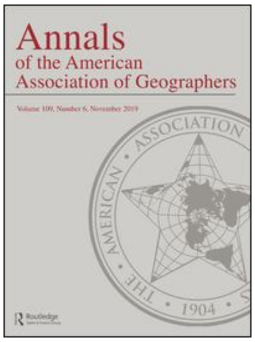


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U.S. federal government agencies play an important role in mitigating some risks posed to communities by natural hazard events, especially communities with high proportions of low-income or minority residents. Ongoing efforts of the U.S. Forest Service (USFS) to reduce the buildup of forest fuels on national forests, particularly in dry mixed-conifer forests of the U.S. West, are an example. Federal land management agencies must comply with the Executive Order on Environmental Justice (EJ Order, 59 Fed. Reg 7629, 1994), but there is scant documentation of whether these agencies have substantively complied with the EJ Order in implementing land management activities. There is also little quantitative environmental justice (EJ) research on dispersed rural populations, such as those often found adjacent to national forests. Our research addresses these gaps. We apply a novel mixed-methods approach, including quantitative pattern analysis and interviews with forest managers, to examine whether the benefits of wildfire risk reduction created on twelve national forests in four western U.S. states were equitably distributed among nearby populations. We found that EJ impacts might have occurred on all twelve forests, but they tended to be localized and context specific. We also learned from interviewees that EJ was not considered in decisions about where and how to conduct wildfire hazard reduction and that EJ populations rarely engaged in collaborative project planning apart from the formal tribal consultation process. Our research expands the range of quantitative geographical analysis of EJ issues and our methods could be adopted by land management agencies to achieve more equitable distribution of costs and benefits from their management activities. *Key Words: environmental justice, federal land management, rural populations, spatial analysis, wildfire risk reduction.*

在减轻自然灾害给社区带来的部分风险方面, 美国联邦政府部门发挥着重要作用, 特别是在低收入或少数民族居民比例较高的社区, 一个很好的例证就是美国森林服务局(USFS) 目前为减少国家森林中可燃物积累所做的努力, 尤其是美国西部干旱地区的针叶混交林。联邦土地管理机构必须遵守《环境司法行政法令》 (EJ Order 59 FR 32 1994), 但很少有书面证明这些机构在实施土地管理活动中, 是否真正遵守了 EJ 法令。对分散的农村人口 (例如通常居住在国家森林附近的人群) 所做的定量环境公正 (Environmental Justice, EJ) 研究也少之又少。我们的研究关注的就是这方面的空缺。 为此我们采用了一种全新的组合方法, 包括定量模式分析以及对森林管理方进行访问, 以研究在美国西部四个州的十二个国家森林中减少野火风险行动所获得的收益, 是否在周边的人口中公正分配。我们发现可能所有的 12 个森林都产生了EJ方面的影响, 但这些影响往往是局部现象, 且根据具体情况而有所不同。我们还从受访者处了解到, 他们在决定减少野火危害时具体时间和地点时并未考虑 EJ; 而且除了正式的部落协商决议以外, EJ 相关人口很少参与协作项目的规划工作。我们的研究拓展了 EJ 问题的定量地理分析范围, 土地管理机构可以使用研究中的方法, 对其管理活动中的成本和收益进行更公平的分配。 *关键词: 环境公正, 联邦土地管理, 农村人口, 空间分析, 减少野火风险。*

Las agencias del gobierno federal de los EE.UU. juegan un papel importante para mitigar los riesgos que imponen a las comunidades eventos naturales peligrosos, especialmente en aquellas comunidades que tienen altas proporciones de residentes de bajos ingresos o de minorías. Un ejemplo al respecto, son los esfuerzos en curso del Servicio Forestal Estadounidense (USFS) en pro de reducir la expansión de combustibles forestales en los bosques nacionales, en particular en los bosques secos de coníferas mixtas del Oeste norteamericano.



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Las agencias encargadas del manejo de tierras federales deben cumplir con la Orden Ejecutiva sobre Justicia Ambiental (EJ Order 59 FR 32 1994), pero no hay mayor documentación sobre si estas agencias han cumplido de manera significativa con aquella disposición en lo que concierne a poner en real ejecución las actividades de manejo de la tierra. Es también cuantitativamente limitada la investigación sobre justicia ambiental (EJ) en el contexto de poblaciones rurales dispersas, tales como las que a menudo se encuentran adyacentes a los bosques nacionales. Nuestra investigación se orienta a llenar estos vacíos. Aplicamos un enfoque novedoso de métodos mixtos, incluyendo análisis cuantitativo de patrones y entrevistas con administradores de bosques, para examinar si los beneficios de la reducción del riesgo de incendios forestales creados en doce bosques nacionales de cuatro de los estados del oeste se distribuyeron de manera equitativa entre la población correspondiente. Descubrimos que los impactos de la EJ podrían haberse dado en todos los doce bosques, pero esos impactos tendieron a ser localizados y específicos en contexto. También aprendimos de entrevistados que la EJ no fue tenida en cuenta en las decisiones acerca de dónde y cómo conducir reducción del peligro de incendios forestales, y que las poblaciones de la EJ raramente se involucraron en la planificación de proyectos colaborativos más allá del proceso formal de consultas tribales. Nuestra investigación amplía el ámbito del análisis geográfico cuantitativo de cuestiones de la EJ y nuestros métodos podrían adoptarse por las agencias de manejo de la tierra para alcanzar una distribución más equitativa de los costos y beneficios asociados con sus actividades administrativas. *Palabras clave: análisis espacial, justicia ambiental, manejo de tierras federales, poblaciones rurales, reducción del riesgo de incendios forestales.*

Environmental justice (EJ) scholarship has expanded and diversified considerably from its origins in the 1980s. Geographers have been at the forefront in at least three dimensions of this expansion: innovation in quantitative methodologies for evaluating EJ impacts (e.g., Boone et al. 2009; Maantay and Maroko 2009; Marko 2012; T. W. Collins et al. 2015), introducing qualitative and historical perspectives to a heavily quantitative field (e.g., Pulido 2000; Pincetl and Gearin 2005), and engagement with theoretical perspectives on social power and place (e.g., Wolch 2007). EJ can now be seen as an interdisciplinary field unto itself, one that geographers have played an important role in shaping. Yet key aspects of EJ scholarship remain neglected. We engage two of these: EJ consequences of actions by U.S. federal land management agencies and EJ impacts to dispersed rural populations that might be affected by these agencies' actions.

Since promulgation of Executive Order 12898 on Environmental Justice (EJ Order) by President Bill Clinton in 1994, every U.S. government agency has been charged with making "environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations" (§1-101, 59 Fed. Reg. 7629, 1994). In 1997, the U.S. Council on Environmental Quality (USCEQ) directed agencies to incorporate the EJ Order's directives into the process of environmental impact assessment already required by the U.S. Environmental Protection Agency (USEPA) for implementing the National Environmental Policy Act (NEPA) (USCEQ 1997; USEPA 1998). The NEPA process continues to be the locus of nearly all EJ compliance actions by federal agencies (Geltman, Gill, and Jovanovic 2016).

Although the EJ Order is twenty-five years old, there is scant research investigating either the efficacy of agency compliance with its directive through the NEPA process or the actual impacts of federal agency actions on minority and low-income communities in rural areas. One reason for this neglect might be methodological: U.S. Census data estimating rural population characteristics in small geographic areas are highly uncertain (Adams and Charnley 2018). Another reason could be that EJ is most often investigated in the context of unequal exposure to harms, such as health hazards or disaster events. Natural resource management primarily occurs in rural settings and is typically conceived as creating public benefits rather than harms. The EJ Order, however, stipulates that a disproportionate lack of access by low-income or minority populations to benefits generated by federal agency programs is also an EJ impact: "Each Federal agency shall conduct its programs … in a manner that ensures that such programs, policies, and activities do not have the effect of excluding persons (including populations) from participation in, denying persons (including populations) the benefits of … such programs … because of their race, color, or national origin" (§2-2, 59 Fed. Reg. 7629). We address these gaps by assessing the EJ implications of one natural resource management activity by a federal agency: hazardous fuels reduction (HFR) conducted by the U.S. Forest Service (USFS) on national forests in the Western United States.

HFR refers to a suite of vegetation treatments that remove, disperse, or consume forest stand biomass that is potential fuel for a future wildfire. The USFS projects a need for such treatments far exceeding its current capacity to achieve them (U.S. Department of Agriculture [USDA] and U.S. Department of the Interior [USDI] 2014), especially in the Western United States. The agency is trapped in what Calkin et al. (2014) termed the "wildfire paradox" (747): a positive feedback loop created by highly effective fire suppression. The paradox mainly occurs in forest ecosystems that were historically characterized by frequent fires causing a patchwork of low to mixed severity mortality (Agee 1993; B. M. Collins and Stephens 2010). In the Western United States, ponderosa pine–dominated forest stands might be the most iconic example of this forest type, although they are not the only example (Reilly et al. 2017). In these forests, suppression ensures that forest fuels continue accumulating, ultimately building fuel volume that is far outside historic norms, and fuel "ladders" that allow fire burning in understory vegetation to reach into the tops of older canopy trees that are otherwise resistant to low-intensity fire (Hessburg, Agee, and Franklin 2005; Hessburg, Salter, and James 2007; Perry et al. 2011). When wildfires ignite in these altered forest ecosystems and are not immediately suppressed, the available fuel and altered stand structure can facilitate extremely rapid growth in both fire area and severity. Nearly all of the growth in acreage burned in wildfires in the Western United States in the past twenty-five years is attributable to only a few such "megafires" (Stephens et al. 2013). Climate change is a primary driver of megafires across many forest types in the U.S. West (Barbero et al. 2015), but in dry mixed-conifer forests, fire suppression also contributes substantially (Calkin et al. 2014). Such fires are costly and difficult (sometimes impossible) to control and inflict major losses to natural resources and private property (Stephens et al. 2013). In 1995 the USFS expended 16 percent of its budget on fire suppression, but that figure reached 50 percent ($2 billion) in 2015 (U.S. Department of Agriculture-Forest Service 2015) and is projected to reach 67 percent by 2025 if current trends continue. This trend seriously hampers the agency's ability to perform other critical management tasks, including fuels reduction, and underscores the value of HFR activities if they succeed in reducing the potential for future megafires.

This article reports on the application of a method we previously developed (Adams and Charnley 2018) for studying the EJ impacts of limited-scale natural resources management phenomena affecting rural populations in the United States. We address three research questions:

1. Is there general association (correlation) between the spatial patterns of HFR activity on national forests and locations where EJ-protected populations potentially affected by HFR concentrate?
2. Regardless of general association, are there local areas where EJ-protected populations concentrate but wildfire risk reduction benefits from USFS HFR are minimal or absent?
3. How do USFS managers factor EJ into decision making about HFR implementation?

Based on the limited evidence available from relevant research, we hypothesized that wildfire hazard risk reduction benefits generated by the USFS through its HFR program are disproportionately received by communities with high social resilience, meaning that EJ-protected populations likely fail to access these benefits equitably.

## Environmental Justice, Rural Populations, and Resource Management

EJ is a broadly encompassing term that has numerous nuanced interpretations according to context. The term invokes a general principle: Minority and low-income communities should not be disproportionately subject to health risks caused by environmental degradation or pollution. It also describes a political movement, which has as a core goal ensuring "that all people and communities are entitled to equal protection of environmental and public health laws and regulations" (Bullard 1996, 493). Articulation of the EJ principle was an outgrowth of the civil rights movement of the 1960s, spurred by documentation of long-standing practices: targeting minority and low-income communities as sites for dumping pollutants and relegating them to living in locations that were at greater risk of environmental hazards such as flooding. This documentation began in earnest around 1980 (Bullard 1990; Bullard and Johnson 2000). The EJ movement reached an early culmination in the 1991 People of Color Environmental Leadership Summit, at which more than 300 delegates adopted seventeen formal principles of environmental justice (see https://www.ejnet.org/ej/principles.html), expanding the term's application beyond its original focus on human health impacts. Leaders of the 1991 summit played a role in the issuance of the EJ Order three years later (Walker 2012).

