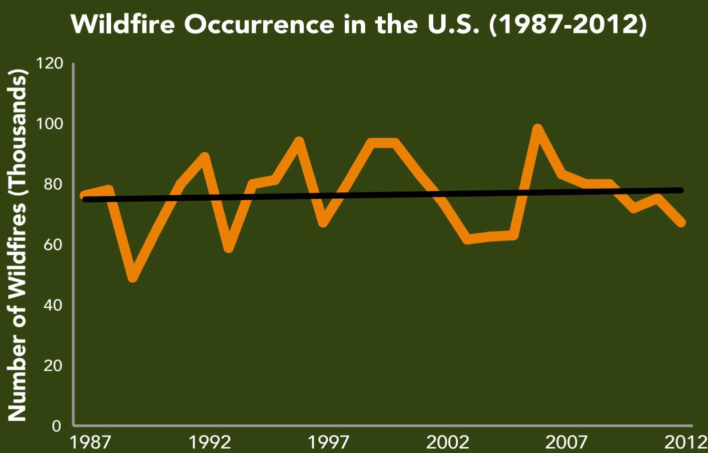

Figure 4. The total number of wildfires in the U.S. per year from 1987 to 2012, showing an essentially flat trend in the number of fires over time ("Total Wildland Fires and Acres.", n.d.).

Figure 5. This side by side comparison of a sequoia grove shows the effects of years of fire prevention on overgrowth in federal forests (National Parks Service, 2014).

Nearly a century of fire suppression policy in the United States has led to the accumulation of significant fuel loads in dense forests that would otherwise have been eliminated through the natural fire cycle (Figure 5; Allen et al., 2002). Wildfires typically cease burning when they encounter a natural fire barrier, such as a fuel break, and exhaust their fuel source. However, overgrowth in forests has reduced the extent of natural fire barriers, allowing conflagrations to burn over larger areas and reach abnormally high temperatures (MacDonald, 2010). Even natural barriers like bodies of water cannot prevent the spread of these large wildfires; fires "jump" between canopies through wind-carried embers and ignite other trees from above (Allen et al., 2002).

In addition to overgrowth, the effects of climate change have exacerbated the conditions favorable to wildfires (Climate Change and Wildfire, 2012). Rising temperatures increase rates of evapotranspiration and decrease available surface moisture. Drier brush in a forest burns more readily and rapidly once ignited, with significant consequences in the drought-stricken Western United States. In addition, the progressively early onset of warm weather in the spring affects the timing of snowmelt, which in turn causes streams to dry earlier in the year and can increase the incidence of catastrophic wildfires, particularly in the Northern Rockies (Westerling, 2006).

Climate change and forest fires constitute a positive feedback model. Living vegetation serves as a crucial sink for carbon dioxide, removing the gas and its heat-trapping potential from the atmosphere. Carbon uptake through sequestration in the planet's forests average between 0.3 to 1.3 petagrams per year (Lorenz and Lal, 2010). In comparison, estimates of carbon emissions from wildfires are approximately 2.0 petagrams per year, a third of total global carbon emissions (Liu et al., 2014). Wildfires not only emit additional carbon dioxide, but they also simultaneously reduce the environment's ability to sequester this gas from the atmosphere.

Ecological Effects of Wildfire

Water Quality

Vegetation acts as a protective cover for soil by sheltering it from exposure to wind and precipitation. When wildfire eliminates plant cover, precipitation can erode soils; soil erosion after moderate and high intensity wildfires results in the loss of soil nutrients, negatively affecting both water quality in receiving waters and the ability of forest vegetation to recover. Loose soil particles easily flush into local surface water systems, particularly after the flash floods that often follow wildfires. This accumulation of soil from erosion increases turbidity and can result in eutrophication, altering aquatic food webs (Writer et al., 2012). Without the vegetation that anchors soil in place, runoff increases the risk of landslides and floods, potentially permanently altering the path of the waterways (Franklin, 2014).

Diminished water quality negatively affects the health of humans and other organisms, even in areas miles away from the location of the fire (Wiedinmeyer and Friedli, 2007). Wildfire ash in water bodies can reduce macroinvertebrate populations to less than 1% of their original numbers, with devastating effects on aquatic food webs (Earl and Blinn, 2003). The chemicals used to fight, retard, and control fire also increase the mortality of aquatic species and contaminate drinking water supplies (Chepseiuk, 2001).

