RESEARCH ARTICLE

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fire & fuels management

An Evaluation of the Forest Service Hazardous Fuels Treatment Program—Are We Treating Enough to Promote Resiliency or Reduce Hazard?

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The National Cohesive Wildland Fire Management Strategy recognizes that wildfire is a necessary natural process in many ecosystems and strives to reduce conflicts between fire-prone landscapes and people. In an effort to mitigate potential negative wildfire impacts proactively, the Forest Service fuels program reduces wildland fuels. As part of an internal program assessment, we evaluated the extent of fuel treatments and wildfire occurrence within lands managed by the National Forest System (NFS) between 2008 and 2012. We intersected fuel treatments with historic disturbance rates to assess the extent to which the program compensates for the disturbance deficit caused by fire suppression and with current wildfire hazard to evaluate whether fuel treatments strategically target high hazard locations. Annually, 45% of NFS lands that would have historically burned were disturbed by fuel treatments and characteristic wildfire, indicating that NFS lands remain in a "disturbance deficit." The highest wildfire hazard class had the lowest percentage of area treated and the highest proportion of both wildfire of any severity and uncharacteristically high-severity wildfire, suggesting that an alternative distribution of fuel treatment locations will probably improve program effectiveness.

Keywords: LANDFIRE, mechanical treatment, prescribed fire, resiliency, wildfire hazard

Fire exclusion, past land management, increased frequency of drought, higher temperatures, and longer periods of "fire weather" have contributed to the increased number, extent, and cost of wildfires over the last several decades (Westerling et al. 2006, Dennison et al. 2014, Stephens et al. 2014, Thompson et al. 2015). The 10-year average number of acres burned has more than doubled from the 1985–1994 to 2005–2014 periods (National Interagency Fire Center [NIFC] 2015). The 2015 fire season experienced a record number of megafires (>100,000 ac) and burned a record 10.1 million ac nationally. This trend is not likely to change as the frequency of conditions and the duration of the season associated with large fire growth are predicted to increase through the mid-21st century as a result of anthropogenic climate change (Barbero et al. 2015). As the area burned has doubled, the cost associated with suppressing wildfires has quadrupled (NIFC 2015). Between 1995 and 2015, the amount of annual funding allocated to fire suppression has risen from 16 to 52% of the US Department of Agriculture (USDA) Forest Service budget (USDA Forest Service 2015a). Even with an increased budget allocation, the Forest Service has relied on emergency funding transfers to continue to suppress fires during the past four fire seasons at the cost of other programs within the agency (Thompson et al. 2015, USDA Forest Service 2015a) including hazardous fuel treatments. Given the predictions for longer fire seasons and a higher frequency of large fires in the future (Barbero et al. 2015), the cost of fire will probably continue to increase unless effective mitigation actions are taken.

Fuel treatments are designed to reduce or redistribute ground, surface, and canopy fuels by removing trees, masticating/mowing small diameter trees and shrubs, piling fuels and burning them, or applying prescribed fire. An effective fuel treatment will slow the spread of fire and reduce the likelihood of crown fire, aid suppression efforts, and reduce the intensity and severity of a

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wildfire under all but the most extreme weather conditions (e.g., Agee and Skinner 2005, Reinhardt et al. 2008). Effective treatments could theoretically reduce the cost of future fire suppression efforts by reducing total acres burned (Thompson et al. 2013), although suppression expenditures depend on a host of variables. Although reducing the rate of fire spread is often the primary target of treatments, the number of burned acres can be less important than reducing fire intensity and, therefore, fire effects (Reinhardt et al. 2008). Ideally, strategic use of fuel treatments can facilitate our ability to manage wildfire for resource benefits and might eventually lead to beneficial increases in wildfire acreage (Reinhardt et al. 2008, North et al. 2015).

Fuel treatment strategies typically fall within two overarching land management objectives: ecosystem maintenance/restoration or fire control (Omi 2015). The primary goal of ecosystem maintenance/restoration is to promote or maintain fire-resilient landscapes. For fire control, the goal of fuel treatments is to facilitate wildfire suppression activities through the reduction of fuel hazards with strategic placement across a landscape. Spatial strategies for fuel management will vary, depending on the objective. Treatments aimed to promote resiliency can be either concentrated in a set area or dispersed across a landscape to break up the continuity of fuels with the goal of promoting variable fire effects when a wildfire inevitably arrives (Ager et al. 2013). Those designed to aid in suppression actions can be for "point protection," where the treatments are concentrated around a specific value or asset needing protection or to create a network of treatments to contain fires at defensible locations, such as along roads and ridge tops (Agee et al. 2000, Ager et al. 2013). Although a treatment may be designed for fire control or to promote resiliency, these objectives are not always mutually exclusive, and benefits may be seen beyond the treatment boundaries. In a simulation study, Ager et al. (2010) demonstrated that treatments designed to protect homes (fire control) also reduced off-site large tree mortality (resiliency) and vice versa.