EJ research is voluminous and engages many distinct disciplines. Three themes from this literature are related to our focus: (1) social vulnerability and resilience in relation to wildfire risk management; (2) EJ and federal agency natural resource management; and (3) participation of EJ populations in collaborative resource management by U.S. federal agencies. We review in depth a fourth key literature, quantitative methods of EJ assessment, in Adams and Charnley (2018) and so do not address that topic here.

## Environmental Justice, Social Vulnerability and Resilience, and Wildfire Risk

Management that could mitigate the risk of loss from wildfire is a particularly appropriate subject for evaluating the EJ implications of federal agency actions. A substantial research literature in the field of natural hazards and society investigates inequity from the perspectives of vulnerability and resilience (Cutter, Boruff, and Shirley 2003; Frazier et al. 2013; Burton 2015). These concepts have strong affinity with EJ. Common characteristics of populations with low resilience to hazard events include high proportions of racial or ethnic minorities, low household incomes, low educational attainment, and high rates of residency in rental housing or mobile homes. In the context of wildfire, resilience includes economic factors (e.g., the ability to afford home insurance, rebuild destroyed structures, and cope with lost income resulting from a wildfire-related business shutdown; Kent et al. 2003; Downing et al. 2008), psychological factors (e.g., managing postfire emotional trauma; Langley and Jones 2005; Cohn, Carroll, and Kumagai 2006), and social factors (e.g., responding to the alteration or loss of community institutions and social networks due to fire; Carroll et al. 2005).

Although wildfire events appear less frequently in the hazards literature than other disasters, there is evidence that communities in the United States with characteristics predictive of low social resilience are especially vulnerable to wildfire (Poudyal et al. 2012; Davies et al. 2018) and to smoke from prescribed fire (Gaither et al. 2019). Two complementary tasks are necessary to reduce the impact of wildfire in a community: reducing hazardous fuels and minimizing the susceptibility of structures to ignition (Calkin et al. 2014). Studies in the Western United States have found that communities with larger proportions of racial minorities, low-income households, renters, and older, lower value housing stock, all indicators of low social resilience, accomplish much less structure protection than communities with higher socioeconomic status (T. W. Collins 2008; Paveglio et al. 2016). Additionally, research conducted in high fire frequency forest landscapes of different U.S. regions has found that communities with higher proportions of poor, non-white, and low educational attainment populations are less likely to obtain technical assistance with hazard mitigation from initiatives such as the National Fire Protection Association's Firewise program than other, more resilient, communities (Gaither et al. 2011; Ojerio et al. 2011). Such communities also struggle with firefighting capacity. A 2006 study found that poorer rural populations adjacent to federal lands in the Pacific Northwest suffered much longer fire suppression response times compared to more affluent populations due to a lack of local infrastructure (Lynn and Gerlitz 2006). Poor counties in Florida experienced larger and more severe wildfires between 1975 and 2000 when an ignition occurred, owing in part to a lack of fire suppression resources available for rapid deployment (Mercer and Prestemon 2005). The heightened vulnerability of low-resilience populations, coupled with their limited capacity to implement structure protection measures and support local fire suppression capacity, implies that fuel reduction is critically important in reducing their wildfire risk.

Despite this importance, HFR activity on federal lands might be spatially biased away from low-resilience communities. Policy and legislation guiding the HFR activities of the USFS and other federal land management agencies since 2000, such as the Healthy Forests Restoration Act of 2003 (16 USC

§6501 et seq.) and the National Fire Plan (USDA and USDI 2000), have explicitly directed the agencies to emphasize protection of wildland–urban interface (WUI) zones in the implementation of forest fuels reduction (Steelman and Burke 2007). This policy was recently reaffirmed by the interagency National Cohesive Wildland Fire Management Strategy (USDA and USDI 2014) and by executive proclamation (81 Fed. Reg. 70909, 2016), despite some ecologically based critiques of a WUI focus (e.g., Schoennagel et al. 2009; Odion et al. 2014). In the Western United States, WUI zones have expanded more rapidly than in other parts of the country (Radeloff et al. 2018). Because recent and rapid housing growth tends to be associated with higher levels of educational attainment and household incomes (Hammer, Stewart, and Radeloff 2009), populations in recently created WUI areas might tend to possess high hazard resilience. Research from Utah (Roberts 2013) and Florida (Mercer and Prestemon 2005) also suggests that people who live in higher income areas of the WUI are less vulnerable to wildfire risk because they can afford to purchase home insurance and have better access to fire suppression and mitigation resources. Hence, in areas of the interior U.S. West with rapidly growing WUI and predominantly dry mixed-conifer forests, focusing HFR on the WUI without considering the minority and low-income characteristics of the affected population might increase the probability that low-resilience communities, either within or outside of the WUI, will not benefit equitably.

### EJ Analyses of Natural Resource Management by Federal Agencies

Natural resource management by federal agencies as a trigger for EJ impacts is unstudied in quantitative EJ research. Researchers using qualitative or historical methods, including archival research, interviews, content analysis, ethnography, and participant observation, have addressed the EJ impacts of federal agency resource management, but such studies are typically single case studies. For example, researchers have investigated the EJ consequences of resource management programs of the USFS (Pulido 1996; Norgaard 2007, 2014; Macias 2008; Roberts 2013), U.S. EPA (Holifield 2012), and U.S. Department of Energy (Voyles 2015). Their approaches give voice to the experiences that some minority and low-income communities have with federal resource management activities and yield useful management insights in context. None explicitly address the EJ Order, and qualitative methods alone are not well suited to systematic analysis of whether an agency program complies with the EJ Order beyond a specific case. Complementary methods are needed.

### EJ and Equitable Participation in Management Processes

Hazardous fuels management on federal lands increasingly takes place through collaborative processes centered on local landscapes, rather than through regional or national administrative hierarchies (Fleeger and Becker 2010; Davis et al. 2017). This approach began gaining ground with the 2000 National Fire Plan (USDA and USDI 2000) and was reinforced by congressional legislation in 2003 (the Healthy Forests Restoration Act [HFRA]; 16 U.S.C. § 6501 et seq.) and 2009 (the FLAME act; 43 U.S.C. § 1748a-b). Wildfire research focused on WUI populations generally finds a high level of public lands management awareness among local residents (Vining and Merrick 2008; Toman et al. 2011), although awareness does not necessarily lead to engagement. Literature examining collaborative planning approaches to wildfire hazard mitigation by public agencies (e.g., Reams et al. 2005; Sturtevant and Jakes 2008) is notably lacking in discussion of a key issue: whether low-income or minority individuals representing neighborhoods or communities that are prone to EJ impacts are stakeholders in the collaborative process. For example, nearly all nonagency participants in Oregon forest collaboratives studied by Davis et al. (2017) were white and had very similar incomes. This is another manifestation of a "procedural equity" problem for low-income and minority populations that has also been identified in a range of urban EJ studies (e.g., T. W. Collins et al. 2015). There is insufficient evidence to verify whether low-income or minority perspectives are adequately incorporated in collaborative wildfire management processes, where these populations could play a role in addressing any disproportionate lack of access to HFR benefits.

## Methods

Our research addresses limitations in existing EJ scholarship by applying novel spatial analysis procedures we previously developed for population and resource management activity data and integrating them with qualitative analysis. A detailed pilot test of the spatial analysis procedures has been previously published (Adams and Charnley 2018). In this section, we summarize them and show how they are linked to a qualitative interview protocol designed to uncover national forest decision-making factors in the planning and implementation of HFR that are not readily quantifiable.

### EJ Implications of HFR

Negative EJ outcomes of agency program implementation include a disproportionate lack of access to the program's benefits by minority and low-income populations (§2-2, 59 Fed. Reg 7629). We conceptualize reduced risk of experiencing loss from a wildfire as the primary human benefit of HFR, although other conceptualizations of benefit, such as water quality protection or reduced exposure to wildfire smoke, are possible. Failure of low-income or minority populations to access this risk reduction benefit proportionally with non-EJ populations that are more likely to be resilient is thus an EJ impact (§1-101, 59 Fed. Reg. 7629). Our previously published spatial analysis method facilitates a comparative assessment of spatial disproportionality in the distribution of HFR activities and their associated benefits. The qualitative phase investigates what causes this disproportionate allocation of HFR benefits and whether it is practically consequential. We performed this multistage comparative analysis on a sample of twelve national forests in different subregions of the U.S. West.

### National Forest Sample

The USFS has identified an especially acute need for forest restoration in dry mixed-conifer forests it manages. Forest ecologists have generally classified the fire regime of dry mixed-conifer forests as one of frequent fire recurrence with a broad range of severity, measured in terms of tree mortality: predominantly low severity (Agee 1993), low to moderate severity (e.g., Allen et al. 2002), and mixed severity (e.g., Perry et al. 2011; Odion et al. 2014). There is considerable variability in historical fire recurrence intervals and typical patterns of burn severity within the broad category of dry mixed-conifer forests. This variability is a function of factors interacting at multiple scales, from the locally specific, such as topography and prevailing winds, to global climate change. Not all dry mixed-conifer forest landscapes have an equal need for restoration, but as a broad class of forest type compared with others across the Western United States, this type might be most in need of restoration related to managing future fire behavior (Agee and Skinner 2005; Larson and Churchill 2012).

To ensure that the management context for HFR was roughly comparable for all potential sample units, we identified all national forest units in the Western United States that have at least some area of dry mixed-conifer forest. Meaningfully comparing the proportion of dry mixed-conifer forest within national forest units in very different geographical settings required using a coarse, broad-scale forest cover data set designed for continental-scale consistency. Figure 1 depicts an approximation of the spatial distribution of dry mixed-conifer forest throughout thirteen Western states where national forests are located, using three broad forest groupings from the USFS Forest Inventory and Analysis CONUS forest group data set (Ruefenacht et al. 2008) that best represent one of the regional dry mixed-conifer forest groupings identified in Odion et al. (2014). The Douglas fir–dominated zone west of the Cascade Mountains and north of the Siskiyou Mountains in the Pacific Northwest was excluded, because these are moist mixed-conifer forests with very different fire regimes. This process yields a sample frame of seventy-two national forest units, from a total of eighty in the U.S. West (compare Figure 1 and Figure 2).

We generated our final sample by selecting national forests from among these seventy-two that satisfied three criteria. First, we identified national forest units that had very high levels of HFR activity between 2006 and 2015, measured as total number of treatments or total acreage accomplished relative to the median for the seventy-two units. Second, we identified national forests where a large proportion of the area that was actively managed ($\geq$30 percent) could be coarsely described as dominated by a dry mixed-conifer forest type. Actively managed means all national forest system lands that are not part of a congressionally designated wilderness area. Third, to avoid sampling forests associated with homogeneous population characteristics, we sought forests intersecting a group of counties where county values for

