Implementation of National Fire Plan treatments near the wildland–urban interface in the western United States

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Because of increasing concern about the effects of catastrophic wildland fires throughout the western United States, federal land managers have been engaged in efforts to restore historical fire behavior and mitigate wildfire risk. During the last 5 years (2004–2008), 44,000 fuels treatments were implemented across the western United States under the National Fire Plan (NFP). We assessed the extent to which these treatments were conducted in and near the wildland–urban interface (WUI), where they would have the greatest potential to reduce fire risk in neighboring homes and communities. Although federal policies stipulate that significant resources should be invested in the WUI, we found that only 3% of the area treated was within the WUI, and another 8% was in an additional 2.5-km buffer around the WUI, totaling 11%. Only 17% of this buffered WUI is under federal ownership, which significantly limits the ability of federal agencies to implement fire-risk reduction treatments near communities. Although treatments far from the WUI may have some fire mitigation benefits, our findings suggest that greater priority must be given to locating treatments in and near the WUI, rather than in more remote settings, to satisfy NFP goals of reducing fire risk to communities. However, this may require shifting management and policy emphasis from public to private lands.

fire mitigation | hazardous fuels reduction | Healthy Forest Restoration Act | prescribed fire | thinning

In recent decades, the western United States has experienced a dramatic expansion of housing in areas that abut or intermix with wildland vegetation (i.e., the wildland–urban interface, WUI) (1, 2), along with a substantial increase in area burned by wildfire (3). Not surprisingly, natural-resource managers and the public are interested in mitigating risk of severe wildfire to homes and communities in the WUI (4). Toward that end, in 2000 the U.S. National Fire Plan (NFP) established "a long-term hazardous fuels reduction program to reduce the risks of catastrophic wildland fire to communities" and to restore forests and rangelands (5). Under the direction set forth in the NFP and associated Healthy Forests Initiative and Healthy Forests Restoration Act, U.S. federal land-management agencies have treated 10 million hectares during 2001–2008 (6). Although the area treated under these initiatives is extensive, there has been neither a comprehensive analysis of the character and scope of NFP management activities nor an evaluation of the extent to which their locations target fire mitigation in the WUI.

The WUI has expanded rapidly over the last decade, resulting in an increase in the number of people and houses located in areas with high risk of wildfire. In the western United States, the WUI increased in area by 61% during 1970–2000 (2) and in total housing units by 68% during 1990–2000 (1). Over half of the WUI area in the western United States is in forests characterized by high-severity fires that are difficult to control (2). Thus, the expansion of the WUI is resulting in increased wildfire risk to private property. In fact, during 2002–2006, 10,000 homes were destroyed by wildfire (7). Protection of property and people in the WUI is a primary driver of NFP and related policies (Healthy Forests Initiative and the Healthy Forests Restoration Act, HFRA). To date, however, there has been no analysis of the degree to which treatments have been located in or adjacent to the WUI, where they are most likely to mitigate risk to private property. Also lacking is an evaluation of the degree to which treatments have been implemented as part of Community Wildfire Protection Plans (CWPPs), which are developed by communities in collaboration with land-management agencies to identify strategic areas for fire mitigation.

In addition to expansion of the WUI, increased wildfire activity in the western United States in recent decades has also contributed to the vulnerability of exurban communities. During 1987–2003, forest area burned increased 6-fold compared to the previous 16 years; this same time period was characterized by increased spring and summer temperatures, longer fire seasons, and earlier snowmelt (3). Climate models predict rising temperatures and decreased snowpack in the West during this century (8), suggesting that burn area will continue to increase.

Given widespread implementation and large investment of public resources in NFP fire mitigation projects [e.g., Congress appropriated $2.7 billion for fuel treatments during 2001–2006 (9)], we assessed whether treatment locations are consistent with NFP goals of fire mitigation to at-risk communities in the WUI. We analyzed recent NFP treatments (2004–2008) implemented by 5 U.S. federal agencies across 11 western states (Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming; hereafter, the "West") (Fig. 1). We examined a standardized interagency database of 44,613 treatments conducted on 3 million hectares during the last 5 years. Specifically, we asked the following: (*i*) *How does the percentage of the total area treated vary with distance to the WUI and by management objective? And* (*ii*) *within the WUI, how does treated area vary by (a) landownership, (b), geographic location (state), and (c) type of treatment implemented?* For reference, we compare results to the overall distribution of wildland vegetation across the West with distance to the WUI, within each category of landownership and within each state.

