ANNALS OF THE AMERICAN ASSOCIATION OF GEOGRAPHERS
https://doi.org/10.1080/24694452.2025.2463503

Identification of High Fire Potential and High-Use Spatial Intersections at a National Forest to Understand Recreation Displacement Related to Wildfire Events

Bijan Gurung,[a] Brian A. Peterson,[a] Sean Fleming,[b] Stacy Drury,[b] Alyssa Thomas,[b] José J. Sánchez,[b] and Elizabeth E. Perry[c]

[a]*Department of Horticulture and Natural Resources, Kansas State University, USA;* [b]*Pacific Southwest Research Station, United States Department of Agriculture Forest Service, USA;* [c]*Department of Community Sustainability, Michigan State University, United States*

U.S. National Forest Service units in California are increasingly vulnerable to wildfires that could result in people being displaced during and after these events. The purpose of our study was to identify characteristics of national forest users potentially displaced due to recreation site closures from a wildfire event. This information is useful for managers to inform public outreach strategies. Our study focused on California's Los Padres National Forest, which is a popular recreation area and has five resident communities. First, we produced a burn probability map using the FlamMap fire behavior modeling platform to identify where potential wildfires might occur. Second, we analyzed Spectus mobile device data to determine areas that receive high use and to understand forest use differences during and after a potential wildfire event. This information was mapped and overlaid with the findings from the first phase, which resulted in the identification of spatial intersections of areas with high burn probability and high use. Next, these areas were analyzed for recreation opportunities and then input into an automated Spectus dashboard that analyzes mobile device data to understand demographic characteristics for those who could potentially be displaced. This information is useful for assisting forest managers with the formulation of effective public outreach that targets high volumes of people where wildfire-related displacement is most likely and where messaging campaigns might have the greatest audience. *Key Words: burn probability, displacement, high use, mobile device data, wildfire.*

Wildfires have become more frequent, larger, and seasonally extensive (Cattau et al. 2020). In 2022, there were 68,988 wildfires in the United States, burning over 7.5 million acres. This trend is expected to continue as climate models predict warmer and drier conditions. In addition to the immediate damage to vegetation and human communities, wildfires can displace visitors through the closure of recreational sites. After a wildfire starts in a national forest, managers often issue an emergency forest closure order for the area at risk. This closure order can expand in size, even to cover the entire forest, if firefighters are unable to quickly contain the wildfire. Once the wildfire is contained, the closure area is revised to include only the burned area, and many sites are reopened. High-severity wildfires have the potential, however, to substantially damage recreational sites (trails, picnic areas, campgrounds, etc.) to an extent that requires repairs that are complex and difficult. The result is that burned portions of the forest remain closed due to public safety risk, often for months or even years after the fire. For example, Winter, Sánchez, and Olson (2021) described how the 2009 Station Fire in California left a segment of the twenty-six-mile Gabrielino Trail (Angeles National Forest) closed for public use for almost a decade. More recently, the 2020 Bobcat Fire in California severely damaged the Chantry Flats picnic area, and it remains closed more than four years later.

ARTICLE HISTORY
Initial submission, January 2024; revised submissions, September and October 2024; final acceptance, November 2024

CORRESPONDING AUTHOR Brian A. Peterson brianpeterson@ksu.edu

Recreation site closures can varyingly affect sociodemographic groups due to different motivations and preferred recreation activities, locations, and seasons (Jean et al. 2022). For example, Thomas, Sánchez, and Flores (2022) reviewed more than three decades of Latinx recreation research on public lands and found that Latinx recreationists preferred developed sites (e.g., sites with cooking grills, potable water, and picnic tables). Also, loss of recreation opportunities or degraded facilities disproportionately affects lower income communities as they often have limited resources or lack transportation to recreate at different sites (Winter, Sánchez, and Olson 2021).