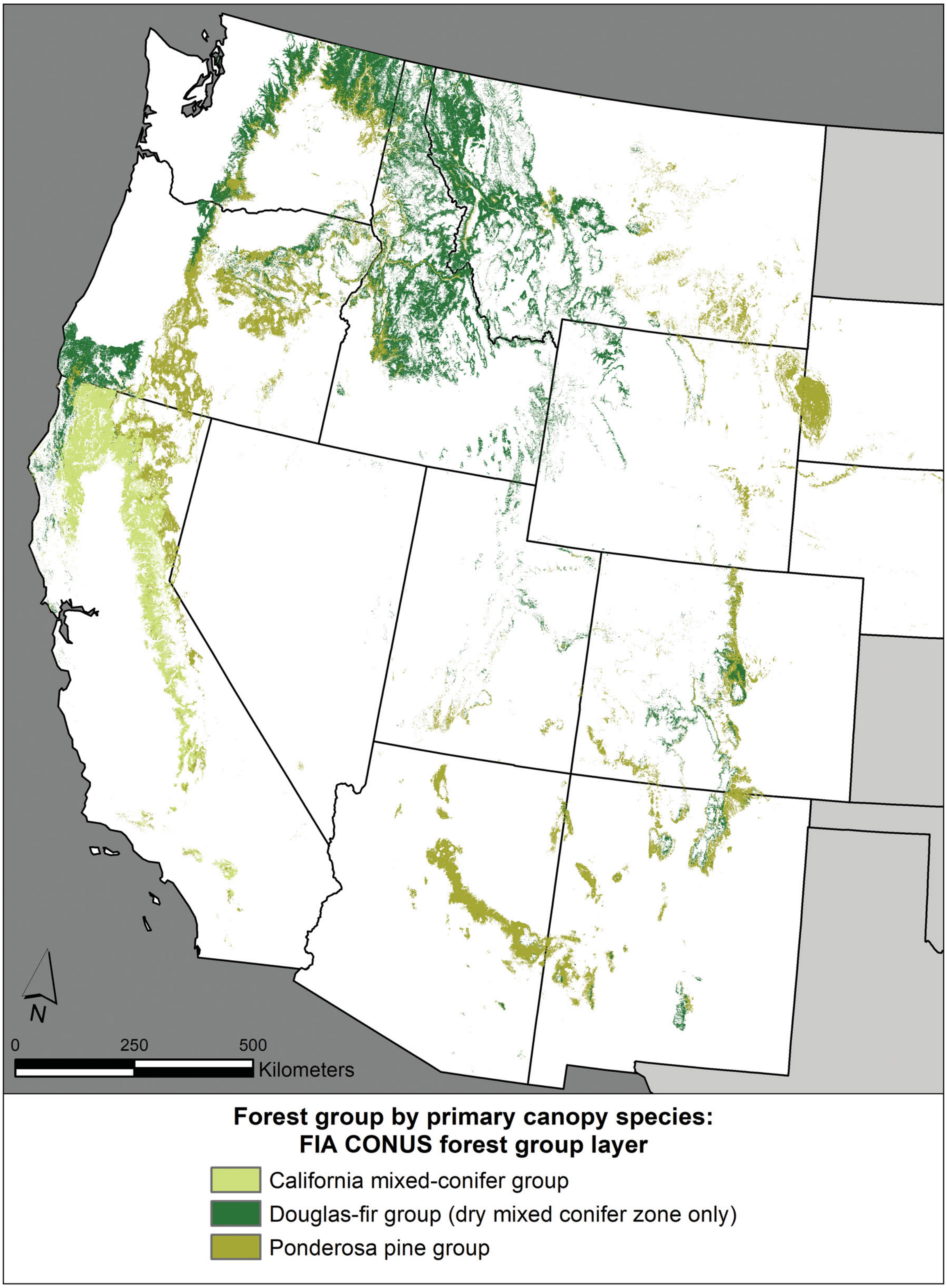


**Figure 1.** Approximate distribution of dry mixed-conifer forests of the U.S. West. Note: FIA = Forest Inventory and Analysis.

minority population share, poverty rate, and median housing value spanned a large range. Thirteen national forests met the first two criteria. From these, we selected eight that satisfied the third criterion. These eight were all neighboring forests—four in USFS Region 6 (Pacific Northwest Region) and

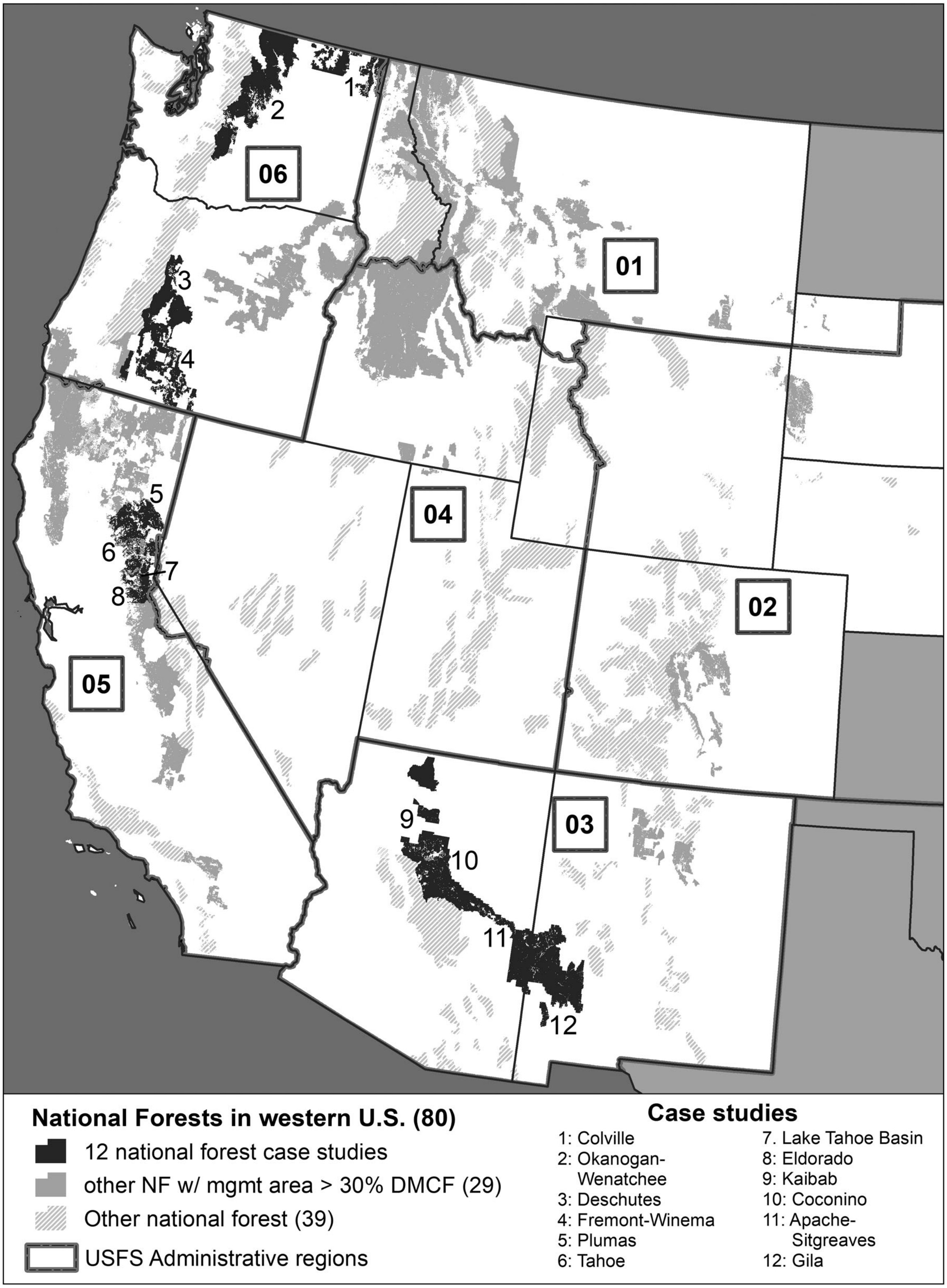


**Figure 2.** Twelve national forests sampled for environmental justice analysis. Forty-one forests shown in solid shading meet the criterion that roughly 30 percent of managed area is DMCF. Solid light gray shaded forests were not selected due to limited hazardous fuels reduction activity, probability that affected populations would lack racial and income diversity, or both. *Note:* NF = national forest; DMCF = dry mixed-conifer forest; USFS = U.S. Forest Service.

**Table 1.** Dry mixed-conifer forest and HFR activity characteristics of sample national forests

| National forest | U.S. Forest Service total active management acreage, all land covers | Percentage of active management area that is dry mixed-conifer forest | Count of total HFR activities 2006–2015 | Total acres of HFR activities 2006–2015[a] |
|---|---|---|---|---|
| Region 3 | | | | |
| Apache–Sitgreaves | 1,987,151 | 43.3% | 1,268 | 220,839 |
| Coconino | 1,685,942 | 47.4% | 422 | 136,507 |
| Gila | 2,474,264 | 29.7% | 147 | 119,254 |
| Kaibab | 1,434,862 | 37.4% | 265 | 106,937 |
| Region 5 | | | | |
| Eldorado | 501,601 | 65.5% | 1,671 | 52,748 |
| Lake Tahoe Basin | 126,026 | 47.1% | 2,682 | 22,808 |
| Plumas | 1,168,812 | 78.5% | 1,436 | 54,232 |
| Tahoe | 809,838 | 63.7% | 1,326 | 60,662 |
| Region 6 | | | | |
| Colville | 1,093,810 | 68.7% | 2,290 | 83,829 |
| Deschutes | 1,424,211 | 54.9% | 4,915 | 291,050 |
| Fremont–Winema | 2,123,427 | 60.5% | 3,542 | 301,988 |
| Okanogan–Wenatchee | 2,564,190 | 66.5% | 3,015 | 185,326 |
| Forty-one national forests[b] | | | | |
| Median | 1,424,211 | 51.1% | 1,464 | 57,835 |

*Notes:* HFR = hazardous fuels reduction.
[a]This figure is not convertible to percentage of management area treated, because many HFR treatments occur in sequence at the same location.
[b]The forty-one national forests in the twelve western states with at least 30 percent of management area in dry mixed conifer forest type shown in Figure 2.

two each in Regions 3 (Southwest Region) and 5 (Pacific Southwest Region). We completed the sample with two additional forests from Regions 3 and 5 that nearly satisfied the first two criteria, yielding four neighboring national forests from each of three distinct USFS regions. The sampling process is depicted in Figure 2. Table 1 summarizes HFR characteristics of the twelve forests.

## Data

HFR data come from the Forest Activity Tracking System (FACTS) database, a clearinghouse for recording and accessing the accomplishments of all USFS program activities (USDAFS 2016). To minimize the potentially high variability in year-to-year HFR program accomplishments, we collected records for the period 1 January 2006 to 31 December 2015 for each forest unit. Older data were not reliable. FACTS data have many attributes, but most are qualitative. Acreage accomplished is the only quantitative field in our FACTS data set that was reliable for all twelve forests. We thus examined only total acres treated in the quantitative analysis, although we acknowledge that acreage treated might not always be linearly related to a reduction of wildfire risk. We used additional descriptive attributes, including the type of fuel reduction treatment, to inform our interviews. HFR data from FACTS exist in tabular as well as geospatial form; both have data quality issues that we address in detail in Adams and Charnley (2018). For this analysis, each HFR polygon was reduced to its centroid and then expanded to form an abstract circular feature exactly matching its acreage accomplished attribute. This generalization was necessary to deal with many records where the acreage of the digitized polygon differed radically from the acreage accomplished attribute. The national forest is the unit of analysis; HFR data are not pooled across forests.

Population data are from the 2010 U.S. Census block-level Summary File 1 (SF1) release. There is an obvious temporal disparity between the decade-long span of HFR data and the single point in time demographic data. Unfortunately, this temporal disjunction is unavoidable, because the block-level data that are required to maximize the spatial precision with which communities are described are only available from the decennial census. Population and housing estimates from the American Community Survey (ACS), which replaced the earlier Summary File 3 estimates from the decennial census, have untenable estimate errors for data units appropriate to small-scale spatial analysis (Bazuin and Fraser 2013; Spielman, Folch, and Nagle 2014; Adams and Charnley 2018).

The 2010 SF1 data only report age, gender, race, Hispanic ethnicity, and family characteristics for population and unit type for housing units. USDA EJ guidelines stipulate that poverty should be used by its agencies in analyzing prospective EJ impacts to low-income communities, but income data are not available in SF1. Because low household income and renter occupancy are frequently strongly correlated (Stone 1993), the latter might function as a proxy for low household income populations that are identified as protected in the EJ Order, although the proxy relationship is likely strongest in urban areas with high housing costs (Kutty 2005). We thus analyzed racial and ethnic minority status and renter-occupied units. For minority status, we aggregate all Hispanics with non-Hispanics who identify as a racial category other than white alone, to create a racial/ethnic minority (hereinafter minority) population. This category does include some individuals who identify as white if they also identify as Hispanic. Our minority population grouping is the converse of the non-Hispanic, white (race) alone field that has been systematically reported in U.S. Census data output since 1990.