Air Pollution

Wildfires contribute to air pollution through the release of substances such as carbon monoxide, nitrogen oxide, ketones, mercury, lead, iron, hydrocarbons, and particulate matter into the atmosphere (Chepseiuk, 2001; Kristensen and Taylor,

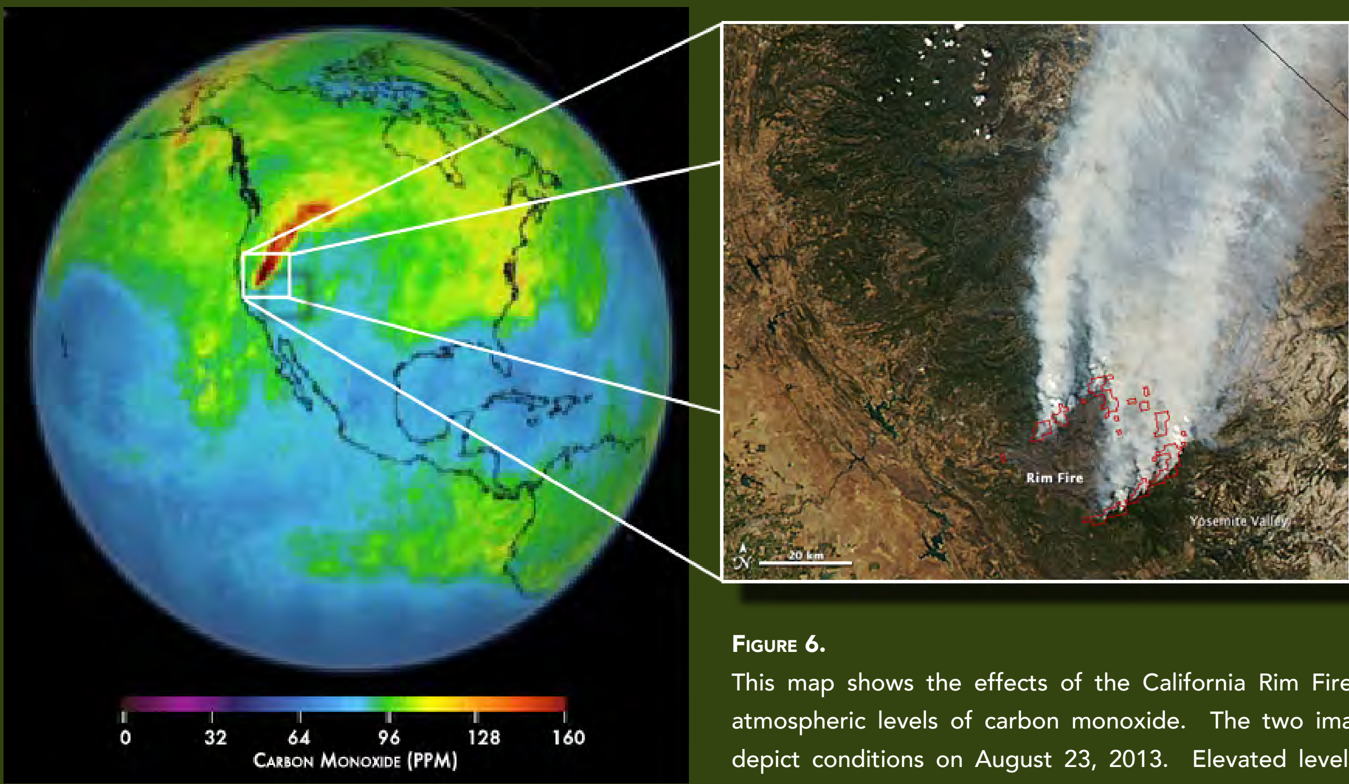

Figure 6.

This map shows the effects of the California Rim Fire on atmospheric levels of carbon monoxide. The two images depict conditions on August 23, 2013. Elevated levels of carbon monoxide were detected hundreds of miles from the wildfire source (Greicius, 213; Nelson et al., 2013).

2012). The release of these materials can spread by wind across vast expanses. For example, emissions from a fire in Quebec in 2002 landed in Baltimore, 955 miles away, raising levels of particulate matter to eight times their normal level (Sapkota et al., 2005). Particles smaller than 2.5μm pose the greatest health threat because they can enter buildings, contributing to indoor air pollution and respiratory conditions like asthma, emphysema, and bronchitis ("How Forest Fires Affect", n.d.; "Forest Fires and Respiratory", 2014). Soon after the 2003 wildfires in Southern California, hospitals experienced a 26% increase of individuals admitted for asthma and a 48% increase for those admitted for acute bronchitis and bronchiolitis due to atmospheric particles smaller than 2.5μm (Delfino et al., 2003).

In the United States, wildfires contribute about 44 tons of toxic mercury into the atmosphere annually, roughly 0.8% of the global input of mercury into the atmosphere (Wiedinmyer and Friedli, 2007; "Mercury Study Report to Congress," 2014). Exposure to mercury vapor can cause such serious health consequences as chest pain, dyspnea, cough-impaired pulmonary function, and interstitial pneumonitis (Veiga and Baker, 2004; Friberg, 1991). Elderly populations and young children are at most risk for these health concerns. Babies exposed in utero during any trimester to wildfire air pollution, including carbon monoxide and particulate matter, weigh less on average when compared to children with no exposure to wildfire air pollution (Holstius et al., 2012). Low birth weights adversely affect the health and development of infants.