When recreation site conditions are unavailable or undesirable, visitors could be prevented from recreating as they would prefer. They could then choose a substitute experience (i.e., spatial, temporal, or activity displacement) or decide to forego recreation completely (i.e., total displacement; Manning et al. 2022). Resource (e.g., wildfire), managerial (e.g., campground closure), or social (e.g., crowding) conditions can trigger displacement. Jenkins et al. (2023) found visitation to mountainous national parks in California decreased in extreme wet years (e.g., snowpack restricting access) but increased at some coastal and arid parks, suggesting intersite spatial displacement. Also, they also found that extreme drought variably affected visitation annually and monthly, indicating nuanced temporal displacements in drier and potentially more wildfire-prone times. Studies examining more granular displacements at Vermont state parks found visitor adaptations to climate-change-induced summer shifts, with visitors choosing elevations, latitudes, times, and activities aligned with their preferences and their displacements and fidelities shaped by their place attachments (e.g., Perry et al. 2021).

Burn Probability

Spatially explicit, landscape-level fire behavior modeling is increasingly used to identify where a wildfire is likely to occur and the potential harm (Keane et al. 2010; Thompson et al. 2022). FlamMap (Finney 2006) is an intuitive fire behavior modeling framework that estimates fire behavior potentials and outputs include flame length, rate of spread, intensity, fire growth, fuels treatment optimization, and burn probability. Conditional burn probability analysis allows researchers to spatially identify areas that are most likely to experience wildfire given an ignition and a weather scenario and are commonly used to identify potential high hazard and risk areas.

Mobile Device Location-Based Data

Passively collected mobile device location-based data can be used to understand patterns of people in protected areas (Monz et al. 2021). This refers to geolocational data in which users consent for data to be recorded by their device's locational applications. These data are not dependent on cellular connectivity because the device's Global Positioning System (GPS) collects location data, which are uploaded when cellular connectivity is available (Lawson, Monz, and Larkin 2023). At Yellowstone National Park, Liang et al. (2022) found mobile device data (MDD) to be strongly correlated with the park's count data. Creany et al. (2021) found MDD to be strongly correlated with trail counter data collected at an urban-proximate protected area in Southern California. Also, MDD can be analyzed to determine demographics of people in protected areas (Monz et al. 2021) through inferred home locations (privacy-protected) at the census block level (Lawson, Monz, and Larkin 2023). MDD should be used with caution, however. These data sets can introduce bias representing people who approve mobile device applications to collect location data (Whitney et al. 2023). MDD should be validated and if needed it should be scaled, such as with field data collection techniques. For the purposes of this study, MDD was used because analysis focused on relative use patterns of large areas with high visitation, as in which areas receive high visitation compared to other areas in the forest.

Study Purpose

Wildfires in national forests are becoming increasingly more common. Research, however, has scarcely coanalyzed fire modeling data and MDD to identify areas with high fire potential and high visitation. This information can be used to understand types of recreational opportunities offered in these areas and characteristics of forest users that would potentially be displaced. Therefore, the study had two aims: (1) to identify areas where national forest users could potentially be displaced due to recreation site

closures from a wildfire, and (2) to understand socioeconomic characteristics of potentially displaced visitors. This was accomplished by modeling wildfire probability and spatially intersecting that information with MDD analysis of high-use areas. These intersecting areas were analyzed for recreation opportunities and to understand user demographics. This information can assist managers with public outreach messaging and promotion of alternative recreation experiences during forest closures.