## Defining the Affected Population

We define the population potentially affected by HFR as residing within roughly 1.5 miles (2.4 km) of lands where HFR activities could occur, excluding lands covered by nonforest vegetation or low-density pinyon–juniper woodland. The 1.5-mile threshold is derived from an empirical assessment of firebrand travel in a dry mixed-conifer forest fire (California Fire Alliance 2001, cited in Radeloff et al. 2005) and is consistent with the nationwide classification of individual census blocks as WUI by the SILVIS lab at the University of Wisconsin–Madison, a data set that is now widely used in many aspects of fire research (SILVIS 2018). Nevertheless, we acknowledge that there are limitations with this approach because it makes assumptions about fuels conditions within the treatment area and between the area treated and property within 1.5 miles of lands where HFR can occur.

In rural areas, only census blocks are appropriate for representing population within this narrow buffer zone. Most rural census blocks in our sample have no housing units, however. Including the no-housing blocks would seriously bias the analysis, so we aggregated blocks into whole or partial block group clusters to ensure that no data units lacked housing and the units match a recognized census data geography. The procedure is described in detail in Adams and Charnley (2018), which also includes evaluation of alternative approaches. The whole and partial block group features that result define a unique affected

**Table 2.** Racial or ethnic minority and rental housing characteristics of populations potentially able to benefit from hazardous fuels reduction, by national forest

| | | | Not Hispanic (any race) | | | | | Housing units | | |
|---|---|---|---|---|---|---|---|---|---|---|
| National forest | Total population | Hispanic (any race) (%) | White (%) | Black (%) | Native American/ Alaska Native (%) | Asian/ Pacific Islander (%) | Other (%) | Occupied units | Percentage renter-occupied (%) | Housing unit density (acres/unit) |
| Region 3 | | | | | | | | | | |
| Apache–Sitgreaves | 40,239 | 13.1 | 81.4 | 0.4 | 2.9 | 0.6 | 1.7 | 16,321 | 24.2 | 5.8 |
| Coconino | 65,101 | 14.2 | 72.0 | 1.4 | 8.4 | 1.6 | 2.4 | 22,615 | 35.1 | 4.1 |
| Gila | 6,920 | 23.8 | 72.4 | 0.7 | 0.8 | 0.3 | 1.9 | 3,251 | 17.9 | 79.4 |
| Kaibab | 7,071 | 26.3 | 67.3 | 0.9 | 2.2 | 1.2 | 2.0 | 2,902 | 31.9 | 20.1 |
| Region 5 | | | | | | | | | | |
| Eldorado | 25,363 | 8.1 | 86.8 | 0.2 | 1.3 | 0.8 | 2.8 | 10,450 | 19.8 | 20.1 |
| Lake Tahoe Basin | 56,835 | 21.6 | 72.3 | 0.5 | 0.4 | 3.4 | 1.8 | 24,382 | 44.5 | 1.6 |
| Plumas | 37,811 | 7.6 | 85.4 | 0.7 | 2.1 | 0.9 | 3.4 | 16,364 | 26.3 | 24.4 |
| Tahoe | 30,930 | 12.8 | 82.6 | 0.3 | 0.7 | 1.3 | 2.1 | 12,683 | 29.6 | 19.5 |
| Region 6 | | | | | | | | | | |
| Colville | 13,169 | 3.1 | 90.4 | 0.2 | 2.7 | 0.7 | 2.9 | 5,655 | 26.1 | 74.4 |
| Deschutes | 35,028 | 3.9 | 92.4 | 0.2 | 0.7 | 0.6 | 2.1 | 14,416 | 19.5 | 13.4 |
| Fremont–Winema | 6,049 | 5.1 | 79.6 | 0.3 | 10.6 | 0.5 | 3.9 | 2,740 | 23.4 | 257.1 |
| Okanogan–Wenatchee | 35,147 | 14.8 | 81.9 | 0.2 | 0.8 | 0.6 | 1.7 | 14,514 | 25.6 | 35.7 |

population for HFR activities conducted by each national forest. The minority population and rental housing characteristics of these twelve affected population data sets are described in Table 2. The buffer zone in which USFS HFR activities might confer risk reduction benefits has very small populations on four of the twelve forests. Three of these also have extremely low housing densities, whereas the other nine have aggregate housing densities that are greater than the forty acres per unit standard that defines WUI in the *Federal Register* (Radeloff et al. 2005). Two forests have a sizable proportion of racial minorities in this buffer zone, primarily Native American. The buffer zone of one of these two forests, as well as those of six others, have large proportions of Hispanics. Populations in the affected zone of four forests are overwhelmingly white. Four forests, all with a medium-sized city nearby, have a housing stock that is least 30 percent renter occupied within the buffer zone; the remainder are between 18 and 25 percent.

## Comparing the Spatial Distributions of HFR and EJ Population

To compare the distributions of HFR activity and EJ-protected population, we allocated the acreage treated from each individual HFR record to the appropriate aggregate census block unit using a proportional rule we previously derived (Adams and Charnley 2018) to acknowledge the "boundary problem" affecting this form of aggregation. Partial HFR acreages were summed for each unit. Then total acreage and population counts were converted into location quotients. A location quotient has the value 1.0 when a subpopulation proportion of the total population of a single analysis unit is identical to the same subpopulation proportion among the total affected population of the entire data set. Substantial deviation from the value of 1.0 indicates that a subpopulation such as minorities either is concentrated in a single unit (values are well above 1.0) or is disproportionately absent (values approaching 0).

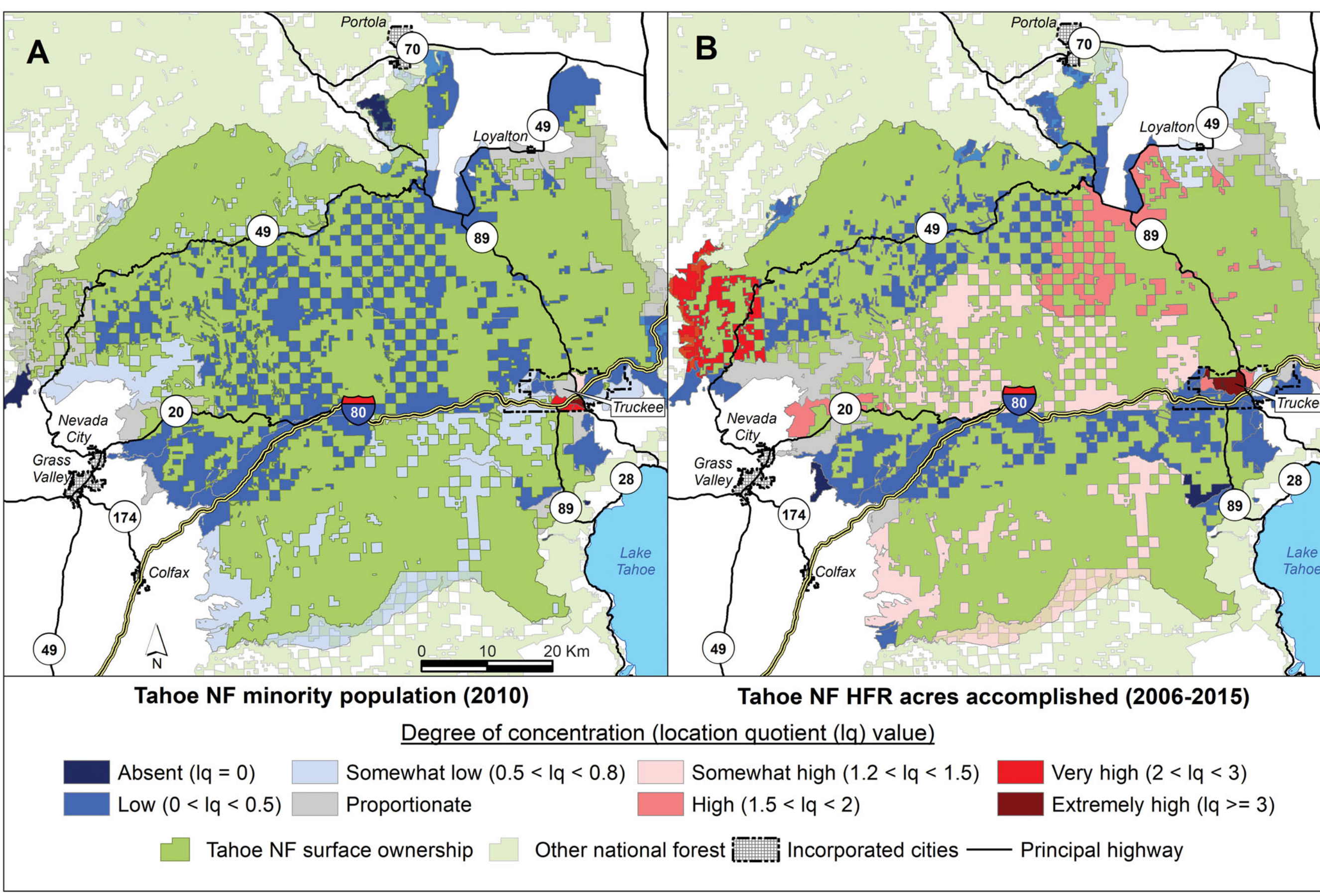


**Figure 3.** Spatial concentration pattern of (A) minority population in 2010; (B) HFR acres treated by the Tahoe NF, California, 2006–2015. There is no correlation between these location quotient values for the Tahoe NF (Table 3). Note: NF = National Forest; HFR = hazardous fuels reduction; lq = location quotient.

Figure 3 illustrates this process. Figure 3A displays location quotient values in each census data unit for the minority subpopulation of the Tahoe National Forest's total affected population. Figure 3B depicts location quotient values for acres of HFR treatments accomplished relative to all acres that are eligible to benefit from HFR. The degree of concentration or absence recorded for the HFR or population metrics exists on a continuum of values strictly relative to the analysis unit—in Figure 3, the affected population of the Tahoe National Forest—rather than being problematically compared to an arbitrary threshold value such as greater than 25 percent minority (Lewis and Bennett 2013). This method of defining concentrations of a subpopulation represents a best practice for the "substantially greater than" approach to identifying EJ populations outlined by the U.S. EPA in its NEPA process guidelines for federal agencies (US EPA 1998).

### Hypothesis Testing

We test for a relationship between the spatial locations of EJ population characteristics and HFR activity by a national forest unit at two scales. First, we perform correlation analysis on the location quotients for HFR and minority population and HFR and renter-occupied housing units. Because the location quotients are not necessarily normally distributed in each of the twelve data sets, we performed and compared the results of three principal correlation tests: Pearson's, Spearman's, and Kendall's. If minority populations or renter-occupied housing units systematically concentrate in units where HFR is disproportionately low or absent, this tendency would yield moderate to strong negative correlation between the values of the respective location quotients, implying that HFR disproportionately accrues in locations where the bulk of EJ-protected populations cannot benefit from it. Following research findings that low-income or minority communities are less likely to obtain technical assistance for fire risk reduction and the lack of evidence that low-income and minority populations participate in collaborative forest management processes, we hypothesized that a negative correlation exists between the spatial concentration of HFR benefits and EJ-protected populations. To contextualize these results, we also tested correlation between location quotients for HFR and disproportionate concentration of dry mixed-conifer forest area, area of WUI-designated census blocks (SILVIS 2018), and housing unit density regardless of WUI designation.

Second, we examine the magnitude of difference between location quotient values for the two population metrics and HFR acreage within each population unit. We use the term hotspots to identify one or more adjacent census units where the location quotient for minorities or renter-occupied units is substantially larger than that for HFR. Hotspots have highly concentrated EJ-protected populations and disproportionately low (or absent) wildfire risk reduction benefits from USFS HFR. Their existence implies a localized, potentially problematic lack of equitable access to benefits for EJ-protected populations that is independent of any general association tendency between HFR and EJ-protected populations at the national forest scale. Figure 4 depicts hotspots and the range of values for the difference between non-white and HFR location quotients for each population data unit associated with the Tahoe National Forest.