Results

Only 3% of the total area treated across the 11 western states was within the WUI, which includes both interface (relatively high-density development that abuts wildland fuels) and intermix (low-density development that is interspersed with wildland fuels); together these components of the WUI represent 2% of

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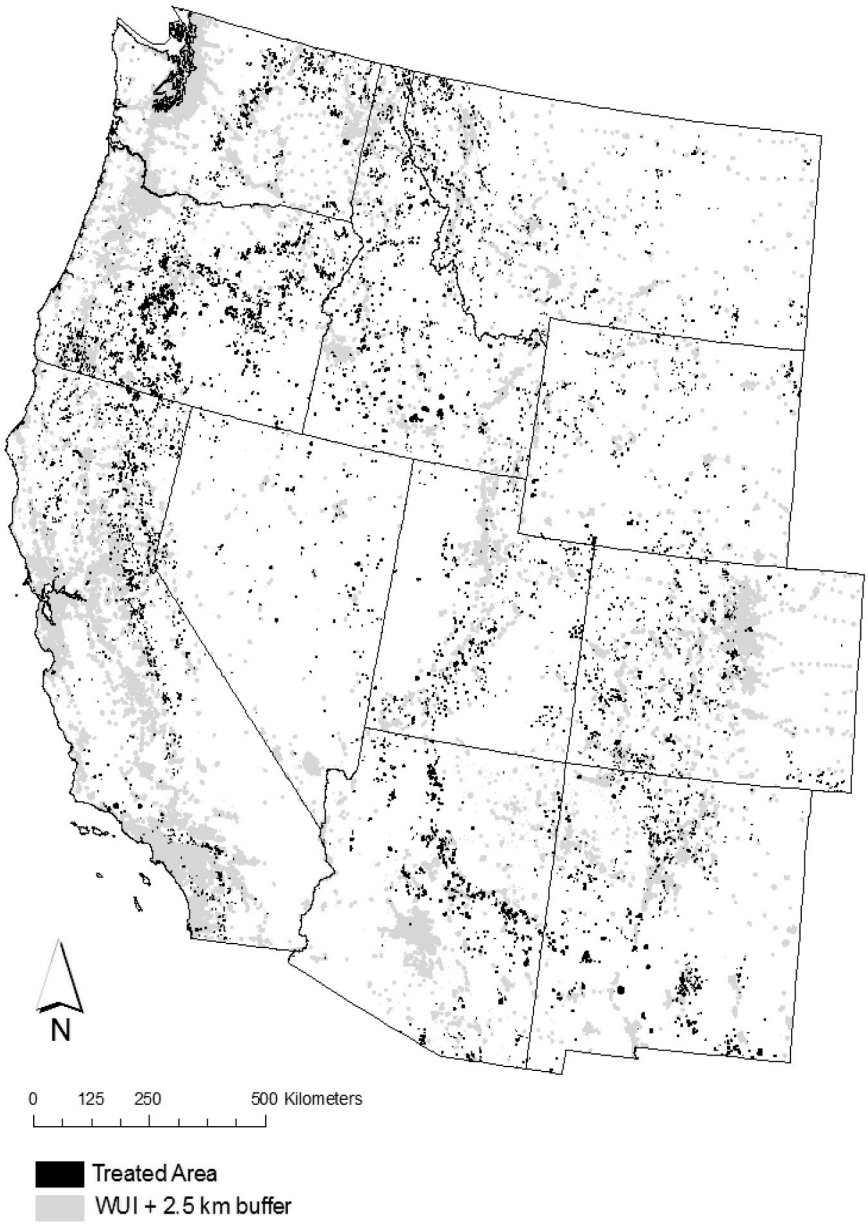