Methods

Study Area

The Los Padres National Forest (LPNF) was chosen as the study area because it has a history of wildfires, high visitation, a range of recreation opportunities, and a variety of visitor types. The LPNF encompasses almost 2 million acres in Southern California, including ten wilderness areas totaling 876,012 acres. Recreational opportunities abound, such as hiking, backpacking, hunting, mountain biking, and horseback riding. LPNF offers sixteen day use areas, including eight picnic sites, for visitors (U.S. Forest Service n.d.). There are 1,134 miles of streams and rivers for activities including fishing and kayaking, 407 miles of motorized trails, 1,020 miles of nonmotorized trails, and thirty-two campgrounds (LPNF, personal communication, September 3, 2024). In 2019, the LPNF had 1.4 million site visits, with the most popular activities being hiking and walking, viewing natural features, relaxing, and viewing wildlife (U.S. Forest Service 2024). Visitors to the LPNF were predominantly White (90 percent) and Hispanic (16 percent). Twenty-four percent of visitors had a household income under $50,000; 31 percent between $50,000 and $99,999; and 46 percent reported a household income of $100,000 or more. Although most visitors were from the nearby counties of Santa Barbara and San Luis Obispo, 9 percent were from another country (U.S. Forest Service 2024).

LPNF has a dry Mediterranean climate with winter and spring punctuated by rainy conditions followed by a long, dry summer and fall in which rainfall rarely occurs (Los Padres ForestWatch 2013). The ecosystem is primarily chaparral, featuring many plant species coated with flammable resins (National Park Service 2018). These conditions encourage an intense wildfire to easily spread once ignited. Additionally, LPNF regularly receives offshore Santa Ana winds, which warm and dry the western side of California and eliminate air moisture near the ground.

LPNF is comprised of a northern and a southern unit. The southern unit receives higher visitation because it is more accessible from Los Angeles and Ventura Counties to the south, Santa Barbara County to the west, Interstate 5 to the east, and Highway 101 to the north. The northern unit is more secluded along the coast and accessible only from the two-lane Highway 1. Five communities are located within the LPNF (Frazier Park, Lake of the Woods, Pine Mountain Club, Cuddy Valley, and a part of Ojai Valley). Residents of these communities are exempted from forest closure orders and must leave only if law enforcement issues an evacuation order for an active wildfire that poses an imminent risk to public safety.

Analysis of Burn Probability

The burn probability model within the FlamMap fire behavior modeling platform was used to identify areas most likely to burn within the LPNF provided there is an ignition, very dry fuels, and an extreme weather event. FlamMap inputs included vegetative fuels (biomass available to burn), topography (elevation, aspect, slope), fuel moisture conditions, and weather (temperature, wind speed, wind direction) covering the entire LPNF. The most recent LANDFIRE landscape data set, updated to be ready for the 2020 fire season (LF 2020-2.2), was downloaded from the LANDFIRE project data distribution site (see https://www.landfire.gov/index.php). As described in Rollins (2009), LANDFIRE provides a FlamMap-ready, contiguous, spatially explicit landscape data set containing eight bands: elevation, aspect, slope, fuel model, canopy cover, canopy height, and canopy base height. FlamMap algorithms apply these variables simultaneously to produce spatially explicit fire behavior potential gridded data layers including the burn probability layer we used in this project (Finney 2006).

We modified the out-of-box LANDFIRE landscape file using a nearest neighbor approach to input data into empty pixels around trails that were mapped as unburnable. We set fuel moisture to represent very dry drought conditions (Scott and

Burgan 2005). To represent a problem case weather scenario, we set wind direction and wind speed to 45 degrees (northeast offshore winds) at 12 mph, approximating local Santa Ana wind patterns and weather conditions (Westerling et al. 2004) and used the Wind Ninja program within FlamMap to map winds across the landscape.

We used FlamMap to randomly place 10,000 ignitions within LPNF to ensure that each pixel had an opportunity to burn. Next, FlamMap estimated fire growth for each ignition point. Each simulation was run for a thirty-hour burn period. FlamMap then combined the 10,000 fire footprints to determine how many times a pixel would burn, divided that number by the number of ignitions, and imputed values for each pixel into a raster file (90 m × 90 m resolution). For example, a 2 percent burn probability represents the raster cell burning 200 times for every 10,000 ignitions.