### Interviews

Our quantitative analysis cannot address why a negative general association between HFR and EJ-protected populations might exist or whether EJ impacts actually occurred in any hotspots discovered. To obtain such insights, we conducted twenty-two interviews with twenty-seven USFS staff who had some responsibility for planning, approving, or carrying out HFR at the administrative level of a national forest or ranger district. Seventeen of the twenty-two interviews were with district rangers; staff officers for fire, fuels, or timber; planners; and district fuels crew members. The other five interviewees were located in forest supervisor's offices and had oversight and coordination responsibilities for NEPA or fuels management in multiple districts. Three criteria determined from which forests and districts we collected interview data: (1) an initial goal of conducting interviews on two forests in each USFS region sampled; (2) response rate of USFS staff to our initial outreach; and (3) presence and location of potentially significant hotspots. The interviews were semistructured, with three sections. First, we showed interviewees a map we prepared of HFR activity in their district during the period from 2006 to 2015 and asked what factors they believed

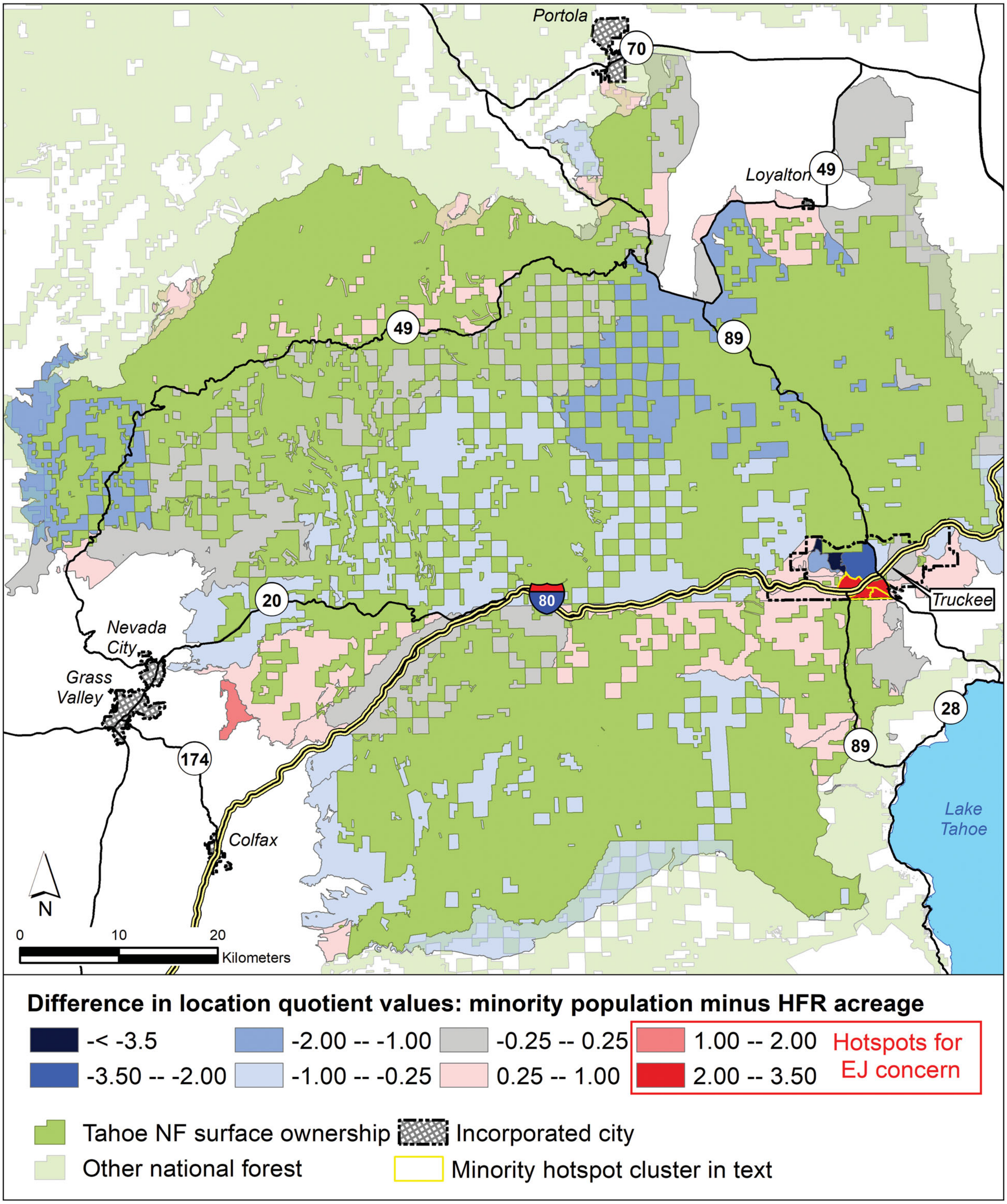


**Figure 4.** Hotspot identification for minority population and HFR activity acres on the Tahoe National Forest NF. Darker red population data units have location quotients that are significantly larger for minority population than for HFR acreage, implying the possibility that localized minority populations might lack equitable access to the risk reduction benefit of HFR. Dark blue areas are the converse: Populations that are largely non-Hispanic white receive disproportionate benefit from HFR. *Note:* HFR = hazardous fuels reduction; EJ = environmental justice; NF = National Forest.

accounted for the activity pattern. Second, we asked interviewees to describe any engagement they had with community members in the execution of HFR activities and to characterize who from the engaged community was represented in the exchange. Last, we asked interviewees to describe their familiarity with the principles of EJ generally, the EJ Order specifically, the degree to which they were knowledgeable about local EJ populations, and whether EJ was a factor in planning and implementing HFR.

## Results

### Forest-Level Spatial Association

We hypothesized that the wildfire hazard risk reduction benefits from USFS HFR are not equitably distributed to EJ populations but, rather, disproportionately benefit high-resilience communities. We thus expected to find a negative correlation at the national forest scale between the location quotient values for HFR and either minority population or renter-occupied units; for example, spatial patterns of concentration that rarely, or never, overlap. Our hypothesis was not supported on any of the twelve national forests. Statistically insignificant association between HFR activity acreage and both population characteristics was the rule, regardless of the correlation test employed (Table 3). There were three exceptions: Spearman's coefficient between minority populations and HFR on the Fremont–Winema National Forest and Spearman's and Kendall's coefficients between HFR and renter-occupied units on the Deschutes and Gila National Forests, although significant only at $p < 0.1$ for the latter. We give little weight to results where only the Spearman coefficient is statistically significant, because a location quotient in one of these data sets can both indicate relative absence (value is less than 1) and have a high ordinal rank. The limited support for association between HFR and renter occupancy on two forests has contrary signs. A correlation test between renter-occupied units and minorities shows that they are statistically significantly and highly correlated in all but three cases—Kaibab, Colville, and Fremont–Winema—so testing for correlation with both minority population and renter-occupied units might be redundant except for these three forests, which lack urban-density populations.

We found few statistically significant correlations of note for the HFR contextual factors (Table 4). HFR activity is for the most part significantly, and strongly, correlated with dry mixed-conifer forest area on all four forests in USFS Region 3 and the Okanogan–Wenatchee National Forest in USFS Region 6; it is moderately correlated with three forests in USFS Region 5—all except the Plumas. Plumas, Colville, Deschutes, and Fremont–Winema National Forests have the largest proportion and broadest spatial distribution of dry mixed-conifer forest in the area under management. HFR is not as widely distributed, hence the lack of correlation. Housing density correlation with HFR is statistically significant on two forests, Deschutes (strong, positive) and Eldorado (moderate, negative). WUI area, as defined by SILVIS (2018) data, is statistically significantly correlated with HFR on two forests, Kaibab (strong, positive) and Eldorado (strong, negative), although only the Pearson test yields a high degree of significance for the Kaibab. Hence, there are two instances in twelve of a statistically significant, strong positive correlation between housing unit density or WUI area and HFR that suggests HFR being deployed primarily for structure protection (Deschutes and Kaibab). Although HFR is positively correlated with renter-occupied housing on the Deschutes, this forest has the third-lowest proportion of renter-occupied units and lowest proportion of minorities in its affected population data set (Table 2).

None of these contextual factors is sufficiently correlated with the distribution of HFR to imply that any one factor among those we tested consistently shapes the spatial distribution of HFR across multiple forests. Correlation occurs repeatedly only between HFR and dry mixed-conifer forest type, which our research design expected to find. Our results imply that protecting housing in the WUI is not an overriding priority in shaping HFR activities for these twelve forests. Some of the lack of correlation could be attributable to the variability in size and shape of census data units relative to national forest boundaries and forest groups, although it is difficult to specify whether it increases or decreases the likelihood of correlation or, indeed, whether it has one consistent directional effect. Related research has found that HFR implementation is largely locally driven—for example, by the staff of a ranger district—rather than proscribed by a centralized authority such as the forest supervisor. The staff of two ranger districts in the same national forest might

**Table 3.** Correlation coefficients for Pearson's, Spearman's, and Kendall's tests between location quotients for U.S. Forest Service HFR acreage and environmental justice population characteristics, as well as between renter-occupied units and racial and ethnic minorities

| | | Correlation between HFR units accomplished and | | | | | | Correlation between | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Racial and ethnic minorities | | | Renter-occupied units | | | Racial and ethnic minorities and renter-occupied units | | |
| National forest | Data units | Pearson | Spearman | Kendall | Pearson | Spearman | Kendall | Pearson | Spearman | Kendall |
| Region 3 | | | | | | | | | | |
| Apache–Sitgreaves | 40 | –0.11 | –0.22 | –0.14 | –0.06 | 0.01 | 0.01 | **0.54*****| **0.72***** | **0.51***** |
| Coconino | 54 | –0.20 | –0.20 | –0.14 | –0.08 | –0.06 | –0.05 | **0.43***** | **0.45***** | **0.30**** |
| Gila | 17 | –0.33 | –0.42 | –0.29 | –0.27 | –0.48Φ | –0.35Φ | **0.75***** | **0.61**** | **0.46**** |
| Kaibab | 13 | 0.03 | 0.16 | 0.09 | 0.01 | 0.26 | 0.20 | 0.28 | 0.27 | 0.31 |
| Region 5 | | | | | | | | | | |
| Eldorado | 34 | 0.07 | 0.10 | 0.07 | –0.24 | –0.23 | –0.18 | **0.50**** | **0.58***** | **0.44***** |
| Lake Tahoe Basin | 84 | –0.06 | 0.03 | 0.02 | 0.01 | –0.01 | –0.02 | **0.72***** | **0.73***** | **0.56***** |
| Plumas | 51 | 0.06 | 0.01 | 0.02 | 0.01 | –0.06 | –0.04 | **0.47***** | **0.41**** | **0.31**** |
| Tahoe | 39 | –0.06 | 0.12 | 0.07 | –0.08 | –0.08 | –0.05 | **0.71*** | **0.66***** | **0.49***** |
| Region 6 | | | | | | | | | | |
| Colville | 33 | 0.17 | 0.31Φ | 0.21 | –0.08 | 0.02 | 0.05 | –0.03 | 0.07 | 0.04 |
| Deschutes | 38 | 0.18 | 0.25 | 0.12 | 0.28Φ | **0.40*** | **0.30*** | **0.62***** | **0.58***** | **0.40***** |
| Fremont–Winema | 18 | 0.14 | **0.51*** | 0.30 | 0.02 | 0.12 | 0.04 | 0.21 | 0.24 | 0.19 |
| Okanogan–Wenatchee | 68 | 0.01 | –0.02 | –0.01 | –0.09 | –0.13 | –0.08 | **0.72***** | **0.76***** | **0.60***** |

*Notes:* Values shown in bold indicate statistically significant moderate to strong correlations. Shaded cells indicate strong agreement on statistically significant correlation among all three correlation tests. HFR = hazardous fuels reduction.

*$p < 0.05$.

**$p < 0.01$.

***$p < 0.001$.

Φ$p < 0.1$.