Fig. 1. Map of the 11 western states showing area treated under the National Fire Plan during 2004–2008 (solid areas) and the wildland–urban interface plus a 2.5-km buffer ($WUI_{2.5}$) (shaded areas).

areas with wildland vegetation in the West (Fig. 2). Eleven percent (8% in forested areas and 3% in shrubland/grasslands) of the total area treated was within a zone comprising the combined interface and intermix WUI, plus a 2.5-km buffer from the interface WUI (hereafter referred to as the $WUI_{2.5}$), the approximate "community protection zone" set forth in the Federal Register and HFRA. The majority of the area treated (62%) was >10 km from the interface WUI. Within the $WUI_{2.5}$, 42% of the area treated was associated with a Community Wildfire Protection Plan compared to only 22% at distances >10 km from the interface WUI.

In terms of management objectives, 80% of the area treated within the $WUI_{2.5}$ recorded "wildland–urban interface" and/or "defensible space" as objectives (Table 1). This proportion declined with distance from the WUI, but 41% of the area treated >10 km from the interface WUI was still associated with these fire mitigation objectives. The objectives "ecosystem restoration," "forest health," and "rangeland health" each comprised 20–45% of the area treated in the $WUI_{2.5}$ and mostly increased with distance from the WUI. "Reducing invasive species" was associated with 11% of the area treated within the $WUI_{2.5}$, increasing to 25% at >10 km from the interface WUI. Less-common treatment objectives included "municipal watershed or water supply protection" (10% of area treated), "protecting/enhancing threatened and endangered species habitat" (15% of area treated), and "controlling epidemic insects or disease" (3% of area treated); area treated with these objectives did not vary much with distance to the WUI.

In terms of landownership within the WUI, 71% of the $WUI_{2.5}$ is privately owned (Fig. 3). The remaining 29% of land within the $WUI_{2.5}$ is public land [owned by federal (17%), state (4%), and local (1%) governments or by Native American tribes (6%)]. Of the public land in the $WUI_{2.5}$ across the West, more than half is in 3 states: Arizona (22%), California (20%), and New Mexico

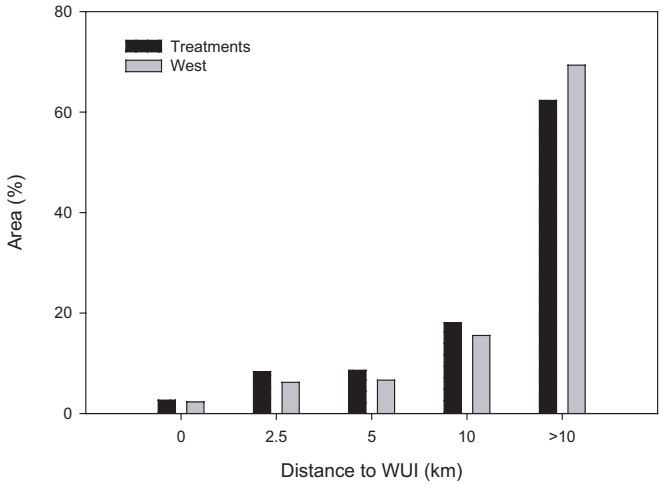

Fig. 2. Percentage of area treated under the National Fire Plan during 2004–2008 (solid bars) compared to percentage of the West (shaded bars) at various distances from the wildland–urban interface (WUI), showing that a small proportion of the area treated was within or near the WUI and that treatment distribution generally reflects West-wide trends in area available at each distance from the WUI. The WUI (distance = 0) includes both interface and intermix, while distances to the WUI >0 are calculated from the interface only (see *Materials and Methods*). In the text, we refer to the WUI plus a 2.5-km buffer from the interface WUI as $WUI_{2.5}$.