Analysis of Mobile Device Data

MDD were provided by Spectus (Cuebiq Group LLC), which is a location intelligence platform that provides aggregated mobility data (Spectus, 2023). Data are collected from anonymized users who have opted in to have their data collected by location applications. The Spectus platform allows researchers to query anonymized, aggregated, and privacy-enhanced data following guidelines for responsible data sharing through a Data Cleanroom environment.

We used Spectus data to identify relative high use within LPNF from 1 June 2022 to 31 October 2022, which includes the months that wildfires are most common. Stops were identified using a sequence oriented clustering (SOC) approach, which extracts stops from a single trajectory, while accounting for noise points, by identifying clusters of adjacent points per time period (Xiang, Gao, and Wu 2016). This approach was chosen to focus analysis on forest users because there are several roads and highways that traverse LPNF. Also, this approach prevented inclusion of data from passengers on board low-level overflights above LPNF. The SOC algorithm considers spatial proximity, continuity, and duration when clustering trajectory points and eliminates false positive stops. We used a duration of five minutes to explore the spatiotemporal proximity of points within a stop, producing two shapefiles: one including the five communities and one excluding them to understand differences during and after a wildfire event (i.e., areas of LPNF that remain closed for recreation, but are open to resident communities, after a wildfire has been extinguished). The different shapefiles allowed us to assess if there were important differences when residents were not included in the visitation analysis.

Both shapefiles were imported into ArcGIS Pro 3.2.1 and point density analysis was conducted. Areas with intersecting high burn probability and relative high use were identified. High burn probability areas were those that had the highest 60 percent burn probability. Relative high-use areas were those in the highest quantile of stops out of five quantiles. Next, polygons were created around areas with the highest density that intersected areas with high burn probability. These polygons were assessed for size and recreation sites. Trails and off-highway vehicle (OHV) trails were identified using a geographic information systems (GIS) layer provided by the U.S. Forest Service and campgrounds were identified from a Los Padres campground camping list (U.S. Forest Service 2023). Using Google Maps, each campground's location in decimal degrees was identified and subsequently input into a point shapefile. Finally, the polygons were imported into an automated Spectus dashboard to identify racial and ethnic categories of potentially displaced people, median household income, primary home counties, and primary days of forest use, which were all analyzed from 1 June 2022 to 31 October 2022. Race and ethnicity, median household income, and home counties were derived from home census block groups using 2020 U.S. census data.

Results

We identified areas of high burn probability throughout LPNF. In the southern unit, there is a distinct high burn probability trend extending from the southeast to northwest boundary (Figures 1 and 2). Analysis to understand socioeconomic characteristics of people potentially displaced during a wildfire (including residents of LPNF) identified three high-use-density polygons that intersected with high burn probability. These polygons are denoted A, B, and C (Figure 1). Polygon A is on the east side of the