**Table 4.** Correlation coefficients for Pearson's, Spearman's, and Kendall's tests between location quotients for U.S. Forest Service HFR acreage and HFR management factors

| | Correlation between HFR units accomplished and | | | | | | | | | Correlation between | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total area of dry mixed-conifer forest type | | | Total area of WUI-designated blocks in event space | | | Housing density in non–Forest Service area of event space | | | Total area dry mixed-conifer and total area of WUI-designated blocks | | |
| National forest | Pearson | Spearman | Kendall | Pearson | Spearman | Kendall | Pearson | Spearman | Kendall | Pearson | Spearman | Kendall |
| Region 3 | | | | | | | | | | | | |
| Apache–Sitgreaves | **0.49**** | **0.65***** | **0.49***** | –0.13 | –0.18 | –0.13 | 0.03 | –0.01 | 0.01 | –0.06 | 0.07 | 0.05 |
| Coconino | 0.39** | 0.40** | 0.28** | –0.23Φ | –0.21 | –0.15Φ | –0.26Φ | –0.21 | –0.15 | –0.24Φ | –0.25Φ | –0.16Φ |
| Gila | 0.29 | **0.65**** | **0.48*** | –0.44Φ | –0.30 | –0.23 | –0.34 | –0.43Φ | –0.34Φ | –0.44Φ | –0.18 | –0.11 |
| Kaibab | **0.85***** | **0.77***** | **0.77***** | **0.64**** | **0.58Φ** | 0.42Φ | 0.60Φ | 0.59Φ | 0.46Φ | 0.70* | 0.54Φ | 0.37 |
| Region 5 | | | | | | | | | | | | |
| Eldorado | 0.42* | **0.50**** | 0.36** | **–0.50**** | **–0.60***** | **–0.45***** | –0.28 | **–0.51**** | –0.37** | **–0.67***** | **–0.66***** | **–0.52***** |
| Lake Tahoe Basin | 0.40*** | 0.42*** | 0.31*** | 0.22* | 0.13 | 0.23 | 0.07 | 0.05 | 0.03 | 0.31** | 0.36*** | 0.26*** |
| Plumas | 0.27 | 0.27 | 0.20 | –0.21 | –0.22 | –0.16 | –0.26Φ | –0.20 | –0.13 | –0.41** | –0.37** | –0.25* |
| Tahoe | 0.37* | 0.38* | 0.26* | 0.10 | –0.13 | –0.08 | 0.19 | –0.16 | –0.11 | 0.05 | 0.16 | 0.11 |
| Region 6 | | | | | | | | | | | | |
| Colville | 0.10 | 0.15 | 0.11 | –0.11 | –0.28 | –0.22Φ | –0.52** | –0.02 | –0.08 | –0.17 | –0.08 | –0.05 |
| Deschutes | 0.15 | –0.01 | 0.01 | 0.24 | 0.21 | 0.17 | **0.49**** | **0.56***** | 0.40*** | 0.14 | 0.04 | 0.04 |
| Fremont–Winema | 0.02 | –0.18 | –0.13 | –0.05 | 0.20 | 0.14 | –0.19 | –0.39 | –0.24 | 0.33 | 0.13 | 0.12 |
| Okanogan–Wenatchee | **0.46***** | **0.68***** | **0.50***** | –0.21Φ | –0.05 | –0.05 | –0.20 | –0.15 | –0.13 | –0.15 | 0.06 | 0.06 |

*Notes:* Values shown in bold indicate moderate to strong correlation. Shaded cells indicate strong agreement on statistically significant correlation for at least two of the three correlation tests. WUI = wildland–urban interface.; HFR = hazardous fuels reduction.

*$p < 0.05$.

**$p < 0.01$.

***$p < 0.001$.

Φ$p < 0.1$.

implement HFR activities very differently, even in cases where the biophysical setting is similar (Charnley et al. 2015). This variability in managerial judgment would likely minimize correlation as we have measured it between HFR and any other factor.

### Hotspot Assessment

Our second research question explores whether there are local areas where EJ-protected populations concentrate but HFR is minimal or absent, regardless of forest-scale correlation. Hotspots typically occur at scales comparable to or smaller than the ranger district, the smallest management unit of a national forest. At this scale, our hypothesis was supported: All twelve forests had hotspots, although their characteristics varied substantially. The total affected population residing in hotspots ranges from a low of 744 (Deschutes National Forest), of which 86 (12 percent) are minorities, to 17,144 (Coconino National Forest), including 7,410 minorities (43 percent). HFR acreage has a similarly wide range of values. Renter-occupied housing characteristics of hotspots are largely redundant to those for minority population, so only minority population results are shown in Table 5.

Population units were not identified as belonging to hotspots by a statistical procedure, so determining which have the greatest potential for serious EJ impacts is subjective. Table 5 compares the twelve national forests by the degree to which the percentage of affected minorities in hotspots exceeds the percentage of HFR benefits generated by each forest and the degree to which affected minority population is concentrated in hotspots relative to all affected population. The most striking disparity occurs for the Fremont–Winema National Forest, where 66 percent of minorities, 40 percent of all population, and only 6 percent of HFR benefits are located in hotspots. Examining the raw data, however, qualifies the interpretation of these simple percentage disparities. For example, on the Tahoe National Forest, three times more minorities (2,492 individuals) are located in hotspots than on the Fremont–Winema (817 individuals).

In Table 6 and Figure 5, we examine characteristics of each discrete hotspot from the forest in each region with the largest cumulative disparities in Table 5. The differences among individual hotspots are striking. The Chemult/Crescent hotspot results from the difference in location quotient values for renter-occupied housing units (2.03) and HFR acres accomplished (0.4). This hotspot, however, contains 300,000 acres that are hypothetically in range of HFR benefits, more than 11,000 acres of actual HFR accomplishments, and only twenty-nine renter-occupied households. The EJ implications are not likely to be serious. At the other extreme are the Coconino National Forest hotspots composed of neighborhoods in the northeastern part of the city of Flagstaff, Arizona. Each unit in the northeast Flagstaff hotspots has fewer than 300 acres hypothetically eligible to benefit from HFR, but the affected renter-occupied units and minority populations are much more numerous than in Chemult/Crescent.

Two of the three forests in Table 6—Coconino and Tahoe—are adjacent to a city, but it is not necessarily the case that hotspots with the most serious implications for EJ impacts are on the edge of cities. The two hotspots in Table 6 with the greatest disparity between the proportions of minority population and all population in the hotspot are the south side of Truckee, California, and Chiloquin–Sprague Valley, Oregon. Truckee is a small city, with a 2010 population around 16,000; the hotspot mostly consists of an aggregation of adjacent city neighborhoods. Chiloquin's 2010 population was 740, and the hotspot includes extensive rural areas bordering the national forest to the east and south of the town (Figure 5). The 2,334 minorities residing in the Truckee hotspot constitute nearly half of the affected minority population for the entire Tahoe National Forest and 94 percent of minorities that reside in any of the three Tahoe National Forest hotspots (Table 5). Less than a tenth of a percent of the Tahoe National Forest's total HFR activity generated benefits accessible to this hotspot. Although the Chiloquin hotspot's minority population is one third the size of its south Truckee counterpart, it represents an even greater concentration: 64 percent of the minorities potentially affected by HFR on the Fremont–Winema National Forest are in this one hotspot, where benefits from just over 5,700 acres of HFR activity—1.9 percent of the forest's total—accrued.

### Interview Results

We began each interview with an open-ended question about which factors interviewees believed accounted for the pattern of HFR activities

**Table 5.** Hotspot characteristics for minority population of twelve national forests

| | | Hotspots | Affected population in hotpots | | | | HFR characteristics of hotspots | | | | Disproportionate impact on minorities | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| National forest | *n* | Population units in hotspots | (A) Total | (B) % of total affected population | (C) Racial/ethnic minority | (D) % of minority population affected | (E) Acres eligible to benefit from HFR | (F) % of national forest acres eligible | (G) HFR acres treated | (H) % of national forest acres treated | (H)–(D) | (B)–(D) |
| Region 3 | | | | | | | | | | | | |
| Apache–Sitgreaves | 4 | 7 | 7,965 | 19.8 | 2,259 | 30.2 | 7,646 | 0.4 | 189 | 0.1 | –30.1 | –10.4 |
| *Coconino* | 6 | 12 | 17,144 | 26.3 | 7,410 | 40.7 | 8,016 | 0.6 | 767 | 0.6 | *–40.1* | *–14.4* |
| Gila | 2 | 4 | 1,931 | 27.9 | 750 | 39.3 | 240,843 | 8.7 | 4,264 | 3.6 | –35.7 | –11.4 |
| Kaibab | 1 | 3 | 594 | 8.4 | 340 | 14.7 | 312,807 | 23.6 | 18,854 | 18.1 | 3.4 | –6.3 |
| Region 5 | | | | | | | | | | | | |
| Eldorado | 1 | 4 | 4,798 | 18.9 | 890 | 26.6 | 20,201 | 2.5 | 0 | 0.0 | –26.6 | –7.7 |
| *Lake Tahoe Basin* | 3 | 12 | 9,939 | 17.5 | 5,677 | 36.1 | 3,060 | 1.5 | 114 | 0.6 | *–35.5* | *–18.6* |
| Plumas | 3 | 7 | 6,660 | 17.6 | 1,331 | 24.1 | 98,826 | 5.6 | 1,040 | 1.9 | –22.2 | –6.5 |
| *Tahoe* | 3 | 8 | 6,978 | 22.6 | 2,492 | 46.3 | 9,888 | 0.8 | 36 | 0.1 | *–46.2* | *–23.7* |
| Region 6 | | | | | | | | | | | | |
| Colville | 4 | 4 | 2,053 | 15.6 | 340 | 27.0 | 137,014 | 8.2 | 4,495 | 5.5 | –21.5 | –11.4 |
| Deschutes | 2 | 2 | 744 | 2.1 | 86 | 3.2 | 42,021 | 2.4 | 1,164 | 0.4 | –2.8 | –1.1 |
| *Fremont–Winema* | 2 | 4 | 2,462 | 40.7 | 817 | 66.2 | 435,516 | 13.5 | 16,977 | 5.7 | *–60.5* | *–25.5* |
| Okanogan–Wenatchee | 6 | 12 | 6,710 | 19.1 | 2,020 | 31.8 | 65,688 | 1.9 | 55 | 0.0 | –31.8 | –12.7 |

*Notes:* Values in italics identify the forests that appear to have the most significant hotspots, warranting further environmental justice analysis. Population units refers to contiguous Census block groups or partial block groups that collectively comprise the number of hotspots for each national forest in the preceding column (*n*). HFR = hazardous fuels reduction.

**Table 6.** Raw data assessment of all hotspots on three national forests, one from each U.S. Forest Service region

| Community or place name(s) | Contiguous data units in hotspot | Area eligible to benefit from HFR (acres) | | | | | Area (acres) of HFR activity | Nonwhite population in hotspots | Renter-occupied units in hotspots |
|---|---|---|---|---|---|---|---|---|---|
| | | In data units | National forest parcels | National forest parcels and dry mixed-conifer forest | Non–national forest parcels and dry mixed-conifer forest | Non–national forest land that is part of the WUI | | | |
| Fremont–Winema National Forest (Region 6) | | | | | | | | | |
| Chemult/Crescent | 1 | 296,730 | 239,994 | 83,648 | 35,682 | 64 | 11,234 | 29 | 29 |
| **Chiloquin/Sprague Valley** | **3** | **138,785** | **97,226** | **64,755** | **27,667** | **8,639** | **5,742** | **788** | **277** |
| Total | 12 | 435,515 | 337,220 | 148,403 | 63,349 | 8,703 | 16,976 | 817 | 306 |
| Tahoe National Forest (Region 5) | | | | | | | | | |
| Foresthill | 2 | 2,401 | 595 | 7 | 179 | 863 | 5 | 95 | 168 |
| Sweetland | 1 | 2,298 | 262 | 18 | 37 | 1,424 | 13 | 63 | 95 |
| **Truckee–South** | **5** | **5,189** | **139** | **105** | **3,359** | **2,700** | **18** | **2,334** | **1,070** |
| Total | 12 | 9,888 | 995 | 130 | 3,576 | 4,987 | 36 | 2,492 | 1,333 |
| Coconino National Forest (Region 3) | | | | | | | | | |
| NE Flagstaff –1 | 3 | 295 | 0 | 0 | 17 | 280 | 1 | 1,861 | 586 |
| Smokerise Valley | 1 | 54 | 0 | 0 | 0 | 38 | 3 | 304 | 17 |
| NE Flagstaff –2 | 1 | 71 | 10 | 0 | 0 | 43 | 4 | 491 | 83 |
| Far E. Flagstaff/Walnut Canyon | 1 | 3,362 | 2,451 | 911 | 225 | 181 | 535 | 600 | 538 |
| NAU Campus | 5 | 1,410 | 148 | 135 | 448 | 785 | 96 | 4,065 | 1,870 |
| W. Flagstaff/Thorpe Park | 1 | 2,824 | 659 | 659 | 1,950 | 914 | 127 | 89 | 53 |
| Total | 7 | 8,016 | 3,268 | 1,705 | 2,640 | 2,241 | 766 | 7,410 | 3,147 |

*Notes:* The communities shown in bold are referenced in the discussion. The two hotspots shown in bold, plus all of the hotspots shown for the Coconino National Forest, are depicted in Figure 5. HFR = hazardous fuels reduction; WUI = wildland–urban interface; NAU = Northern Arizona University.