Since the inception of the National Fire Plan (2000) in 2001, the use of fuel treatments to reduce the likelihood of uncharacteristic fires by the Forest Service has nearly doubled (USDA Forest Service 2014). The FLAME Act of 2009 and resulting National Cohesive Wildland Fire Management Strategy ("Cohesive Strategy") (Wildland Fire Leadership Council [WFLC] 2014) reiterate the need to evaluate wildland fire management in the United States. The Cohesive Strategy recognizes that fire is a necessary natural process in many ecosystems and strives to reduce conflicts between fire-prone landscapes and people (WFLC 2014). To achieve this, one of the core goals of the Cohesive Strategy is to manage fuels at the landscape scale to restore and maintain fire-resilient landscapes in accordance with management objectives. Another is to implement safe, effective, and efficient wildfire responses that can be facilitated by hazard reduction through fuel treatments. Prior studies have analyzed federal fuel treatments in the western United States with respect to fire regime (Schoennagel and Nelson 2010) and proximity to the wildland-urban interface, used as a proxy for hazard (Schoennagel et al. 2009). However, because of the lack of spatially explicit data, they created circular buffers based on the treatment centroid. With the development of nationally available, spatially explicit data, it is now possible to evaluate the Forest Service fuel treatment program using the actual treatment footprints. Seeking improved strategies for reducing fuels, the USDA Forest Service fire management leadership initiated this effort to evaluate whether fuel management is impacting enough area in the correct locations. To complete this, we evaluated the extent of mechanical treatments, prescribed fire, and wildfire occurrence within Forest Service-administered lands from 2008 to 2012 with respect to historic fire return intervals and current wildfire hazard.

Methods

Fuel Treatments Completed and Wildfire Acres Burned

LANDFIRE provides more than 20 geospatial layers characterizing vegetation, fuels, fire regime, and disturbance for the United States and insular areas, which are widely used in fire and land management, resource assessment, and wildlife habitat modeling (e.g., Rollins 2009, Nelson et al. 2013, Ryan and Opperman 2013). LANDFIRE Disturbance (LANDFIRE 2014a) data layers were used to quantify the type and location of fuel treatments and wildfires on lands administered by the National Forest System (NFS). The disturbance layers were developed using a mix of the LANDFIRE Events database (LANDFIRE 2014b), wildfire occurrence data, and remote sensing-based disturbance detection techniques (Vogelmann et al. 2011, Jin et al. 2013, Nelson et al. 2013). The LANDFIRE Events database includes point and polygon data from both natural (e.g., wildfire and insects) and anthropogenic (e.g., harvesting and fuel treatments) sources and includes at a minimum the year, type, and location of the disturbance (Nelson et al. 2013). LANDFIRE Events data were acquired from federal, state, tribal, local, and private entities, vetted by LANDFIRE personnel, and cleaned by overlapping all the data sources and types to create a single unique event per year and location (Nelson et al. 2013). Wildfire occurrence data come from the Monitoring Trends in Burn Severity (MTBS) (Eidenshink et al. 2007), Burned Area Reflectance Classification (BARC), or Rapid Assessment of Vegetation Condition after Wildfire

Management and Policy Implications

The Forest Service Strategic Plan (USDA Forest Service 2015b) acknowledges the natural role of fire in many ecosystems as well as the potential threat of wildfire to public safety, property, and natural resources. One of the tools used to proactively mitigate potential negative wildfire impacts is fuel treatments. Understanding where past fuel treatments and wildfires have occurred is important for prioritizing future fuel treatments. We found that current treatment implementation is not focused on the areas that would most reduce fire hazard nor is it at a scale that approximates historic disturbance rates across NFS lands. Strategies to reduce fire hazard and achieve the ecological benefits of fire include the following: increasing the extent of fuel treatments if resources permit; designing treatments to create conditions conducive to naturally ignited fires burning under desired conditions while fulfilling an ecological role; and placing treatments to reduce hazard while providing options for firefighting when highly valued resources and assets are present. The data sets employed in this analysis can be used to better inform future fuel treatment placement when appropriate.

Table 1. Disturbance type groups, LANDFIRE Disturbance classes associated, total area disturbed, and annual average area disturbed for NFS lands from 2008 to 2012.

Disturbance type	LANDFIRE Disturbance classes	Total (ac)	Annual (ac/yr)
Mechanical treatment	Clear cut, Harvest, Thinning, Mastication, Other mechanical	2,708,102	541,620
Prescribed fire	Prescribed fire, Wildland fire	5,407,592	1,081,518
Wildfire	Wildfire, Wildland fire use	7,862,655	1,994,010
Characteristic severity		5,755,547	1,151,109
Uncharacteristically low severity		1,232,694	246,539
Uncharacteristically high severity		874,413	174,883

Wildfire severity was defined as characteristic, uncharacteristically low, or uncharacteristically high based on assigned severity class and presumed historical fire regimes. LANDFIRE Disturbance classes are from LANDFIRE (2014a).

(RAVG) programs. The Multi-Index Integrated Change Analysis (MIICA) method, which uses Landsat pairs to detect disturbance and land cover change patterns, was used to detect vegetation change (Jin et al. 2013). LANDFIRE Events were buffered and then overlaid on the MIICA-detected changes to assign a disturbance type. If the disturbance did not fall within any buffered events, it was labeled unknown (Nelson et al. 2013).

LANDFIRE Disturbance types include residential and commercial development, silvicultural treatments (clearcut, thinning, or harvest), mastication, other mechanical treatments, fire (wildfire, wildland fire use, wildland fire, or prescribed fire), weather, chemical (insecticide or herbicide), insects, disease, biological, and unknown. For our analysis we created three disturbance groups: mechanical treatments, prescribed fire, and wildfire (Table 1). The mechanical treatment is a broad category including many disturbance types, all of which have been considered fuel treatments within the Forest Service Activity Tracking System (FACTS). With the exception of the assignment of the prescribed fire disturbance type, we used unaltered LANDFIRE data.

We updated the prescribed fire type assignment because these fires can be incorrectly categorized during the LANDFIRE processing steps. During the LANDFIRE processing steps, if a disturbance was detected and it coincided with a MTBS program fire perimeter, it was categorized as a wildfire, regardless of the fire type. To correct this, prescribed fire perimeters from the LANDFIRE Events data and fire type assigned to the MTBS perimeters were used to check and update the fire type to prescribed fire when warranted. In addition, we reassigned the remaining LANDFIRE unknown/other fire types to the prescribed fire category for our analysis. Totals were checked against the Incident Management Situation Report (IMSR) archives to verify that prescribed fire and wildfire acres were similar after correction.