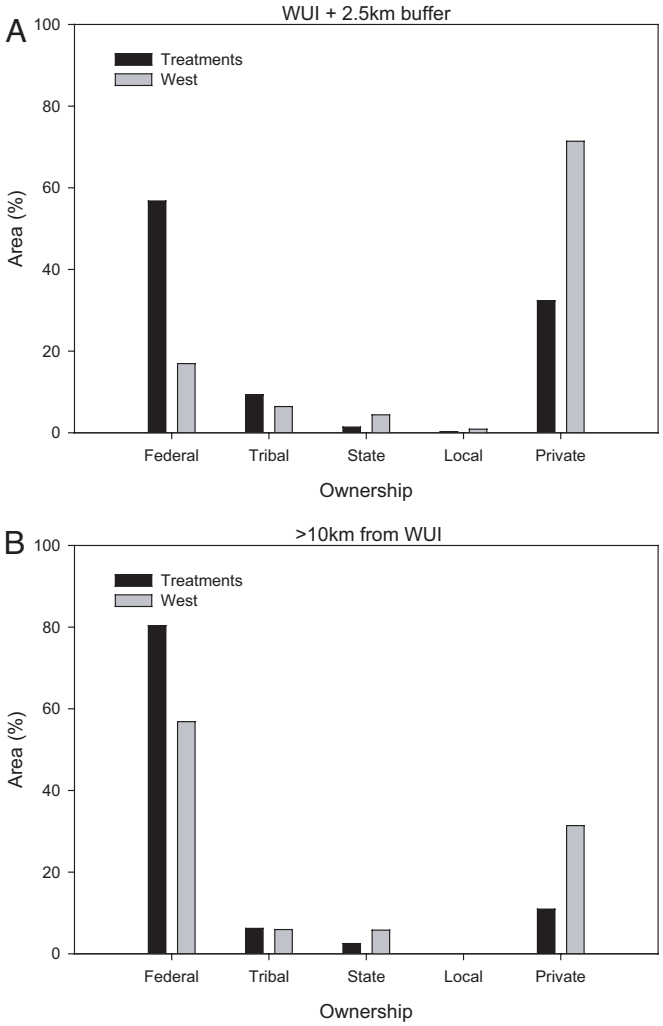

Fig. 3. Percentage of area treated under the National Fire Plan (2004–2008) (solid bars) compared to percentage of the West (shaded bars) under different landownerships (*A*) within a 2.5-km buffer from the WUI and (*B*) 10 km from the WUI.

(14%), and no other state has >10%. California, Arizona, and Colorado have the largest share of the $WUI_{2.5}$ that is federally owned (25, 14, and 13%, respectively). Despite limited public ownership within the $WUI_{2.5}$, 68% of the area treated there was on public lands. In contrast to trends within and near the WUI, almost 70% of wildland vegetation >10 km from the interface WUI is publicly owned.

The 11 western states varied considerably by their relative proportion of the total West-wide area treated within the WUI. Arizona and California accounted for the largest percentage of the total area treated within the $WUI_{2.5}$ (22 and 24%, respectively), while Wyoming, Nevada, Washington, and Utah had the smallest percentage of the total West-wide area treated within the $WUI_{2.5}$ (≤3% each; Fig. 4). Of the 11 states, 4 (Arizona, Idaho, New Mexico, and Oregon) treated more area within the $WUI_{2.5}$ than expected given the proportion of the West-wide $WUI_{2.5}$ that occurred within each of these states. In Arizona, the state with the highest concentration of treatments in the WUI, the proportion of the West-wide area treated in the $WUI_{2.5}$ was more than twice its proportion of the West-wide $WUI_{2.5}$. In contrast, in 3 states (California, Washington, and Wyoming) the percentage of the West-wide area treated was less than the percentage of $WUI_{2.5}$ within that state. Washington contains 13% of the $WUI_{2.5}$, but implemented only 3% of the area treated West-wide; thus, WUI treatments in this state received less priority than in others. California, which contains the highest percentage of the total $WUI_{2.5}$ area in the West (29%) but conducted only 24% of $WUI_{2.5}$ treatments, showed a slight bias

Table 1. Percentage of area treated with management objectives recorded under the National Fire Plan (2004–2008) in distance to WUI areas