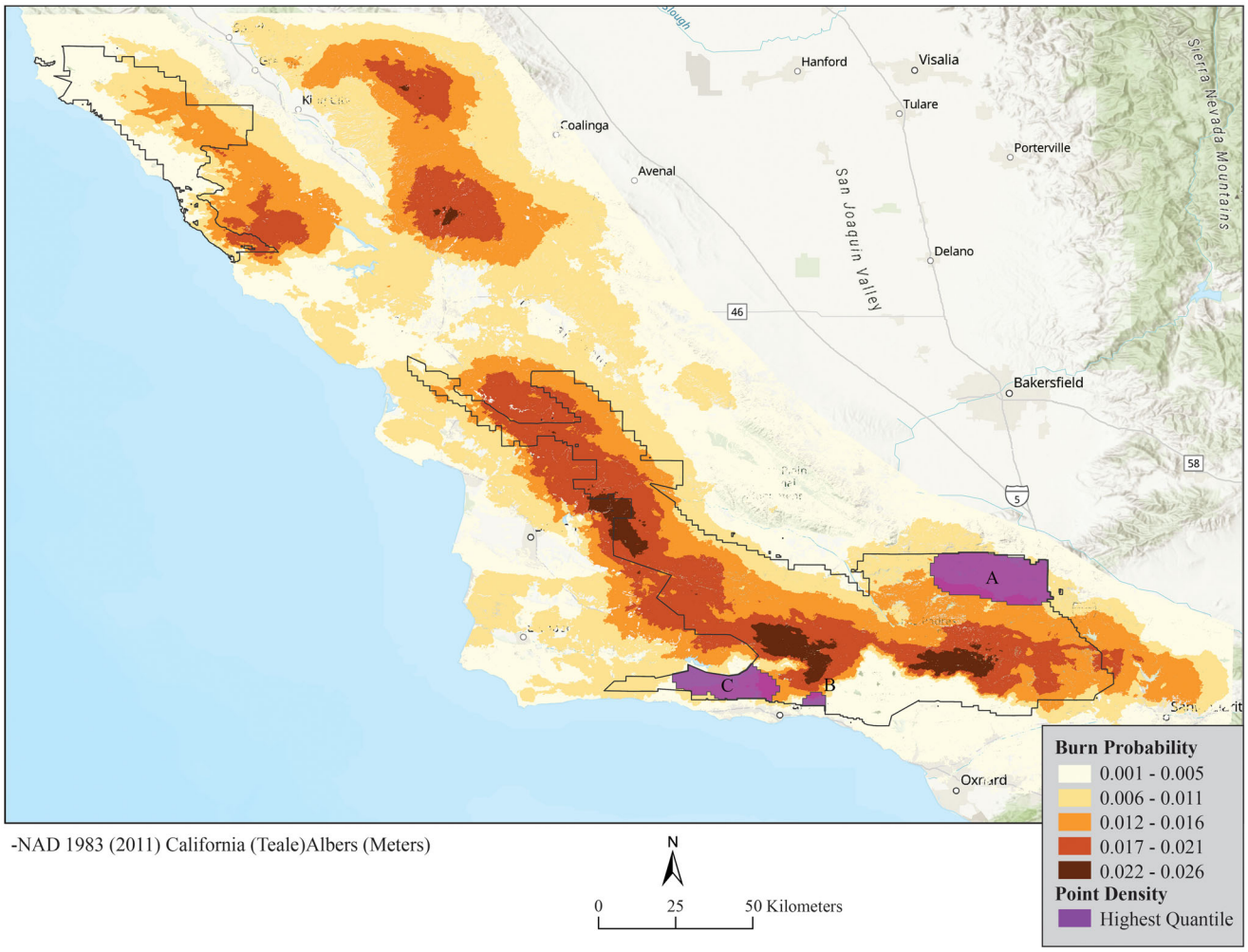

Figure 1. Burn probability and visitation analysis including Los Padres National Forest (LPNF) resident communities to understand where displacement is most likely to occur during a wildfire.

forest near Interstate 5, which spans California and connects Los Angeles to LPNF (downtown Los Angeles to LPNF is about a 1.25-hour drive in non-traffic conditions). Polygons B and C are located on the west side of LPNF near Santa Barbara County (population of 448,229; U.S. Census Bureau 2023).

Similarly, our analysis to understand socioeconomic characteristics of people potentially displaced after a wildfire (excluding residents of LPNF) identified three high-density polygons of high use that intersected with high burn probability. These polygons are denoted D, E, and F (Figure 2). Polygon D is on the east side of LPNF and is porous because it contains four of the LPNF communities removed from analysis (the fifth community is not within the six high-density polygons). Polygons A and D are in a similar geographic area that is accessible from Interstate 5. Polygon E is located on the west side of LPNF and encloses Polygons B and C. Polygon F is located near San Luis Obispo and is traversed by Highway 101 (a major north–south coastal highway).

We analyzed each polygon for size and recreation infrastructure (Table 1). Polygons A, D, and E were the largest and Polygons B and F were the smallest. Recreation opportunities differ across polygons. Polygons A and D, which are in a similar geographic area, provide many recreational opportunities for OHV recreationists, trail recreationists, and campers. Polygons C and E, which are located in a similar geographic area, primarily provide opportunities for trail recreationists.