Repercussions for Biota

Wildfires can also affect habitats for a variety of animal and plant species. For example fires in home ranges significantly reduce levels of black bear cub survival (Cunningham and Ballard, 2004). The intensity of wildfire can also impact animal populations. Herbivorous mammal populations in Arizona increased in areas of moderate burns, but decreased in areas of severe burning (Campbell et al., 1977). In addition, high intensity fires can damage small trees and understory vegetation, depleting nutrient capital, reducing infiltration of water, increasing soil erosion, and ultimately producing a decline in habitat quality for wildlife. Most of these effects tend to diminish over time as secondary succession occurs and plants grow, insects and microorganisms produce organic material and soil cover, and animal species adapt to changes in available food and other resources. However, total plant nutrient capital, especially nitrogen, and an overall loss of soil permeability are notable long-term ecosystem losses (Campbell et al., 1977).

Economic Effects

The full economic effects of catastrophic wildfire can be difficult to calculate due to the high number of impacted sectors. Direct economic costs include damage to property, utility lines, parks, infrastructure, and timber supply, as well as rehabilitation costs such as restoring watersheds and combating erosion and the influx of invasive species. The best-documented costs are associated with fire suppression actions including firefighting crews, agency personnel, and machinery. The average annual cost of fire suppression activities paid by the federal government has risen from $453 million throughout the 1990s to $1.4 billion in the 2000s. Most

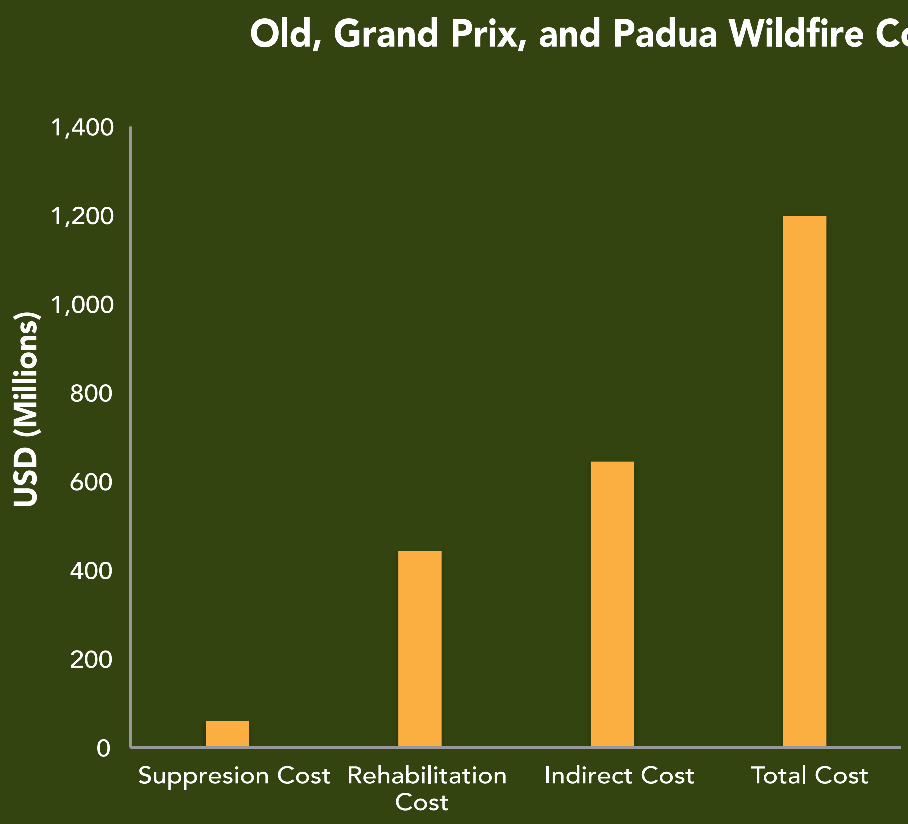

Figure 7. The costs associated with the Old, Grand Prix, and Padua Wildfire Complex in California. Suppression costs, the most easily tracked of the three categories, accounts for only a small fraction of the total cost associated with this wildfire event ("Federal Firefighting Costs (Suppression Only)", 2014).

recently, the average annual cost of fire suppression for the current decade (2010-2013) has surpassed $1.6 billion ("Federal Firefighting Costs (Suppression Only)", 2014). This is approximately 10% of the combined annual budgets of the federal agencies responsible for fire suppression (US Department of the Interior, 2013; US Forest Service, 2013).

Suppression costs, however, account for only a fraction of the total cost of wildfires (Dale, 2010). Wildfires can cause loss of life, respiratory health issues, and a decrease in ecosystem services. The indirect costs of wildfires can also include private property damage, loss of sales and other local taxes from fire-affected properties, and decreased business revenue. All socioeconomic levels share this potentially sizeable economic burden, although these indirect costs can be difficult to quantify on a national scale. Studies of individual fire systems can provide some insight into the costs; the Old, Grand Prix, and Padua fires in California combined to form a wildfire system in October and November of 2003 that cost a total $1.2 billion (Figure 7). Only $61.3 million, or about 5% of the total costs, were associated with suppression activities. Indirect costs reached over $646 million, or about 54% of the total costs, with the insurance industry incurring the vast majority of the losses. Rehabilitation costs, including watershed restoration activities and utility repair costs surpassed $443 million (Dunn, n.d.).