Within the LANDFIRE Disturbance product, severity is assigned to each pixel burned in a wildfire. MTBS, BARC, and RAVG wildfire severity classes include unburned/low, low, moderate, and high and were determined by each project's criteria and applied to the LANDFIRE data. These programs accounted for 94% of area burned. For wildfires not mapped by these programs (typically fires of <1,000 ac in the West and <400 ac in the East), LANDFIRE determined severity by using mosaicked difference normalized burn ratio data classified into high-, medium-, and low-severity levels based on a statistical comparison with the MTBS, BARC, and RAVG fire severity (LANDFIRE 2014a). To assess whether severity was characteristic, uncharacteristically low, or uncharacteristically high, we used the LANDFIRE Fire Regime Group (FRG) (LANDFIRE 2014c) definitions of presumed historical severity and compared these to the severity assigned in the LANDFIRE Disturbance products on a pixel-by-pixel basis. For fire regime groups characterized by low- and mixed-severity (FRG I and FRG III), pixels burned at unburned/low, low, and moderate severity were considered characteristic, and pixels burned at high severity were determined to be uncharacteristically high. For fire regime groups characterized by replacement severity (FRG II and FRG IV), pixels burned at high severity were considered characteristic, and all others were uncharacteristically low. For FRG V which is characteristic of any severity, all burned pixels were considered characteristic.

Ideally the fully available temporal period (1999–2012) of LANDFIRE Disturbance data would have been used. Comparisons with tabular data on completed fuel treatment acres (IMSR, National Fire Plan Operations and Reporting System [NFPORS], and FACTS) were poorly correlated with LANDFIRE Disturbance data before 2008. The requirement for National Forest units to spatially define treatment boundaries rather than just the location of the center of each treatment starting in ca. 2007 greatly improved the LANDFIRE Disturbance data starting in 2008. For this reason, the analysis was limited to 5 years, 2008–2012.

Fire Return Interval

Mean fire return interval (MFRI) data from LANDFIRE (LANDFIRE 2014d) were used to estimate the annual area that would have historically burned as a proxy for annual disturbance required to create or maintain fire-adapted resilient landscapes. MFRI quantifies the time between fires under the presumed historical fire regime and was derived using state and transition modeling. The MFRI data comprised 22 classes, plus nonburnable (water, snow/ice, and barren) and indeterminate (indeterminate fire regime characteristics or sparsely vegetated) classes (Figure 1; Table 2). Similar to North et al. (2012), area within each MFRI category was divided by the maximum value of each category to conservatively estimate acres per year requiring disturbance. For the >1,000-year category, a value of 2,000 years was used.

Wildfire Hazard Potential (WHP)

The WHP product was used to characterize hazard across NFS lands (Fire Modeling Institute [FMI] 2013, Dillon et al. 2015) (Figure 2). The WHP is a geospatial product, the primary intended use of which was for identifying priority areas for hazardous fuels treatments from a broad, national- to regional-scale perspective (Dillon et al. 2015). The primary objective of the WHP map was to depict the relative potential for the occurrence of fires that had a high likelihood to escape initial attack and/or be difficult to suppress. The WHP map used existing vegetation and fuel characteristics from LANDFIRE to apply a set of resistance to control weights based on fireline construction rates based on fuel types, historic fire occurrence data (Short 2014) to determine small fire (<300 ac) potential, and national estimates of burn probability and fire intensity modeled using the large fire simulator to determine large fire (>300 ac) likelihood and intensity (Finney et al. 2011). Two versions of the WHP map are available (2012 and 2014). The 2012 version was used because the base data for creation were LANDFIRE 2008, which allows for overlay of fuel treatments and wildfire over the time period of this study.

Results

Assessments of disturbance location with respect to resilient ecosystem maintenance/creation and wildfire hazard reduction were conducted for all NFS lands and for each region (Northern [R1], Rocky Mountain [R2], Southwestern [R3], Intermountain [R4], Pacific Southwest [R5], Pacific Northwest [R6], Southern [R8], and Eastern [R9]; Figure 1).

Between 2008 and 2012, 8.1 million ac were treated with prescribed fire or mechanical methods, and 7.9 million ac burned in a wildfire (Table 1). Of the wildfire acres burned, 73% were characteristic (Table 1). This equates to, on average, 1.9% of NFS lands being disturbed by fuel treatments and wildfire of any severity each year or 1.6% if only characteristic wildfire is considered. Seventy-two percent of all of prescribed fire acres were completed in R8, whereas R5 and R6 led the nation in mechanically treated area (17 and 23%, respectively). R3 and R5 account for 51% of wildfire acres (29 and 22%, respectively) nationally. One-quarter of the uncharacteristically low-severity wildfire was in R1, and one-third of the uncharacteristically high-severity wildfire was in R5. The remainder of the results are presented on a per annum basis averaged across the 5 years of data.