WUI distance	WUI/ defensible space	Municipal watershed or water supply protection	Ecosystem restoration	Forest health	Rangeland health	Reducing invasive species	Protecting/ enhancing threatened and endangered species habitat	Controling epidemic insects or disease
0–2.5 km	80	12	39	45	20	11	13	4
2.5–5 km	75	11	44	48	19	13	12	3
5–10 km	61	11	50	51	24	15	18	4
>10 km	41	9	64	44	42	25	15	2
All areas	53	10	56	46	34	20	15	3

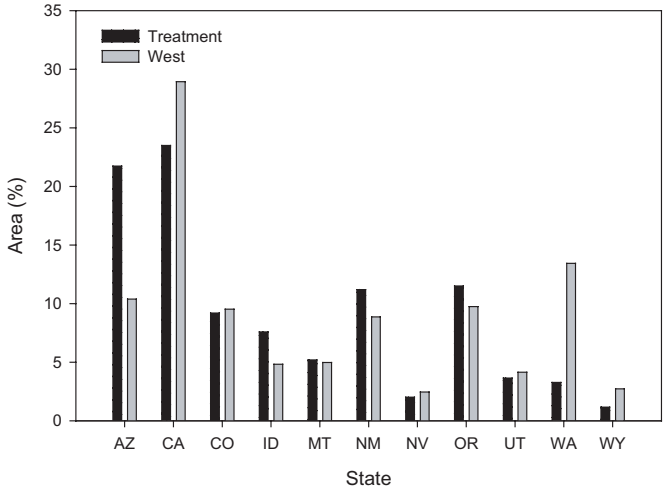

Fig. 4. For each of the 11 western states, the relative proportion of the total area treated under the National Fire Plan (2004–2008) that is located in the WUI + 2.5-km buffer (solid bars) compared to the relative proportion of the total area of the WUI + 2.5-km buffer (shaded bars) across the West that is in that state.

against WUI treatments. In Colorado, Montana, Nevada, and Utah, the relative proportion of area treated within the $WUI_{2.5}$ was similar to each state's proportion of the $WUI_{2.5}$ across the West.

The proportion of specific treatment activities (mechanical, prescribed fire, and "other" types) implemented within the WUI mostly differed from treatment trends across the West. Mechanical treatments were implemented on 62% of the area treated within the $WUI_{2.5}$ compared to 46% of the total area treated across the West (Table 2). Of the area mechanically treated in the $WUI_{2.5}$ (which reflects overlapping treatments), 41% was thinned, 16% had biomass removal, 14% was masticated or mowed, 10% was chipped or crushed, 14% was hand or machine piled, and 4% was lopped and scattered; these trends are similar to trends across the West. In contrast to application of mechanical treatments, prescribed burning was implemented less in the $WUI_{2.5}$ than across the West (29 and 45%, respectively). Of the area treated by fire in the $WUI_{2.5}$, 58% was broadcast burned and 42% was pile burned; in contrast, across the West the vast majority (83%) of the area treated by fire was broadcast burned. Nine percent of the area treated in the $WUI_{2.5}$ was classified as "other" treatment (same percentage as in the West overall): 56% received chemical treatments [e.g., application of pesticides to control or kill "pest" species (as defined by the Dictionary of Forestry), such as cheatgrass, which is highly flammable]; 28% was grazed; and 16% received seeding or biological treatments that involve living organisms (such as plants, insects, or grazing animals) to selectively suppress, inhibit, or remove herbaceous and woody vegetation. The area treated as "other" that involved chemical application was much higher across the West (77%) than within the $WUI_{2.5}$ (56%).

Table 2. Percentage of area treated under the National Fire Plan (2004–2008) by treatment type (fire, mechanical, and other) and treatment subtype, in the WUI + 2.5-km buffer and in all areas across the West

Treatment		Percentage of area treated	
Type	Subtype	$WUI_{2.5}$	West (all areas)
Mechanical		62	46
	Thinning	41	39
	Biomass removal	16	16
	Mastication, mowing	14	15
	Hand/machine pile	14	11
	Chipping, crushing	10	5
	Lop and scatter	4	8
	Seeding	1	6
Fire		29	45
	Broadcast burn	58	83
	Pile burn	42	17
Other		9	9
	Chemical	56	77
	Grazing	28	9
	Biological	10	4
	Seeding	6	10

Percentages are treated by treatment type and by each subtype group, and each sums to 100.