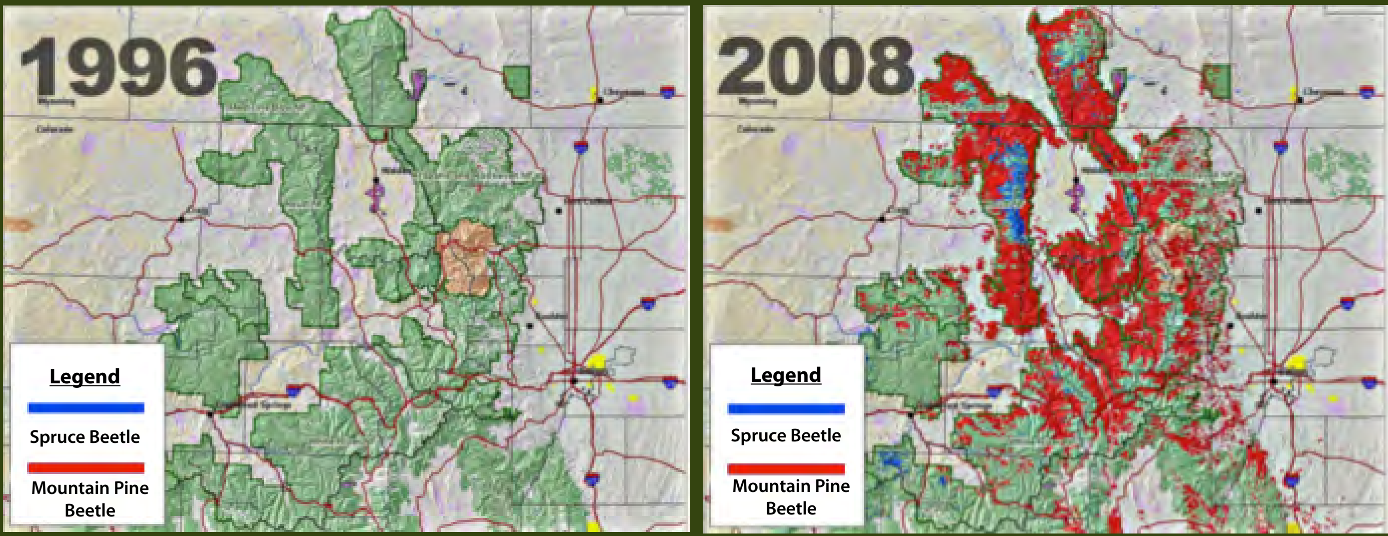

Figure 8. Two topographical maps of northwestern Colorado Rockies showing the extent of bark beetle spread between 1996 and 2008. Rising temperatures have allowed bark beetles to expand their habitat to higher elevations, and prey on local tree species ("What is Responsible for Colorado's", 2014).

Bark Beetle Infestation

Effects on Tree Mortality

Responsible for just as many forest deaths annually as wildfires, bark beetles are common pests associated primarily with conifers that have historically improved local forest ecosystems by infesting patches of forest ecosystems and varying the age, density, and species of local trees. However, because these 600 species of bark beetles often attack and destroy valuable timber, forest managers want to reduce their destructive presence. In addition, these insects exacerbate the likelihood of catastrophic wildfires by transforming live wood into hazardous fuels (Forest Service, 2014). These insects burrow through the tree's xylem and phloem layers, slowly killing it by cutting off its flow of water and essential nutrients (Schalau, 2003). Since 1997, bark beetles have affected 13% of all conifer forests in the West, with more at risk for future infestation (Western Bark Beetle Strategy, 2011). The growth of dense and homogenous forests as a result of the fire suppression policies from the early twentieth century currently provides enormous food sources for bark beetles, particularly of older and more vulnerable trees. Two species of bark beetle spread rapidly in southern Wyoming and northern Colorado, where every day these beetles account for 100,000 downed dead trees which provide fuel for wildfires and damage roads, power lines, trails, water supply reservoirs, and recreational sites (Figure 8; Western Bark Beetle Strategy, 2011).

Links to Climate Change

Cold winter temperatures typically control bark beetle populations, although recent shifts in climate patterns have produced warmer North American winters, enabling more beetles to survive the winter months (Juday, 1998). Higher winter temperatures have also allowed bark beetles to expand their range in both latitude and altitude across the United States where they encounter tree species without any natural defenses (Western Bark Beetle Strategy, 2011).