Ecosystem Maintenance/Creation

Over the duration of the analysis, 51% of the NFS lands that would have historically burned annually were either treated (26%), burned in characteristic wildfire (18%), or burned in uncharacteristic wildfire (7%) (Figure 3). Approximately half of the acres burned with prescribed fire were in the most frequent MFRI (<5 years), and

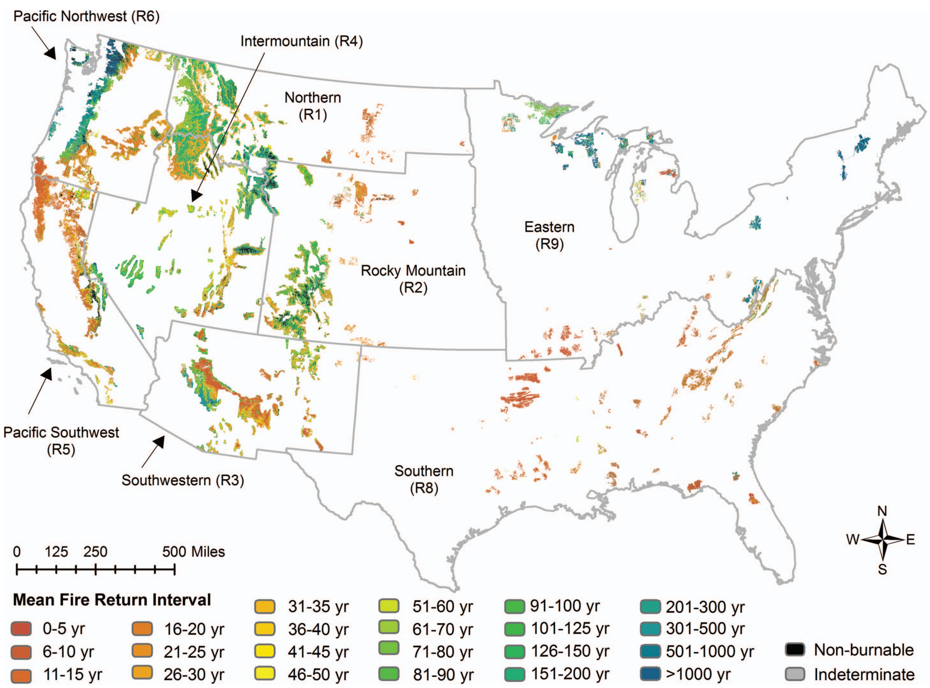

Figure 1. Map of MFRI for Forest Service-administered lands in the continuous United States. Data were obtained from LANDFIRE (LANDFIRE 2014d).

Table 2. Annual treatment requirements based on MFRI data.

MFRI	R1	R2	R3	R4	R5	R6	R8	R9
	. . . .	. . . .	. . . .	. . . . (ac/yr)	. . . .	. . . .	. . . .	. . . .
0–5 yr	12,436	284	3,018	0	1,043	807	1,094,216	340,756
6–10 yr	665	94,885	486,437	91,818	439,914	245,186	196,703	68,017
11–15 yr	130,812	79,632	100,167	104,096	288,580	96,134	176,137	33,980
16–20 yr	20,037	83,862	19,066	11,378	104,751	218,865	13,516	4,401
21–25 yr	99,630	29,325	97,056	44,131	19,427	21,481	0	154
26–30 yr	7,487	97,383	19,216	71,656	15,955	20,100	648	9,393
31–35 yr	40,727	3,544	6,949	91,192	32,409	2,775	5,883	498
36–40 yr	20,900	11,151	3,478	9,109	7,212	34,241	8,127	0
41–45 yr	11,828	6,514	1,283	27,037	0	0	4,619	0
46–50 yr	17,737	16,276	37,365	57,683	43,476	20,605	3	8,098
51–60 yr	2,489	10,528	14,163	15,073	14,926	970	2,604	1,187
61–70 yr	24,668	13,043	10,239	20,343	1,486	8,002	9,315	2,711
71–80 yr	34,135	1,993	34,118	3,735	8,598	41,607	155	18,548
81–90 yr	481	1,366	1,149	17,753	5,348	80	565	109
91–100 yr	171	428	0	1,044	445	5,627	3,972	1,134
101–125 yr	443	12,300	9,369	12,812	5,170	3,246	0	6,725
126–150 yr	12,279	39,969	5,200	13,817	559	726	0	3
151–200 yr	39,082	2,412	1,875	22,239	1,316	7,822	2,602	2,618
201–300 yr	3,014	3,425	166	9,885	1,249	56	1,075	2,000
301–500 yr	1,324	263	2,181	2,398	490	4,835	25	131
501–1,000 yr	20	345	467	62	67	459	69	1,882
>1,000 yr	0	0	0	73	16	1,245	0	1,250
Total	480,363	508,931	852,961	627,332	992,438	734,868	1,520,233	503,594

Annual treatment requirement was calculated by dividing the area within each MFRI class by the maximum value of the class. MFRI data are from LANDFIRE (2014d).