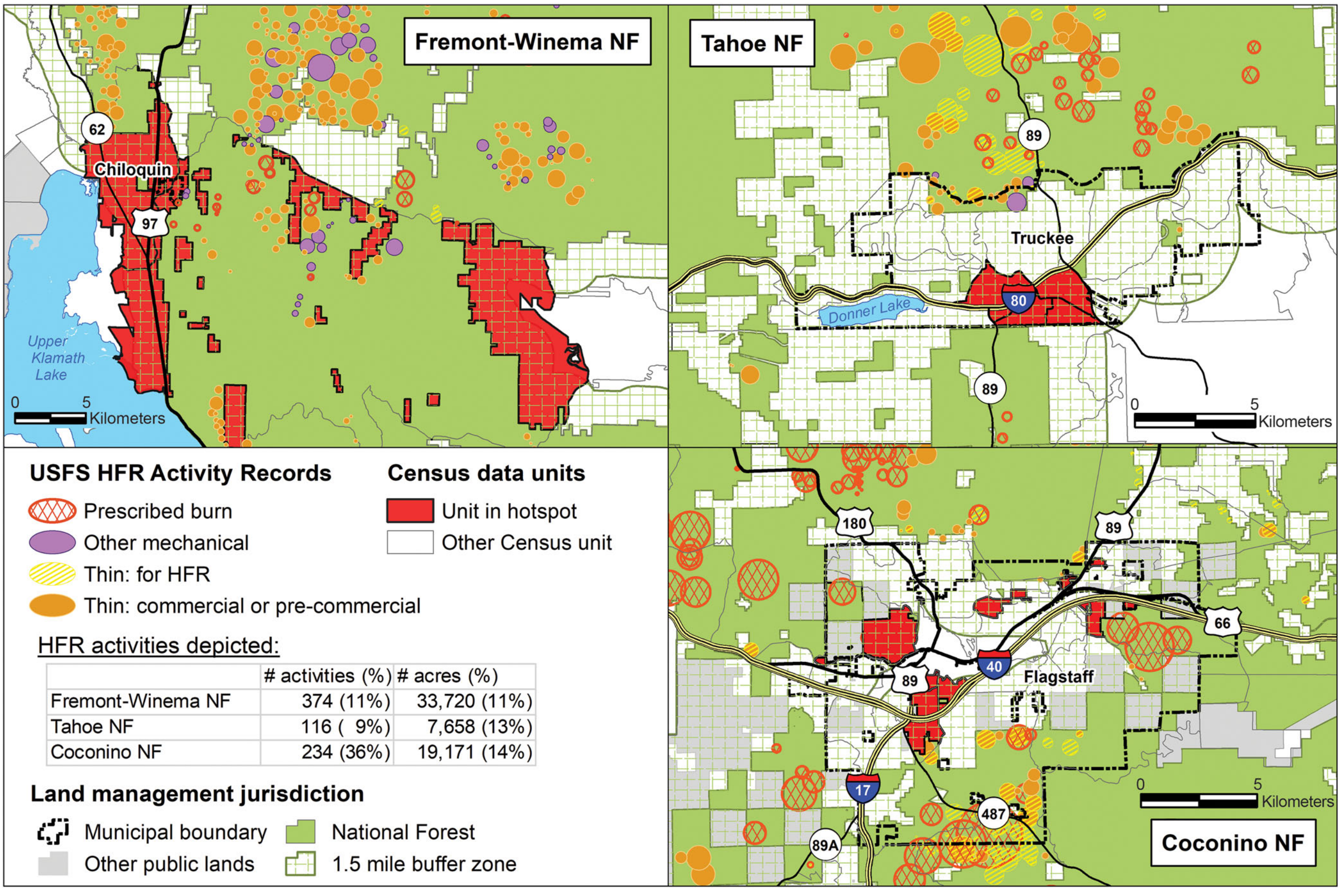


**Figure 5.** Hotspots from Table 6. HFR polygons are proportional to their recorded acreage. All six Coconino NF hotspots are depicted. For Fremont–Winema and Tahoe NFs, only hotspots shown in bold in Table 6 are shown. *Note:* NF = National Forest; USFS = U.S. Forest Service; HFR = hazardous fuels reduction.

accomplished between 2006 and 2015 on a map of their management unit. Interviewees typically discussed biophysical factors (95 percent), such as forest type, fuel accumulation, deviation from reference conditions, topography, accessibility, prevailing winds, and recent wildfires. Managing risk to lives, property, or public infrastructure (77 percent); economic drivers such as markets for small-diameter timber and harvest by-products (64 percent); and following rules established in the forest's management plan (55 percent) were the next three most cited factors. None of the interviewees cited the EJ Order as a factor in shaping the pattern of HFR activity in their open-ended response.

Next, we asked about experiences with community engagement, including the demographic diversity of the communities, and whether community members who engaged with the national forest reflected local diversity. Two thirds of interviewees agreed that community engagement occurred in the context of their HFR program, but only 27 percent had affirmed this in response to the open-ended question. Five respondents had engaged with groups from communities with significant proportions of low-income or minority populations. Three of these (14 percent of all interviews) indicated that the members of the engaged community groups reflected the diversity of their community. All three were cases where USFS staff consulted with resource managers or other leaders from a neighboring Native American tribe. In at least one case, the consultation was legally mandated. There were no other instances in which engaged community groups came from substantially minority or low-income communities and had representatives reflective of those characteristics. Our sample is limited but implies that participation by low-income or minority representatives in the process of planning and implementing HFR—including determining where the risk reduction benefits accrue—is rare and usually occurs with the guidance of a formal mechanism other than the EJ Order, especially the tribal consultation process.

Finally, we asked interviewees about their familiarity with the principles of EJ generally and the EJ Order specifically. Ten of 27 interviewees had heard of the EJ Order, although only five (19 percent) recounted substantive knowledge of what it directed federal agencies to do. Six (22 percent) agreed that consideration of the racial, ethnic, and income characteristics of populations adjacent to the national forest had been a factor in their HFR planning effort, but only one of these six also had substantive knowledge of the EJ Order. Hence, the majority of respondents who factored neighboring population characteristics into planning and implementing HFR did so either out of personal motivation or in response to administrative direction unrelated to the EJ Order. Despite existence of a USFS technical guide designed to assist field managers and planners in complying with the EJ Order (Grinspoon et al. 2014), most remain uninformed about it and of how to comply.

We heard two essential perspectives from the subset of ten interviewees who either knew the substance of the EJ Order or consciously factored the demographics of neighboring populations into planning HFR activities despite lacking knowledge of the EJ Order. One perspective questioned the notion that considering who would benefit from fuels reduction should be within the agency's purview:

> The analysis comes down to, where is the risk of loss, any loss, greatest in terms of the factors that we can control—fuel conditions, likely burn footprints after an ignition, existing containment opportunities, access for suppression. We don't have any control over what kind of house gets built next to forest lands, or who lives there, so I don't think we're on solid ground if we start deciding who should benefit and who shouldn't. … I think [EJ is an important issue, and I know we have people in our community that it is intended to speak for. But I believe we have to strive to manage risk to the community as a whole unit. (Interviewee 27)

The other perspective implied that the USFS has an ethical obligation to weigh the impacts and benefits of HFR activities relative to the affected population's demographic character:

> We're aware that a lot of the people who are down canyon, from areas where [prescribed] burns really make a lot of sense, they are heavily minority, definitely lower income. We don't want to create an impact [prescribed burn smoke] just on that group of people. It seems like we'd be saying that we don't care that you may be more harmed than people that can afford central air conditioning or can vacation at the coast for part of fire season. (Interviewee 17)

When asked about whether EJ was a factor in planning and implementing their work, the most common response from the other seventeen interviewees was that they had never thought critically about how fulfilling their duties might affect people in neighboring communities differently and that the consequences of wildfire could be severest for low-income or minority populations. For example:

> I don't live all that far from those neighborhoods, and I've been aware that they have been some of the few places anywhere around where resort workers can find an affordable place [to live]. But I hadn't really thought at all about that community in relation to managing fuels. Now that we're having this conversation, I see how I've kind of overlooked the whole issue of … are we treating all the different kinds of people who might be exposed to fire risk from our forest as fairly as we could be? (Interviewee 12)

We found no evidence that EJ Order compliance occurred at the stage of the HFR planning process when revelation of potential or past negative impacts could most easily lead to shifts in management direction. This does not automatically imply, however, that HFR implementation caused EJ impacts. Several alternative scenarios exist where the EJ Order is not meaningfully addressed but EJ impacts from HFR do not occur. Staff might informally consider the demographic characteristics of various communities adjacent to their management unit and seek to mitigate disproportionate consequences: The comment shared by Interviewee 17 is an example. Staff might be unaware of, or choose to ignore, the demographic characteristics of potentially affected communities but plan a pattern of HFR activity that coincidentally distributes risk reduction benefits equitably among EJ and non-EJ populations. Or the pattern of HFR activity might produce large disparities between local concentrations of EJ-protected populations and risk reduction benefits but EJ impacts do not occur because the concentrated EJ populations are located in areas where USFS HFR activity is not needed or cannot be conducted—this occurred in the example of Interviewee 27.

## Discussion

### Are EJ Impacts from HFR Activities Extensive or Severe?

We found almost no evidence of statistically significant, negative correlation between concentrations of HFR benefits and minority population or renter-occupied housing when measuring at the scale of a national forest. The lack of correlation strongly suggests that HFR has not caused widespread or systematic EJ impacts spanning one or more national forest units. We found hotspots, however, where localized EJ impacts to these populations might have occurred on each forest. Our interviews revealed that EJ Order compliance was not a factor in planning and implementing HFR, but this lack of formal compliance does not necessarily mean that the hotspots identify severe EJ impacts: A greater understanding of local context is still needed. We illustrate the contextualization process by interpreting interview results for the two most significant hotspots in Table 6.

**Chiloquin, Oregon.** The Chiloquin hotspot resulted from local circumstances that might be unique. Chiloquin is the seat of government for the Klamath Tribes, and roughly half of enrolled tribal members live in the vicinity. The affected population of the Fremont–Winema National Forest outside the Chiloquin hotspot is overwhelmingly white, and renter-occupied housing is uncommon. This spatial disparity causes high location quotient values for both minorities and renter-occupied housing in the three population units that comprise the hotspot. The forest's census data units are few and large; all but one encompasses broad extents of HFR-eligible USFS lands and many HFR treatments. The Chiloquin hotspot benefited from more than 5,700 acres of HFR activities, but because the Fremont–Winema National Forest led all national forests in the nation with just over 300,000 acres treated during the study period (Table 1), and most of these treatments benefited other census units, a small location quotient value for HFR in the data units comprising the hotspot results.

The quantitative results imply significant concern about the EJ impact of HFR in this hotspot, given its highly disproportionate concentration of minorities. It is actually an unusual case, however, where the EJ-protected population, through its representatives, had a role in HFR planning. The Winema portion of the Fremont–Winema National Forest consists largely of former Klamath Indian Reservation lands, and the USFS and Klamath Tribes have a memorandum of agreement regarding the government-to-government consultation process for managing tribal treaty and trust resources located within the Fremont–Winema National Forest (Hatcher et al. 2017). According to a USFS official with a long history of working on the Fremont–Winema National Forest, tribal leadership indirectly played a role in minimizing the proportion of the Fremont–Winema National Forest's total HFR treatment acreage conducted in the Chiloquin vicinity:

> The Tribes had been for the most part resistant to prescribed burning as a tool. There has been agreement on the fact that fuel loading in that area is too high, and needs correction, but not on the best way to accomplish it. … During the time period you're looking at, especially the early part … yeah, we couldn't move forward with burns due to the Tribe's concerns about potential [cultural] resource damage. Thinning was the preferred tool.