Bark beetle infestations are a further component of a positive feedback loop with climate change and wildfires. The increasing number of trees killed by bark beetles reduces the carbon sequestration of western forests and provides dry fuel for wildfires. Wildfires emit carbon dioxide and, when intense enough, reduce the ability of regenerating forests to sequester carbon. This induces further warming, the proliferation of bark beetles, and increased fuel loads and fires (Van Mantgem et al., 2009).

The Proposed Solutions in the Legislation

The Restoring Healthy Forests for Healthy Communities Act seeks to protect communities and habitats from the widespread threat of wildfires and bark beetle infestations in federal forestlands by expediting forest management for hazardous fuel reduction and improving forest health. To do so, the bill proposes transferring some management responsibility to state governors. Governors would be able to designate high-risk areas on federal lands in order to address drought conditions or bark beetle damage, and to designate lands that are at high risk for catastrophic wildfires or pest infestations. Within these high-risk areas, governors could propose projects to reduce hazardous fuels or to improve forest health (H.R. 1526, 2013).

These efforts can be carried out through hazardous fuel reduction and forest health projects, which aim to reduce the density of wildfire fuels, as well as through the implementation of the ecological restoration efforts. The bill specifically recommends hazardous fuels reduction through livestock grazing, timber harvesting, and timber thinning.

Maximum Sustainable Yields

The annual maximum sustainable yield of timber constitutes the amount of timber that can be harvested yearly from a particular population without negatively impacting the population's long-term stability (Rieker, n.d.). The most popular sustainable harvesting practice involves removing older, lower-quality trees from the population to allow younger, healthier trees to grow more quickly. An alternative option clears all vegetation in an area through a silvicultural clearcut before planting new trees and waiting for those trees to grow to a marketable size (Virginia Polytechnic Institute and State University, n.d.)

The Restoring Healthy Forests for Healthy Communities Act would require an annual harvest of at least 50% of the sustainable yield from a Forest Reserve Revenue Area located in every unit of the National Forest System (H.R. 1526, 2013). However, if harvests are based on overestimates of this maximum yield over several years, it can significantly diminish the ability of that forest to recover after harvest. A decision to harvest 100% of the maximum sustainable yield, as would be allowable under the bill, could therefore have disastrous consequences for the forest ecosystem if the actual maximum sustainable yield is less than that initially estimated. Many factors can affect sustainable timber harvest, including recalculations of the impact of logging activities and unforeseen activities like floods or wildfires, making the true maximum yield difficult to determine. For example, concerns about the Northern Spotted Owl prompted the development of the Northwest Forest Plan of 1994. In an aim to protect the endangered species, the plan reduced levels of maximum sustainable timber harvests in California, Oregon, and Washington (Thomas et al., 2006).

The proposed Forest Reserve Revenue Areas would produce sustainable harvests indefinitely so long as the calculated maximum sustainable yield does not exceed the actual maximum sustainable yield. Therefore, forest managers should err on the side of caution and harvest a lower percentage of the maximum sustainable yield at least initially to prevent overharvesting. However, Title I of the Restoring Healthy Forests for Healthy Communities Act attempts to respond to deficient financial support by the federal government in rural counties to fund schools and local infrastructure. Larger harvests mean greater revenues for these communities, contributing to the potential for overharvesting and a rapid decline in forest productivity and health.

Forest Health Management

Dense forest stands and limited management result in accumulations of combustible vegetation that fuel high-intensity wildfires. The build-up of biomass in the understory creates pathways, called "ladder fuels," for surface fires to reach tree crowns. Crown-level fires burn more intensely and are harder to suppress, so forest managers often focus on minimizing the accumulation of ladder fuels in their wildfire reduction efforts (Evlagon et al., 2012). The bill proposes three solutions to reduce fuel loads: livestock grazing, timber thinning, and timber harvesting. Prescribed burns, another common method of fuel reduction, would not be required by the bill (H.R. 1526, 2013).

Livestock Grazing

European settlers expanded the amount of livestock grazing throughout American forests, a practice still continued by ranchers, farmers, loggers, and land managers today (Forest Fuel Management, 2005). Livestock currently graze on national wildfire refuges, federal wilderness areas, and some national parks (Fleishner, 1994). The impact of grazing on forest management and ecological productivity depends on the timing of grazing during the year, duration of a herd's presence, intensity and frequency of consumption, and the type of livestock (Borman, 2005).

Livestock grazing can reduce surface fuel loads and thus diminish the extent and intensity of wildfires. A study of the effects of wildfire and grazing on fuel loads in Idaho suggests that grazing alone can reduce nearly half of the total fuel load (Weber et al., 2011). Extensive grazing depletes perennial grasses and other fine fuels that contribute to the spread of wildfires (Strand and Launchbaugh, 2013). However, forest managers must monitor livestock to ensure that heavy consumption of grasses does not allow woody vegetation to increase, thereby increasing fuel loads (Davies et al., 2010). The presence of an herbaceous understory aids in the spread of more frequent, but less severe fires; an understory consisting primarily of woody vegetation can increase the likelihood of less frequent, but more severe wildfires (Strand and Launchbaugh, 2013). Due to the reduction in fine fuels and the development of larger gaps between fuel-heavy areas, moderate grazing that does not fully remove herbaceous vegetation appears to be the most effective grazing practice to lower the probability of catastrophic wildfires (Davies et al., 2010).