Next, we used an automated Spectus dashboard to identify socioeconomic characteristics of people for the six polygons. Table 2 shows ethnic and

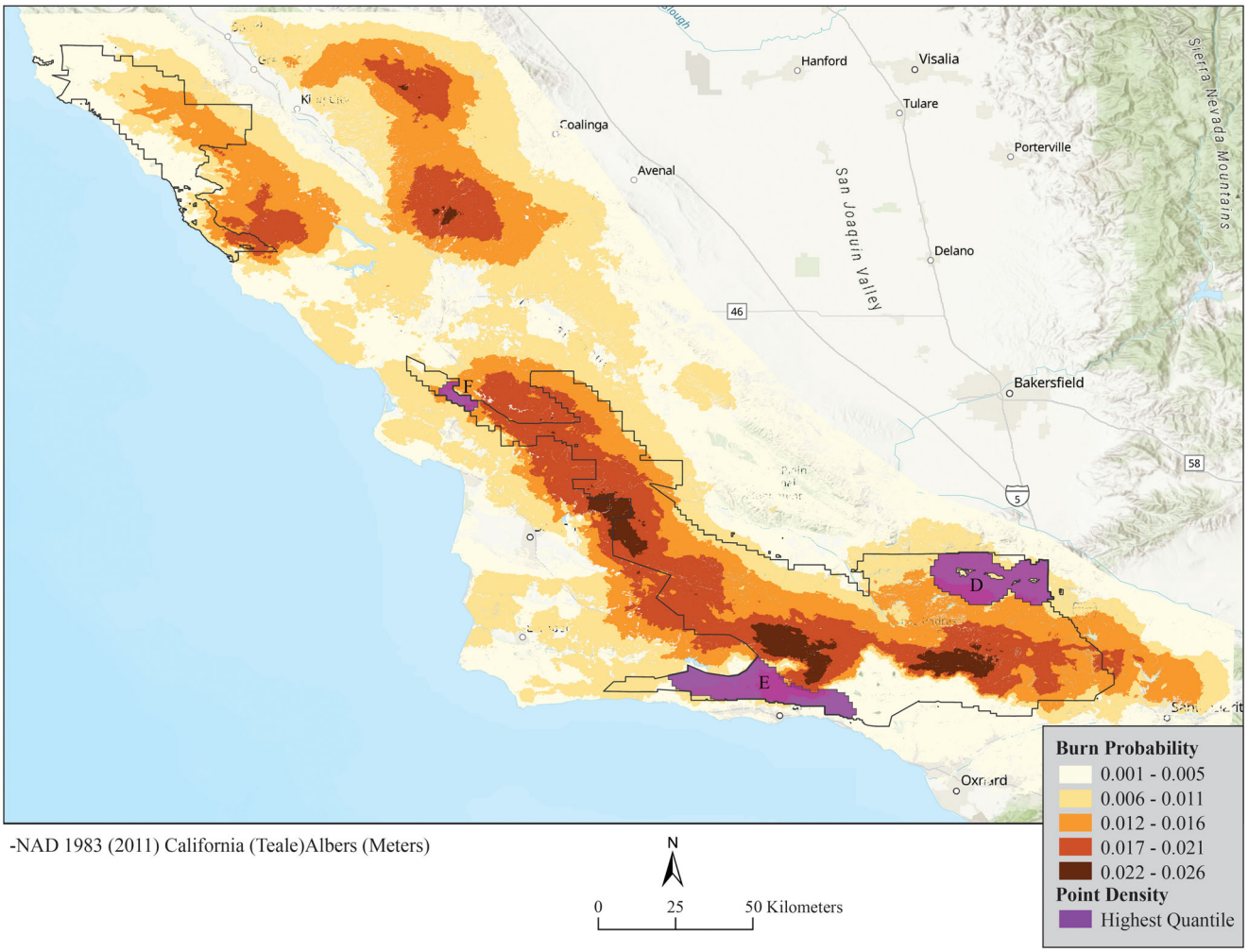

Figure 2. Burn probability and visitation analysis excluding Los Padres National Forest (LPNF) resident communities to understand where displacement is most likely to occur after a wildfire.