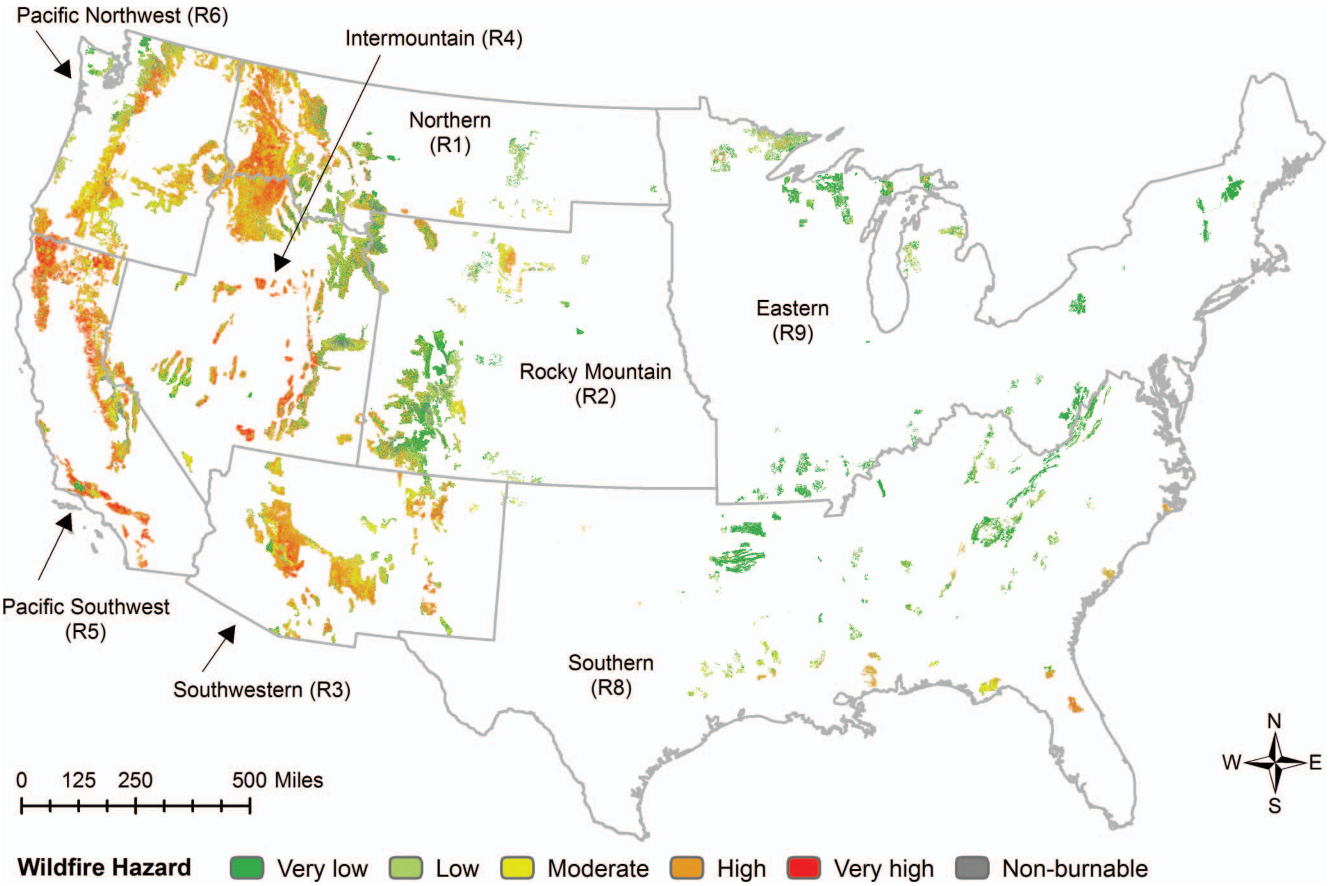

Figure 2. Map of wildland fire hazard for Forest Service-administered lands in the continuous United States. Data were obtained from the WHP map (FMI 2013, Dillon et al. 2015).

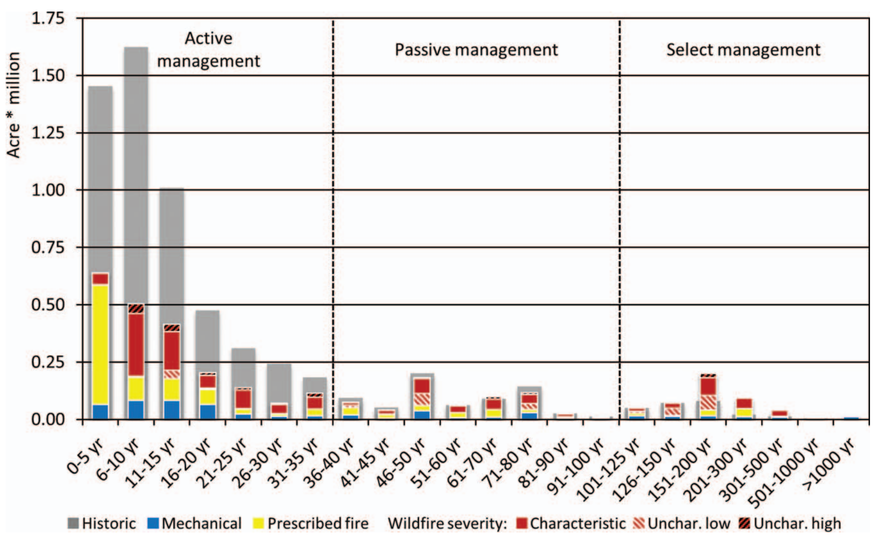

Figure 3. Average annual area being disturbed by mechanical treatments, prescribed fire, and wildfire by severity class (characteristic, uncharacteristically low, and uncharacteristically high) compared with what would have historically burned by MFRI group from 2008 to 2012. Areas that have historically burned frequently would lend themselves to active management with repeated treatment to promote resiliency in the absence of wildfire. Areas that burned less frequently could be treated if needed and then be managed passively allowing for fire to play a more natural role. Areas that burned infrequently can be managed selectively because they only account for a small fraction of the treatment requirement.

two-thirds were within areas that would have historically burned at least every 15 years. Areas with the shortest fire return intervals (<30 years) experienced less disturbance than required to maintain historical area burned, whereas areas with the longest fire rotations (>150 years) experienced more disturbance than would have been historically expected (Figure 3).