Although expanding livestock grazing can decrease fuel loads in forests, it will similarly increase the areas within the United States where livestock damage the natural landscape. These animals can both remove vegetation with important ecosystem functions and introduce exotic species carried in on their fur, altering local species composition (Fleischner, 1994). Trampling can hinder seedling growth, negatively affecting forest regeneration (Salmon et al, 2012). In addition, trampling on vegetation reduces nitrogen fixation and availability, particularly in microbe-rich loamy or clay soil crusts (Schrama et al., 2012). By exposing soil to rainfall, livestock increase runoff and soil erosion, contributing to degradation of local water sources (Hoorman and McCutcheon, 2005). Overgrazing can lead to soil compaction, desertification, elimination of desirable species, and depletion of nutrients (Forest Fuel Management, 2005; Mancilla-Leytón et al., 2013; Evlagon et al., 2012). In contrast, moderate grazing supports the natural landscape processes that keep forests healthy and resilient to wildfire and insect infestation (Borman, 2005).

The Forest Service and Bureau of Land Management currently spend $466 million annually in direct costs related to grazing, while gaining only $6.1 million in revenue ("The Cost of the Forest," n.d.). However, given the vast acreage grazed by livestock, this fuel reduction treatment costs an average of $1.78 per acre. In comparison, the federal government spent over $1.7 billion in 2013 on fire suppression, and some devastating wildfires can cost upwards of $180 million each ("Federal Firefighting Costs (Suppression Only)", 2013; Bureau of Land Management, 2010). In 2013, over 2.5 million acres burned, costing the federal government an average of $684 per acre, a value determined without considering the extent of indirect costs ("National Preparedness," 2014). A relatively small investment in forest grazing may decrease the exorbitant direct and indirect costs of wildfires.

Timber Thinning

Thinning involves the removal of ladder fuels and select trees from a stand to give the remaining trees more space and resources to grow (Punches, 2004). Thinning improves the health of the forest by improving access to water, nutrients, and light for the remaining trees, which in turn increases tree growth and resilience, biodiversity, and wildlife habitat (Stephens and Moghaddas, 2005; Agee and Skinner, 2005). As with livestock harvesting, the optimal intensity of thinning treatments varies given forest management goals, tree species, tree size, and terrain (Punches, 2004). Forest thinning strategies range from the removal of lower canopy or mid-canopy trees and branches to the extraction of individual trees in favor of others. Most thinning diminishes crown densities and prevents the accumulation of surface and crown fuels, reducing wildfire risk. Some approaches are more effective than others; thinning at both high and low tree layers in a forest can still produce dangerous crown fires if forest managers fail to remove

Figure 9. This comparison shows a section of the Kaibab National Forest in Arizona before and after receiving forest thinning treatment. Proper forest thinning eliminates fuel and reduces the intensity of wildfire (Kaibab National Forest, 2013).

the cut material and allow it to remain on the forest floor (Effects of Thinning, 1999). In general, as the intensity of the thinning treatment increases, so too does its effectiveness as a reduction method against wildfires. According to one study, thinning could produce similar results to passive or active fires in the decline of fuel loads and could also transform a wildfire that would have developed into a crown fire pre-treatment into a more manageable surface fire post-treatment (Johnson et al., 2011). Managers overseeing thinning practices must ensure the removal of thinned material; unless they are physically removed from the forest area, branches remain as hazardous fuels (Effects of Thinning, 1999). In addition, reducing the number of trees in a given area improves the health of the remaining trees and their ability to mitigate the negative impacts of bark beetle attack and high-intensity wildfire (Agee and Skinner, 2005).

Thinning can have negative ecosystem impacts through physical and chemical disturbances. Soil compaction from the use of heavy equipment decreases soil porosity and restricts the movement of air, water, and nutrients through soil. Tire ruts displace soil, altering water flows and loosening soil to increase erosion. In addition, the extraction of thinned materials from the environment, necessary to reduce fuel loads and the possibility of wildfires, prevents the replenishment of nutrients in the soil via decomposition. This can reduce primary productivity in forest ecosystems over time (Page-Dumroese et al., 2010). During the spring and early summer, trees undergoing rapid growth can experience severe injuries due to thinning treatments. Thinned trees are at greater risk for wind and ice damage, the results of which can increase fuel loads and the potential risk of wildfire (Thinning Practices in Southern Pines, 1985).

Timber Harvesting

As one of the world's largest producers and consumers of forest products, the United States currently leads the worldwide production of a broad range of industrial timber products (World Maps Atlas, 2014). The American timber industry produces over $200 million in sales annually. Countries like the United States with steady quantities of industrial wood are more likely to manage their forest sustainably because revenues from responsibly managed forests cover management costs. Harvesting also creates jobs, primarily in rural communities ("Cut and Sold Reports," 2014).