Discussion

Concern over protection of residential communities and private property in the wildland–urban interface to a large degree has driven recent federal forest policy in the western United States. For instance, the majority of wildfire suppression costs (which exceed $1 billion/yr) are directed toward protection of people and their homes (10). In addition to controlling active fires, the federal government has targeted forest management policies toward protection of communities within the WUI. NFP goals within the WUI are to reduce fuels around homes, communities, and resources to slow or stop wildland fires from threatening high-value areas. HFRA stipulates that 50% of fuel-reduction resources nationwide be allocated to the WUI, defined as at-risk interface communities plus a 0.8- to 2.4-km buffer (HFRA P.L. 108–148). Given this emphasis on community protection, we expected that a substantial percentage of area treated would have been concentrated near the WUI. We found, however, only 11% of the total area treated was within the WUI defined as interface and intermix WUI plus a 2.5-km buffer from the interface [community wildfire protection zones are typically applied to the higher-density interface and not the low-density intermix (refs. 2 and 11)].

Only about one-third of the area treated in this buffered WUI was nonforest, indicating an emphasis on treatments in forest ecosystems. However, human communities in fast-growing desert exurbs may be also threatened by high-severity wildfire because of recent spread of highly combustible invasive plants (e.g., *Bromus tectorum*, *Pennisetum ciliare*, *B. madritensis* var. *rubens*, *Schismus* spp.) (12) in grassland-dominated systems that previously were characterized by relatively inflammable desert scrub. Thus, treatments in nonforested systems may play an increasingly important role in overall fire mitigation planning.

Mitigation of fire risk to communities is stated as a primary goal of management activities in the NFP. We found that the majority of treatments implemented in the WUI did in fact have WUI and defensible space objectives. In contrast, far from the WUI only 40% of treated area had these fire-mitigation goals. This number may be conservative, as treatments outside the WUI with protection of municipal watershed or water supply as objectives may be considered within the general scope of fire-risk mitigation activities. However, only 10% of the area treated listed watershed or water supply objectives regardless of distance to WUI, suggesting only a minor role of this objective in NFP implementation across the West. Treatment areas associated with ecological objectives, such as restoration, health, or reducing invasive species, increased with increasing distance from the WUI. Caution should be used concerning interpreting trends in treatment objectives, however, as objectives were assigned subjectively without detailed criteria and are not mutually exclusive.

In addition, the extent to which treatments met recorded objectives has not been verified.

Because ≈70% of wildland vegetation in the $WUI_{2.5}$ across the West is privately owned, the ability of federal agencies to implement fire-risk reduction treatments near and within communities is significantly limited and may explain the positive relationship between distance from WUI and area treated. This discrepancy between landownership patterns and the need for fire mitigation presents a vexing problem for federal land-management agencies charged with reducing fire risk within the mostly privately owned WUI.

While the NFP stipulates that treatments associated with a CWPP should be prioritized for funding, and HFRA allows the Forest Service and Bureau of Land Management to expedite implementation of these treatments, only about half of the area treated in the WUI was associated with a CWPP. The National State Foresters Association cites similar statistics: 51% of communities-at-risk in the West (3,145 communities) had a CWPP or equivalent in place in 2007 (13). The collaborative approach to land management used in the CWPP process may be an effective means of strategically targeting treatments around communities, although the extent to which they improve fire mitigation planning has not been evaluated and may vary with the motivation and capacity of community members. At a minimum, the CWPP process can be valuable for heightening community awareness of wildfire risks and promoting implementation of fire mitigation measures. Increasing the number of communities that develop CWPPs may result in more strategic placement of treatments and a higher proportion of the area treated within the WUI.