The eight Forest Service regions differed greatly for historical area burned versus current disturbance (mechanical treatments, prescribed fire, and wildfire) (Figure 4). Regions with more area in frequent fire return intervals have the most area historically burned and therefore the greatest disturbance required for maintenance. For example, R8 had the highest annual disturbance need (1.5 million ac) because 40% of the NFS lands were within the 0–5 year MFRI group (Figure 4; Table 2). Conversely, R1 had the least annual area historically burned (0.5 million ac) because 44% of the land had a MFRI of 100 years or greater (Figure 4; Table 2).

The ratio of area currently disturbed (treated or burned in wildfire) to area histor-

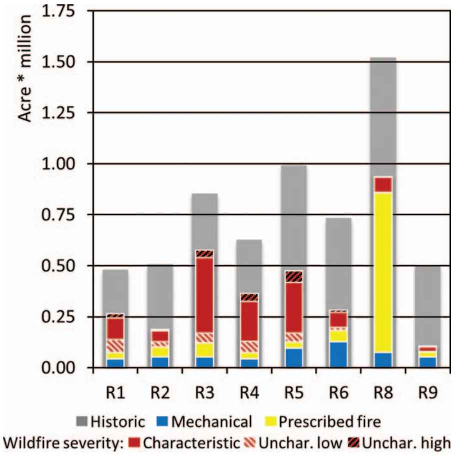

Figure 4. Average annual area being disturbed by mechanical treatments, prescribed fire, and wildfire by severity class (characteristic, uncharacteristically low, and uncharacteristically high) compared with what would have historically burned by Forest Service Region from 2008–2012.

ically burned was calculated to compare the relative ranking across regions. When fuel treatments and wildfires of any severity were considered, R9 and R2 were the most departed (0.21 and 0.37, respectively) and R8 and R3 were the least (0.62 and 0.68, respectively). The same was found when only characteristic wildfire acres were considered. R3 had the highest ratio for wildfire acres (characteristic and all severities) burned, and R8 had the highest ratio for treated acres relative to historic need.

Fire Control

In 2008, based on the WHP map, the moderate hazard class represented the greatest land area (41.6 million ac), followed by the high hazard class (35.3 million ac), with the very high hazard class the least (23.0 million ac) (Figure 5). Across all hazard classes, 3.2 million ac (1.9%) of NFS lands were disturbed annually by treatments and wildfire of any severity, with variation across the categories ranging from 544,335 to 922,908 ac for the low and moderate hazard classes, respectively. In the very low and low hazard categories, almost twice the area was treated than burned by wildfire of any severity (Figure 5). The opposite was true for the high and very high hazard classes where wildfire of any severity accounted for two-thirds of the disturbance each year. Across the wildfire hazard classes, the percentage of wildfire acres that had uncharacteristically high severity ranged from 9 to 15% with the largest proportion in the very high hazard class (Figure 5).

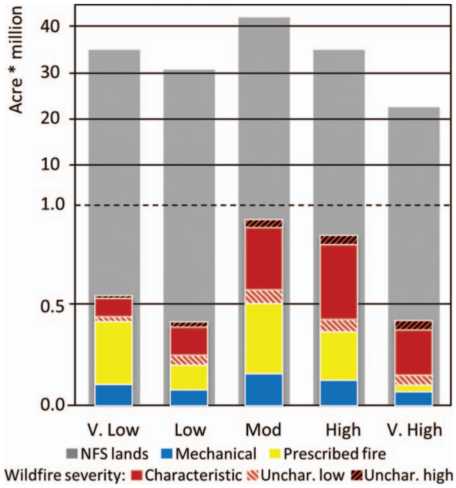

Figure 5. Average annual area disturbed by mechanical treatment, prescribed fire, and wildfire by severity class (characteristic, uncharacteristically low, and uncharacteristically high) relative to NFS lands by WHP class from 2008 to 2012. Note the compressed scale above 1 million ac.

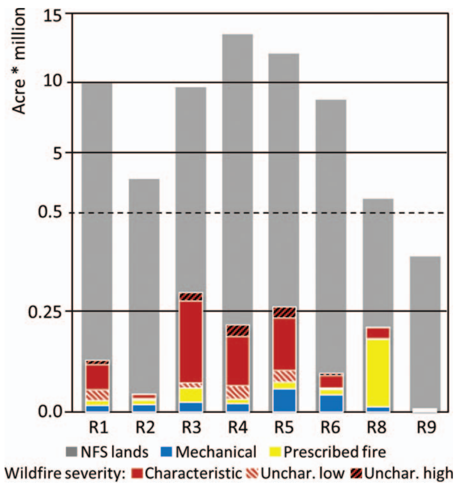

Figure 6. Annual average area disturbed by mechanical treatments, prescribed fire, and wildfire by severity class (characteristic, uncharacteristically low, and uncharacteristically high) in the high and very high hazard classes from 2008 to 2012 by Forest Service Region. Note the compressed scale above 0.5 million ac.

The majority of the high and very high hazard was in the western half of the United States, with areas also in the southeast and northern Lake States (Figure 2). Variability exists among the average annual area disturbed for each Forest Service Region in the high and very high hazard classes relative to the total landmass (Figure 6). R4 and R5 had the largest total area in the high and very high hazard classes, and R9 had the least (Figure 6). Because of the frequent use of prescribed fire, and the relative low area with high or very high hazard, R8 had the highest proportion of high and very high hazard area disturbed annually, which was almost five times that of the next closest region, R3, which had the highest proportion of wildfire of any severity (Figure 6). A higher ratio of area disturbed was by wildfire (any and characteristic severities) than by treatment in half of the regions (R1, R3, R4, and R5) with all wildfire being almost 6 times and characteristic wildfire 4 times that of treatment in R4. Of the regions, R5 had the highest percentage of disturbance by uncharacteristically high-severity wildfire in the high and very high hazard classes (Figure 6).