Timber harvesting, essentially a more extreme form of thinning, generally produces the greatest decrease in fuel loads when compared to either thinning or grazing practices. Harvesting is most economically feasible in areas with a biomass or wood-chip market, but the extreme reduction in fire threat offered by harvesting may encourage subsidized treatments (Stephens et al., 2009). When managed improperly, however, timber harvesting can intensity wildfire behavior. Chipping, burning, or physical transportation of the tree tops away from the specific area must occur to prevent unintentional increases in surface fuels (Agee and Skinner, 2005). For example, the Cooney Ridge fire complex in 2003 burned extensively in Montana due to a harvest treatment that left woody debris at the site (Forest Harvest Can Increase, 2004).

Harvesting timber can also create fuelbreaks for wildfires, wide areas or strips with reduced fuel volume or flammability. Trees growing in close proximity to one another experience crown fires more frequently because the fire "jumps" from one tree's branches to the next, rather than spreading along the ground. Wider fuelbreaks are more effective than narrow ones. Their presence often depends on funding and infrastructural capabilities, with recommended distances between forested areas ranging from 60 meters to 300 meters. The precise width best for a particular forest's fuelbreak depends on tree species and density, local weather, and economic feasibility (Agee et al., 2000).

The same negative effects on ecosystems brought on by improper grazing and thinning management practices could also occur in harvested forests. The construction of roads for logging fragments forest and disrupts the range and distribution of wildlife. In addition, logging roads increase erosion by removing the top layer of soil, altering water runoff into local streams and rivers. Soil compacted by heavy machinery further heightens erosion rates while reducing oxygen and water availability (Sierra Forest Legacy, 2012). Both harvesting and thinning treatments involve removing smaller trees and branches from an ecosystem, which can reduce the presence of vital plants, lichen, and mosses. The probability of infestations and infections can increase after these treatments, although thinning tends to improve the general health of the trees (Thinning Practices in Southern Pines, 1985).

The more intensive thinning and harvesting treatments usually result in greater merchantable volume of timber. Projections indicate that thinning can cost upwards of $100 per acre, but the improvements in the quality of the wood caused by thinning increase the timber's value to between $100 and $500 within sixty years (Thinning and Prescribed Fire, 2004). Given enough time, wildfire fuel loads can be reduced in an economically productive way through thinning and timber harvesting.

Prescribed Fires

Although not included in the recommendations of the bill, prescribed fires are not prohibited and are a common method of fuel reduction. Unlike wildfires, prescribed burns are controlled burns conducted solely under moist, calm conditions and often during different seasons than those in which natural fires would occur, usually in the cool spring or fall. Varying distributions of fuels resulted in historical wildfires burning in patches, allowing fire-sensitive species to repopulate in the affected areas. Prescribed fires alone cannot fully restore a forest ecosystem given the disparity in seasonal climate and moisture conditions, but the combination of controlled burns with other fuel reduction methods can decrease the likelihood of the development of catastrophic wildfires (Ryan et al., 2013). For example, a report on fuel treatments in six western states determined that mechanical thinning in conjunction with prescribed burnings reduced the possibility of crown fires more than any other treatment methods due to the significant decrease in canopy cover and removal of the smallest trees. Fire-only treatment affected the potential for crown fires least, although it contributed to significant reductions in ground and surface fires (Stephens et al., 2009).

The intensity of prescribed fire affects the impact on soil, water, and air quality. Although on a much smaller scale than wildfires, prescribed burns contribute to soil erosion and runoff. Local water sources receive nutrients, soil particles, and heavy metals carried by runoff, diminishing the quality of the water. In addition, over 90% of particulate emissions from controlled burns are $PM_{2.5}$, less than 2.5μm in diameter. These particles can exacerbate respiratory conditions such as asthma (Wade and Lundsford, 1993). Wildfires typically produce fewer $PM_{2.5}$ than PM_{10}, which are less harmful to human respiratory systems than their $PM_{2.5}$ counterparts (British Columbia Ministry of Water, 2003). These particle emissions can affect fire crews working at prescribed burn sites and local communities living downwind from the fires (Naeher et al., 2006). All fires release carbon dioxide, a significant greenhouse gas, along with small particulate emissions containing toxic compounds such as carbon monoxide. Fires can also weaken trees by producing scars into which insects and diseases can easily enter (Wade and Lundsford, 1993).

The cost of prescribed fires can range from $12 per acre to $174 per acre, with variations based on fuel type, site elevation, treatment method, and topography (Fuel Planning, 2004). Prescribed fires, especially when compared to the $684 spent per acre on fire suppression in 2013 alone, are therefore an economically sound method to reduce forest fuel loads.