Prescribed burning accounts for over a third of the Fremont–Winema National Forest's HFR acreage during the study period, but nearly all of it occurs far from Chiloquin, partly due to the tribal consultation process. The Fremont–Winema National Forest's HFR strategy in the Chiloquin vicinity favored mechanical treatments, which are typically more expensive per acre than prescribed burns—hence, fewer acres treated per dollar. The small location quotient value for HFR that generated the hotspot was therefore contingent on circumstances that the quantitative data analysis could not reveal: favorable conditions for large-scale broadcast burns elsewhere in the forest and a preference for mechanical treatments in the Chiloquin vicinity. Our Fremont–Winema National Forest interviewees were unfamiliar with the EJ Order and the concept of EJ, but the presence of a formal tribal consultation process ensured that consideration of the affected minority population was a factor in planning HFR activities. Despite the strong impression created by the quantitative analysis, this hotspot is not an example of EJ impacts from HFR.

**South Truckee, California.** The circumstances of the south Truckee hotspot are similar to others occurring adjacent to urban-density populations in our sample, but it is the extreme example. Lands managed by the Truckee District of the Tahoe National Forest fall into two halves. South of the city, national forest ownership is somewhat patchy, forest road infrastructure is limited, topography is steep, and forest stands grade into moist mixed conifer (with different fire regimes) at the highest elevations. North of the city, national forest ownership is homogenous, road infrastructure is extensive, topography is moderate, and ponderosa pine–dominated stands are common.

According to Tahoe National Forest interviewees, national forest lands along California Highway 89 south of Truckee (Figure 5) were among many locations in the Tahoe National Forest where HFR was necessary to mitigate potentially extreme wildfire behavior. Challenging topography, combined with limited road infrastructure, made the cost of mechanical treatments prohibitive, however. Staff instead planned 2,500 acres of prescribed burn treatments, but state air quality regulations made implementing burns exceedingly difficult. A "burn window" opened only after several years of waiting. After two burns were ignited, a series of complications ensued that resulted in smoke first being trapped in the narrow canyon traversed by Highway 89 and then flowing directly into the city of Truckee. The event triggered an air quality red alert, and USFS staff were admonished by state air quality regulators.

Frustrated by the difficulty of implementing HFR in the south half of the district, staff decided to focus on the district's north half. To use one staffer's own words, the north half offered "the easy acres." Here, a large subdivision community adjoining national forest lands was already actively engaged with forest fuels reduction. Other national forest lands farther from the urban edge were downwind of the city on most days. Forest stands in need of treatment both adjacent to the subdivision and farther north in the district were more accessible, and social license for both thinning and burning the primarily ponderosa pine stands was well established. Collaboration with the subdivision's own forestry department created an opportunity for cross-boundary cooperation in protecting a high-property-value WUI zone. The geography of easy acres and EJ-protected populations did not align, though. During the study period, the two burns executed south of Truckee were the only HFR treatments generating risk reduction benefits to the location where roughly half of the Tahoe National Forest's affected minority population resided. In this example, EJ impacts did occur, although inadvertently, as a result of staff navigating complex biophysical and regulatory barriers to fuels treatment without simultaneously considering the characteristics of local populations that might benefit.

**Implications for EJ Order Compliance**

Our results suggest that hotspots pointing to possible EJ impacts from HFR are more likely to occur in national forests where portions of the forest are adjacent to cities. Such hotspots are also likely to be more practically significant in the context of the EJ Order, because many more people reside in them compared to completely rural hotspots. Urban-density hotpots were more likely in our sample due to the rarity of rural areas with sufficiently high concentrations of minorities or renter-occupied units to generate negative correlation with low location quotient values for HFR. Chiloquin was the only significant exception.

For USFS managers, the practical implication is that pursuing HFR objectives that require treating forest lands far from principal settlements along the national forest boundary creates a trade-off between improving resource conditions in the proposed treatment area and generating risk reduction benefits to the urban-density populations immediately adjacent to national forest lands. Minority and renter-occupied households are concentrated in some of these neighboring urban-density communities. When they are and benefits accrue elsewhere, a potentially concerning hotspot results. Although our interviewees were typically aware of maintaining a balance between protecting private property and meeting other resource objectives when executing HFR program activities, only a few perceived the demographic characteristics associated with the act of property protection. Among these few, none explicitly conceptualized their HFR efforts in terms of generating risk reduction benefits to EJ populations because these populations likely possess very limited means to engage in their own risk mitigation practices. Heightened awareness among HFR managers of EJ Order compliance could make the EJ dimension of the trade-off between resource benefits and property protection more evident.

The USFS officially incorporates EJ Order compliance into the NEPA process. All of our interviewees were familiar with the agency's NEPA process, but their limited knowledge of the EJ Order itself indicates a significant disconnect between official guidance and practice. This finding from our interviews is consistent with previous research findings that EJ analyses in NEPA documents are frequently unsubstantiated "boilerplates" (Rose et al. 2005; Geltman, Gill, and Jovanovic 2016). Increasing awareness of the EJ Order only within the NEPA compliance process, however, might not be the most effective path to addressing the EJ implications of program activities like HFR.

Our interviews suggested that EJ population analysis and the implications of past management for those populations would be most useful to managers at a planning step that occurs prior to undertaking NEPA analysis. Considerable assessment work is done periodically on national forests to chart short-, medium-, and long-range management objectives. A periodic assessment of forest fuels conditions informs subsequent decisions about where and how to plan HFR activities, including administrative strategy like budget and staffing requests and community engagement techniques. By the time a planned series of HFR activities enters the NEPA process, many decisions have already been made about management priorities that might not be easy to reverse if the NEPA analysis finds serious EJ implications that should be addressed by changing or eliminating a proposed project. Roughly half of our interviewees expressed enthusiasm at the prospect of incorporating spatial analysis of past program accomplishments relative to EJ population concentrations into pre-NEPA assessments, when changing course to account for underserved populations is likely to prove much more feasible.

## Implications for the Analysis of Environmental Justice by Geographers

We sought to address two gaps in the EJ research literature: lack of knowledge about the EJ impacts experienced by dispersed rural populations and the potential EJ implications of federal land management. Our approach to addressing these gaps required circumventing limitations imposed by sole reliance on either rigorous quantitative modeling or qualitative case study approaches to EJ. In the process, we identified an alternate avenue for future developments in the geographical study of EJ issues: a hybrid of exploratory spatial data analysis and targeted qualitative research.

The quantitative dimension of our approach can be adapted to different management activities or measurement metrics and can be scaled up or down, provided that the research question is appropriately modified to match. The hotspots can be flexibly defined by altering the duration of the management activity record or using other management activity attributes. A hotspot that exists in a three-year time window might not exist when ten years of activities are considered. Expenditures might be a more appropriate metric for defining potential EJ impact hotspots than activity acreage, although cost data were unavailable for this research. Importantly, hotspots are generated relative to a reference population that is defined by the phenomena analyzed. The spatial dimensions of reference populations—often census tracts, cities, or counties—in much EJ research include substantial numbers of people that might be located far from a zone of potential impact. Hotspots in our approach measure meaningful EJ population concentrations only relative to all people residing in range of the projected risk reduction benefits of USFS HFR—only those whose risk the agency is theoretically capable of mitigating. Other activities or phenomena would yield a different map of EJ population concentrations even for the same national forest, assuming that the reference population is adjusted to match a different zone of effect. Our hotspot results also match the scale at which responsible officials—usually the district ranger's staff—are positioned to take corrective action for any negative EJ implications of management activities that are identified. Other scales appropriate to other management hierarchies are possible.

Discovery of actual EJ impacts and potential remedies in our hybrid approach occurs at the qualitative analysis stage. In our sample, hotspots were always smaller than the smallest scale USFS administrative unit, the ranger district. As a result, interviews could be readily directed to officials with the greatest knowledge of current and past management at the unit level where potential EJ impacts might have been generated in the first place. This targeted interview process can increase the efficiency of qualitative data collection and, in turn, facilitate limited generalized findings, as exemplified by our interview data collection from six geographically diverse management units. Ultimately, the qualitative stage of our process yielded the most impactful findings: What looks quantitatively like an EJ impact hotspot is not necessarily so; the EJ Order was unfamiliar to most interviewees despite official agency policy; and the characteristics of neighboring populations were almost never considered in planning future HFR activities. None of these findings was isolated to one specific location.

The social vulnerability and wildfire literature makes clear that managers in the USFS and other land management agencies should generally expect variability in the capacity of neighboring populations to prepare for, and respond to, a wildfire event. Some communities will possess concentrated EJ characteristics, which indicates that any risk reduction benefits they receive from USFS HFR will form a much higher proportion of their total preparation for a wildfire event in comparison to high-resilience communities. Similar relationships with EJ implications likely exist for other phenomena associated with land management agency activities. Efforts to broadly quantify such locally contingent relationships across an entire agency through modeling would likely founder on data suitability issues. Case studies might yield locally fruitful results but fail to assist agency leaders with determining the applicability of the results generally such that they could prioritize necessary remedies. Our approach demonstrates a promising alternate path for EJ scholarship that is at once geographically informed and also useful in the applied work of federal agency program evaluations and assessments such that the steps that agencies could take to better realize the intent of the EJ Order become clearer.

## Conclusion

EJ scholarship has so far neglected the problem of how to identify and describe EJ impacts when the affected population is small and dispersed across rural areas and the phenomenon triggering the impact has a spatially limited extent. Also largely absent from the quantitative EJ literature are analyses of the EJ impacts of federal land management actions, despite the twenty-five-year existence of the EJ Order. Our research addressed these issues using a mixed-methods approach to quantifying and interpreting the EJ impacts of HFR activities implemented by the USFS on twelve western national forests between 2006 and 2015.

Our quantitative analysis found that the USFS likely does have an EJ problem with the implementation of HFR activities across the dry mixed-conifer forests of the U.S. West but that impacts of these activities are scattered and localized in hotspots, not widespread or systematic. By *problem* we mean inadvertent but potentially avoidable situations in which locations where low-income or minority populations concentrate fail to benefit proportionally from the risk reduction benefits of HFR, even though they are the population that is least resilient to loss from wildfire. This problem does not reflect intentional discrimination against communities based on racial, ethnic, or income prejudice by managers. Rather, we found that managers generally did not consider demographic characteristics of nearby populations when planning projects, focusing instead on biophysical factors. The exception was for tribal populations, following government-to-government consultation processes for management actions on federal lands that might affect Tribal treaty rights. The presence of hotspots depended on local context, the definition of the management unit, and the associated scale of analysis. Hotspots are indicators of potential EJ impacts, not confirmations; the qualitative research phase of the method is a critical step in the process of establishing where and how significant any EJ impacts from HFR actually are.

Our findings are relevant both to the further development of EJ research methodologies and to their application by U.S. federal agencies that already have mandates to conduct social impact analyses of proposed management actions, including the EJ Order. The limitations of U.S. Census data for working with landscape-scale phenomena that affect small dispersed populations in rural areas—such as HFR—are severe. Our solution to the methodological limits imposed by the available population and resource management activity data turned out to be a strength: Applying exploratory spatial data analysis procedures to identify localized hotspots of concern produced very fruitful interview data. Our interviews strongly suggest that the USFS's current approach to following the EJ Order could be improved on and that a hybrid method such as the one detailed here is suited to the task. Our research draws attention to the need for improving understanding of EJ in rural settings, especially in the U.S. West, where roughly half of the land base is federal and land management agency actions are subject to compliance with the EJ Order. It offers a useful alternative approach to assessing EJ impacts when neither case study nor quantitative modeling approaches alone are appropriate.

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