Fire mitigation treatments located far from the WUI may play an important role in protecting timber resources and rare or threatened species or ecosystems from high-severity fire, but their effectiveness in direct community protection requires more systematic evaluation. In contrast, there is strong evidence that the potential for a home to burn is relatively independent of distant wildland-fire behavior. Empirical, modeling, and post-mortem studies have shown that ignitability of building materials and the abundance and arrangement of wildland fuels in the immediate surroundings (<50 m) of a house best predict its potential to burn (14). Thus, fire-proofing houses and their immediate surroundings should provide the most direct and effective wildfire protection of homes and communities in the WUI.

The extent to which past fuels-reduction treatments actually mitigated subsequent fire severity was beyond the scope of our investigation. A number of studies have shown that mechanical thinning with slash removal and prescribed fire can reduce subsequent (within a few years) wildfire severity in stands with historical low-severity fire regimes (15–20). However, similar fuel treatments may be less effective in ecosystems where historical and current fire regimes are characterized by high-severity fires that are driven by extreme weather (21, 22), although treatment size and arrangement remain important factors to evaluate (23). Although prescribed fire and wildland-fire use (the management of naturally ignited fires to achieve resource benefits) are economical means of reducing fuel loads (24), fire was implemented only half as much within the WUI compared to across the West, reflecting the challenge of burning near communities. Overall, there is an urgent need for broad-scale monitoring both of fire-mitigation efficacy (directly within stands and with respect to nearby communities) and of nontarget ecological effects of such treatments, such as increased mortality of presettlement trees (25, 26) and increased abundance of nonnative plants (27, 28).

Currently, ≈3 million hectares burn by wildfire each year on average, a rate that far exceeds fuel treatment accomplishments, which points to the need for spatially optimizing the implementation of NFP treatments. With development in the WUI predicted to continue, further influx of people into already vulnerable wildland communities is expected (7). Furthermore, the intermix, where homes are more dispersed and likely to be outside current fire protection districts and community jurisdictions, is expected to grow faster than the interface (29). Combined with these trends, our results suggest the need for a significant shift in fire-policy emphasis from federal to private lands (30), if protection of communities and private property in the wildland–urban interface remains a primary goal. Toward that end, we recommend fostering fire-adapted communities rather than increased fire protection of ever-expanding communities-at-risk in the WUI. In addition, we suggest strengthening or creating policies within the WUI that (*i*) promote fire-resistant construction and evacuation planning and restrict the growth and configuration of residential development; (*ii*) increase the ability of federal, state, and local agencies to implement fuel-reduction treatments across landownerships; and (*iii*) promote fire suppression cost sharing among agencies, across levels of government, and between public and private entities. Far from the WUI, however, fuels treatments should be implemented only where substantial benefits to watershed protection, biodiversity, or restoration of degraded forests can be demonstrated.

Materials and Methods

The National Fire Plan Operations and Reporting System (NFPORS) database (http://nfpors.cr.usgs.gov) includes systematically entered information on treatments implemented by federal agencies on both federal and private land. Data include treatment year, location (centroid of treatment unit), area, type, subtype, whether the treated area was associated with a Community Wildfire Protection Plan (data available for 25% of area treated), and management objectives of the treatment (data available for 60% of area treated; possible objectives are control of epidemic insects or disease, defensible space, ecosystem restoration, forest health, fuel reduction, protection of municipal watershed or water supply, protect/enhance threatened and endangered species habitat, rangeland health, reducing invasive species, wildland–urban interface, or other). There were multiple objectives for treatments, with 50% of the area treated listing up to 5 objectives per treatment, another 10% listing 6–12 objectives per treatment, and 40% recording no management objectives. We did not report results for ''fuel reduction,'' which is a nonspecific term and was recorded for 80% of the area treated and therefore was not discriminating. We obtained the data in 2007 and 2008. Although data for 2002 and 2003 were available, we limited analyses to treatments accomplished during 2004–2008; inconsistent reporting and less precise treatment-unit locations limited the utility of earlier years.