Discussion

It is neither realistic nor necessary to do fuel treatments on every acre of the 193 million ac encompassing the NFS lands. With limited budgets and capacity as well as other constraints such as wildlife habitat preservation and inaccessible terrain, it is important to prioritize when, where, and how to treat wildland fuels (Collins et al. 2010). This evaluation explores the location of mechanical treatments, prescribed fires, and wildfires with respect to historic fire return intervals or potential wildfire hazard for NFS lands over the period of 2008 to 2012. This assessment considered the footprint acres disturbed by fuel treatments and wildfire to promote resiliency or reduce hazard; however, in many instances, treatments can be designed to accomplish both simultaneously (Ager et al. 2010, Schoennagel and Nelson 2010). Finding a balance between the two objectives may be necessary when managing for multiple objectives, which is common in federally administered lands.

The creation and maintenance of fire-resilient landscapes can include contemporary disturbance that approximates historical disturbance rates. For this to occur, 6.2 million ac of NFS lands would need to be treated or experience beneficial wildfire annually (Table 2). Over the period assessed, 45% of NFS lands that historically would have burned were disturbed by either fuel treatment (26%) or wildfire with characteristic severity (19%) annually. The current scale and pace of treatment implementation is not keeping up with the current needs or addressing the backlog (North et al. 2012) of the many years of wildfire suppression and limited fuel treatment implementation.

A similar assessment for National Forestlands in California's Sierra Nevada reported that approximately half of required disturbance based on need set by the maximum MFRI was accomplished with fuel treatments or wildfire of any severity (North et al. 2012). This assessment found a similar amount of disturbance for R5, which contains the Sierra Nevada, the Sierras when wildfire of any severity was included, and 10% less when only wildfire of characteristic severity counted. Considerable variability in disturbance was experienced across the National Forest Regions (Figure 4). In half of the regions (R1, R3, R4, and R5), wildfire exceeded the amount of area treated. Although in many cases, these wildfires have accomplished what the landscape needs (characteristic severity), from an ecological point of view, this is not always true. Some wildfires burn with uncharacteristically high severity under extreme weather conditions in heavy fuels and may result in ecological damage. We found over the period assessed that 11% of wildfire acres burn with uncharacteristically high severity. Current treatment rates are insufficient to fully create and maintain resilient landscapes, especially in frequent fire rotation areas. One approach to overcoming the low treatment rate is to create conditions conducive to letting naturally ignited wildfires burn when the opportunity arises, so that unplanned wildfires can be used to meet objectives (Reinhardt et al. 2008, North et al. 2012, 2015, Stevens et al. 2014).

MFRI can be used to define different management regimes with the objective to create and maintain fire-resilient landscapes (Figure 3). Areas that have historically burned frequently (<35 years) would lend themselves to active management with repeated treatment to promote resiliency in the absence of wildfire. These frequent fire systems are typically "fuel-limited," meaning that with sufficient fuel accumulation they are almost always conducive to burning during the fire season and a lack of frequent disturbance can lead to uncharacteristic high-severity burning (e.g., Schoennagel et al. 2004, Steel et al. 2015). These areas represent the largest disturbance need nationally: 5.3 million ac/year or 85% of the annual disturbance need. Currently, 39% of this area is being disturbed annually (22% treatment, 14% wildfire with characteristic severity, and 3% uncharacteristically severity wildfire). In a different, although related, approach using fire regime group to define treatment need, Schoennagel and Nelson (2010) reported that 43% of treatments in forested federal lands in the western United States from 2004 to 2008 occurred in areas of high restoration need. High restoration need was defined by areas of a frequent historical wildfire (≤35 years) with low to mixed severity or FRG I. In our assessment, 58% of treatments in the western regions occurred in FRG I, showing an improvement in targeting these areas since 2008.

Areas that burned less frequently (MFRI 35–100 years) could be managed differently. These areas could be actively treated if needed and then be managed passively, allowing for wildfire to play a more natural role. Because of the longer MFRI, 11% of the annual disturbance need was within this group, and, of that, 38% was disturbed by treatment with an additional 52 or 34% by wildfire if all severities or only characteristic severity was considered, respectively. Finally, infrequently burned (MFRI >100 yr) "climate-limited" systems, which have sufficient fuels but often lack extreme climatic conditions conducive to wildfire (e.g., Schoennagel et al. 2004, Steel et al. 2015), could be managed selectively because they account for only 4% of the disturbance requirement. The combined disturbance of treatments and characteristic severity wildfire have exceeded the disturbance need based on historic levels where the MFRI is greater than 150 years. In these climate limited systems, one-third of annual wildfire acres burned had uncharacteristically low severity.

When the primary objective of fuel treatments is to aid in fire control, they are often located strategically to reduce wildfire hazard and facilitate wildfire suppression activities. Within some hazard classes, we found that a nonproportional amount of land was treated or burned in wildfire (Figure 5). For example, the very low hazard class accounts for 20% of the NFS lands, and of the treatments completed annually, 26% are in this class, with 8% of the wildfire acres. The very high hazard class had the lowest treatment percentage and the highest incidence of uncharacteristically high-severity wildfire out of all the hazard classes. With the exception of R8, which treated on average 13% of the elevated hazard land (high and very high hazard) annually, all of the other regions treated less than 1% (Figure 6). Areas of very low hazard often are favored for treatment because they are less complex to plan and implement, are more economical to treat, or are in need of retreatment to maintain effectiveness. Very high hazard areas often require multiple entries to complete treatments, typically with mechanical methods being applied before prescribed fire, if prescribed fire is used, increasing the cost and complexity. In addition, treatments are often placed to protect highly valued resources and assets (HVRAs), where treatment location is predetermined regardless of hazard. Finally, treatments may be placed where they can accomplish multiple objectives, including production of wood products. This may result in selection of locations that are less important for hazard mitigation.