Viability of Solutions

The proposals offered by the Restoring Healthy Forests for Healthy Communities Act have potential as viable options to reduce fuel loads and the likelihood for catastrophic wildfires. The fuel reduction methods suggested are economically feasible and, if managed properly, can decrease fuel loads and the intensity and frequency of catastrophic wildfires. However, the application of these solutions will influence their potential for producing "healthy" forests. Sustainable timber harvesting, grazing, and thinning all contribute to the goals of the bill, but only under specific conditions that will vary from forest to forest.

Measuring Success

The Restoring Healthy Forests for Healthy Communities Act aims to reduce the incidence of catastrophic wildfires, but the bill does not define the term "catastrophic wildfires." Any such definition should include metrics such as thresholds for the number of acres burned per fire, dollars spent on fire suppression, human lives lost, and/or post-fire forest health metrics. In addition, these metrics must also have baseline measurements.

Today, many federal agencies including the Bureau of Land Management, the National Park Service, the Fish and Wildlife Service, the Bureau of Indian Affairs, and the United States Forest Service (USFS) manage and monitor wildfires. In 2009, these agencies have all signed onto The Guidance for Implementation of Federal Wildland Fire Management Policy. This policy created the National Wildfire Coordinating Group which systematizes the reporting standards for fire incidents and reports consistently on wildland fires (National Wildfire Coordinating Group, 2014). These reports typically include the number of acres burned in a fire incident and economic costs incurred based on field surveys, aerial surveys, remote sensing, and information on money spent on fires (National Wildfire Coordinating Group, 2014). The National Interagency Fire Center makes these federal reports readily available, with close regulation by each agency under the management of the National Wildfire Coordinating Group ("Interagency Guides," n.d.). This system provides a framework that could be applied to newly-implemented definitions under the proposed Act, and could require agencies to report on new metrics not currently measured regularly, such as forest health indicators.

A coordinated task force of several universities and the USFS gather measurements on forest health and wildfire measurements, producing multiple reports including one that considered the impacts of timber thinning and prescribed burns on reducing wildfire incidence and the consequent effects on soil health, wildfire, vegetation, and other forest health indicators (Stephens et al., 2012). Metrics applied in these studies for measuring the effects of different thinning methods can similarly be used when considering forests thinned under the proposed Act. For example, information derived from these reports can aid in the determination of how many acres may have burned or what other harmful effects would have been realized without the bill's efforts to reduce catastrophic wildfires.

The USFS also closely monitors and reports on disease and pest infestations in federal forests, updating forest disturbance maps every eight days ("Bark Beetle," 2014). The agency further provides annual condition reports and produces maps of forests at risk for future infestations of bark beetles and other pests (Forest Service, 2014). Universities across the United States and the USFS, working out of the Rocky Mountain Research Station, gather data on the extent of bark beetle infestations, using methods such as field surveys, aerial surveys, and remote sensing (Forest Service, 2014). Despite extensive data on bark beetle damage, no concrete definition exists for how many trees and/or acres must be affected to constitute a "bark beetle infestations," the language used in the proposed Act. Measuring the success of the Restoring Healthy Forests for Healthy Communities Act would require a baseline number of acres affected by bark beetles and diseases in federal forests to classify these areas as "at risk." These baseline values could then be compared to acres affected by bark beetles after the establishment of the bill to measure the program's success. Bark beetle data, like that of catastrophic wildfires and forest health indicators, would require similar ongoing monitoring of federal forests.

Studies to determine data on overall forest health can be very comprehensive. A single United States Department of Agriculture study outlines seven criteria and sixty-seven indicators for tracking the conservation and management of forests and requires coordination by over 20 state forest agencies. This information is regularly published online, making it accessible to policy makers and the general public ("Base Indicators of Forest Sustainability," 2003). One link of the USFS webpage offers eight interactive maps, graphs, and tables tracking pest infestations in federal forests across the nation (Forest Service, 2014). Some examples of these forest health metrics include area of timberland affected by pests, carbon sequestration in forest, and water quality in forested areas. Data regarding these metrics, such as the fact that forests in the United States can absorb and sequester about 16% of annual U.S. carbon dioxide emissions, can be extremely useful for policy makers when prioritizing which forests should have fuel reduction or healthy forest projects implemented (Joyce et al., 2014). However, the extent of the data also requires the creation of a rating system to illustrate the multitude of forest health metrics in a single forest health grading sheet in order to facilitate decision making by policy makers.

Conclusion

The Restoring Healthy Forest for Healthy Communities Act aims to reduce the impacts of catastrophic wildfires, increase forest health, and mitigate the effects of bark beetles in federal forests. Through utilization of the fire reduction and forest health measures outlined by the proposed Act, namely timber harvesting, thinning, and cattle grazing, governors can ensure the continued usage of federal forestland for recreation and timber revenue purposes. However, the need for rigorous analysis of each forest ecosystem in order to determine both the appropriate management may prevent the general application of these treatments. In addition, definitions and reasonable monitoring standards must be developed to quantify the impacts of forest management methods and improve the likelihood of future successful management in America's federal forests.

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