Before analyses, we filtered the 2004–2008 NFPORS data in the 11 western states for errors. We eliminated records that were exact duplicates in terms of treatment year, category, type, subtype, size, and location. In addition, to retain as much treatment information as possible while omitting potentially erroneous data, we deleted points for which there were >10 treatments per location per year. Overall, 96.8% of the remaining point locations had ≤4 treatments in any given year.

In a Geographic Information System (GIS) (ESRI ArcMap 9.2), treatments were represented by circular polygons centered at each point location, such that the size of the circle equaled the area treated. This approach simplified the shape of treatment units and likely underestimated the overall treatment extent by not accounting for irregularly shaped units or untreated islands within units. However, our goal was a broad-scale assessment of treatment locations across the western United States, not a fine-scale spatial analysis reflecting treatment shapes. After converting treatment points into circular polygons, we dissolved overlapping polygons to produce a final map of area treated (reflecting the largest polygon at a point), which we overlaid with distance to WUI (see below), landownership (Protected Areas Database v. 4.6; ref. 31) and state maps. To analyze tabular information contained in the NFPORS database such as treatment type or subtype, we selected all treatments (including overlaps) at locations of interest (see below) and then summarized them in a relational database.

To assess the location of treatments with respect to the WUI, we quantified the distance from treatments to the wildland–urban interface, using Theobald and Romme's map of WUI location (2). The WUI map is composed of (*i*) the interface, where relatively high-density residential areas directly abut

wildland fuels with a clear demarcation, and (*ii*) the intermix, where low-density residences are scattered throughout wildland fuels. The United States Federal Register (2001) gives 2 possible definitions of the interface: 7.4 units/ha or 97 people/km^2. The former definition is about twice as dense as many urban areas in the West, according to the United States Census (2). Therefore, Theobald and Romme relied on the latter definition to construct the interface WUI (2). The Federal Register defines the intermix WUI as $>$0.06 units/ha, which Theobald and Romme used in mapping the intermix WUI. The Theobald and Romme WUI layer included only patches $>$10 ha and excluded public land from census blocks to better define true housing densities, which are primarily on private land.

Radeloff et al. also published a map of the WUI that spans the West (1). This map used the Federal Register (2001) definition of intermix housing densities for both interface and intermix of housing densities 1 unit per 40 acres, but distinguished them by vegetation cover: interface is designated when $<$50% of the census block group is classified as wildland vegetation, and intermix is $>$50% wildland vegetation. There was no modification of the census block groups to exclude public land (1), which poses a problem for calculating housing densities and distance to the WUI from treatments that are primarily conducted on public lands. For these reasons, we used the Theobald and Romme WUI for analysis, although analysis of both maps shows similar overall trends in area treated near the WUI.

We examined the percentage of area treated within 0.0-, 2.5-, 5.0-, 10.0-, and $>$10.0-km buffers from the interface WUI, where distance 0 refers to area actually located within the WUI. In our analyses, the WUI includes both interface and intermix, while distance to WUI is based on buffers around the interface only. Buffers of 0.8–2.4 km have been suggested as community wildfire protection zones around interface communities within which fire-mitigation treatments are most appropriate (HFRA P.L. 108–148; refs. 2 and 11). The majority of our analyses apply to the WUI (interface plus intermix) plus a 2.5-km buffer from the interface, which we designate as $WUI_{2.5}$ for simplicity.

To assess whether the zone within or near the WUI was treated more than expected given its distribution across the West, we characterized wildland vegetation in the 11 western states according to distance zone from the WUI. We used LANDFIRE's existing vegetation type (EVT) layer to categorize wildland vegetation (32). Specifically, we defined areas of wildland vegetation by excluding from LANDFIRE's EVT layer all areas designated as water, snow/ice, developed, barren, quarries/strip mines/gravel pits, and agriculture, which composed 16% of the area within the 11 western states. To be consistent, we considered only treatments that were conducted on land that was also classified as wildland vegetation (94% of all area treated). Therefore, all results refer only to area treated and area of the West classified as wildland vegetation. In some instances, we characterize trends across forested areas, which were areas that included the terms ''forest,'' ''woodland,'' ''parkland,'' or ''savanna'' in LANDFIRE's existing vegetation type classification.

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