The proportion of wildfire (any and uncharacteristically high severity) in each hazard class increased along with hazards, with a near quadrupling of uncharacteristically high-severity wildfire acres between the very low and very high hazard classes. The higher proportion of wildfire acres in the very high class relative to the very low class is not surprising. In the very low hazard areas, suppression activities are typically more effective, limiting the total area burned. The very high class represents areas with a higher probability of experiencing high-intensity wildfire, which is hard to suppress, and are most likely to escape from initial attack and grow large (Dillon et al. 2015). If reducing potential wildfire hazard is a primary goal, placing treatments in areas of the highest hazard is warranted especially when they intersect HVRAs that are detrimentally affected by wildfire. Whereas a number of considerations including locations of HVRAs and opportunities to meet other restoration objectives may lead to placement of a fuel treatment in a lower hazard area, locating treatments in the areas with the highest hazard is most effective when fire control is the objective.

This assessment used LANDFIRE-assigned wildfire severity to characterize acres burned as characteristic or uncharacteristic with respect to severity based on presumed historical fire regimes. This allows for a more robust assessment of wildfire as a treatment than previous work by North et al. 2012, which assumed that all wildfire acres counted as treatments. Similar to North et al. (2012), Schoennagel and Nelson (2010), and Schoennagel et al. (2009), this assessment examined the interactions of fuel treatments and wildfire on the promotion of resiliency or hazard reduction. With the currently available data and fuel treatment reporting systems in the Forest Service, it was not possible to assess the extent to which fuel treatments create and maintain resiliency or reduce hazard at the national scale. The newly implemented requirement in the FACTS system to note the progress (initial/interim or completed) and whether it is a maintenance or new treatment will facilitate future assessments of fuel treatment effectiveness. Additional requirements to quantify changes to fuels and to note whether the treatments were successful in meeting stated objectives would be beneficial. To quantify the impact of treatments (mapped by LANDFIRE) to reduce wildfire hazard, consistently derived maps of wildfire hazard are required. Currently two versions of the WHP map exist (2012 and 2014) and could be compared to make broad assessments; however, with each iteration differences exist in the input data and the final map so that a direct detailed comparison is not advised (Dillon et al. 2015).

One of the objectives of the Forest Service Strategic Plan (USDA Forest Service 2015b) is to mitigate wildfire risk. The plan acknowledges the natural role of fire in many ecosystems and the potential to use wildfire as a restoration tool, as well as the potential threat of wildfire to public safety, property, and natural resources. To assess the progress toward the strategic plan objective, the Forest Service is initiating two nationally based performance measures. The first assesses the risk of future wildfires to HVRAs. This national risk assessment will identify the likelihood of wildfire, expected wildfire intensity, and expected impacts, positive or negative, on HVRAs (Dillon and Scott 2016). This product will provide up-to-date information on landscapes at risk of detrimental wildfire and will be used to help determine where to invest in fuel treatments and where wildfire may be allowed to play its natural role and achieve ecological benefits based on assessments of risk (Dillon and Scott 2016). Once the baseline measure is completed, it will be periodically remeasured to determine whether overall risk has been reduced as a result of fuel treatments or other disturbances. The second measure assesses the extent to which naturally ignited wildfires achieve beneficial results. This measure recognizes the need and commitment to using wildfire as a restoration tool when appropriate. Previous performance measures (e.g., acres treated and acres treated in the wildland-urban interface) essentially treated all areas as equivalent and did not recognize that some areas are more important to treat than others from a risk mitigation or ecological need standpoint. These measures will still be reported for continuity.

The use of LANDFIRE data has limitations. Not all treatments were represented in the LANDFIRE Disturbance data for several reasons: only a single event per year per location is used, sometimes LANDFIRE Events data are lacking, and, finally, small patch sizes confound assessment efforts at the national scale. The disturbance with the greatest change to vegetation and/or fuels composition and structure is ranked highest and maintained in the data set (Nelson et al. 2013). When remotely sensed detected changes were not within LANDFIRE Events, they were labeled as unknown (Nelson et al. 2013). Within the current analysis, on average annually 7% of all disturbance acres were classified as unknown and were not included. Remotely sensed disturbed areas of fewer than 50 pixels (about 12 ac) were too small for the purposes of large area updating and were not included (Vogelmann et al. 2011). On the other hand, vegetation management can be completed over a number of years, resulting in partial treatment counting as repeat treatment within the same footprint. However, LANDFIRE Disturbance data permitted direct overlays of all required data layers to conduct the detailed analysis accomplished.

This is the first assessment that intersects the actual footprint of fuel treatments and wildfire with MFRI and wildfire hazard at a national scale. Over the period from 2008 to 2012, ~2% of NFS lands were being disturbed annually by fuel treatments and wildfire. This equates to half of the historic area burned, with the highest wildfire hazard class experiencing the lowest percentage of area treated and the highest incidence of wildfire (any and uncharacteristically high severity). The "disturbance deficit" created by wildfire exclusion is ultimately self-correcting: large wildfires and increased acreage burned are the correction; however, there is no control on the severity of these fires. Treating fuels mechanically or with prescribed fire is an attempt to impose a disturbance that is less severe than wildfire and is used to mitigate the manner in which wildfire will eventually occur. These results suggest that the rate of fuel treatment implementation needs to be increased for this mitigation to be successful and that proactive wildfire management will need to be an important part of the solution.

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