racial categories, median household income, primary home counties, and primary day of forest use. Across all six polygons, non-Hispanic White was the highest percentage, followed by Hispanic. Polygon B had the highest median household income, above the median household income for Santa Barbara County ($90,894; U.S. Census Bureau 2023). People who went to Polygons A and D primarily reside in Los Angeles County, suggesting they likely use Interstate 5 to access LPNF. Polygons B, C, and E are adjacent to the city of Santa Barbara, which is reflected by most of these people residing in Santa Barbara County. Polygon F is adjacent to the city of San Luis Obispo, which is reflected in most of its visitors being from San Luis Obispo County. Finally, across all six polygons, weekend use was most common.

Discussion

The purpose of this study was to identify characteristics of forest users that potentially would be displaced where high burn probability coincides with high use in the LPNF for 1 June 2022 to 31 October 2022. This information is important because when forests require immediate closure due to fire or fire risk, it is advantageous for managers to quickly construct educative and effective messaging to let recreationists know about alternative sites that maintain desired social and environmental conditions. It is challenging, though, for managers to understand who would likely be displaced and their characteristics. Thus, it is important to understand (1) which areas have high burn potential and high use; (2) characteristics of potentially displaced forest users and recreational opportunities to be maintained if

Table 1. Analysis of recreation sites

Area	Size (km^2)	Types	Notable sites
A	444.38	7 campgrounds	Campo Alto Campground
		8 trails	Cold Springs OHV Trail
		13 OHV trails	Frazier Mountain Road
B	23.48	0 campgrounds	Romero Trail
		8 trails	Divide Peak OHV trail
		1 OHV trail	
C	224.19	4 campgrounds	Los Prietos Campground
		14 trails	Jesusita Trail
		1 OHV trail	Lizard's Mouth Trail
			Romero Camuesa OHV Trail
D	399.04	7 campgrounds	Campo Alto Campground
		8 trails	Cold Springs OHV Trail
		12 OHV trails	Frazier Mountain Road
E	392.31	4 campgrounds	Los Prietos Campground
		35 trails	Cold Spring Trail
		2 OHV trails	Jesusita Trail
			Lizard's Mouth Trail
			Montecito Hot Springs Trail
			Romero Trail
			Divide Peak OHV Trail
			Romero Camuesa OHV Trail
F	42.97	0 campgrounds	Cuesta Springs Road
		0 trails	TV Tower Road
		2 OHV trails	

Note: OHV = off-highway vehicle.

displacement occurs; and (3) data that can assist with public outreach messaging, that effectively resonates with diverse populations, and that promotes alternative recreation experiences during forest closures. Although there are five resident communities within LPNF that managers can directly interact with, it is more challenging to message visitors. Thus, this discussion primarily focuses on characteristics of would-be displaced visitors.

Our study produced similar results for during a wildfire event (visitors and residents analyzed) and after a wildfire event (residents excluded from analysis). The visitors and residents scenario produced Polygons A, B, and C; the visitors-only scenario produced Polygons D, E, and F. Polygons A and D showed similar results and Polygons C and E showed similar results. Analysis of Polygons A and D showed that even though the five communities within LPNF were removed from the closure scenario, that geographic area is popular for a variety of visitors because there are lots of opportunities for OHV recreationists, trail recreationists, and campers. Additionally, this area is easily accessible from Interstate 5 for Los Angeles County residents and had the highest percentage of Hispanic visitors. If a wildfire or fire risk occurs on the east side of LPNF, managers could use this information to target Los Angeles County residents, post updates on digital signs on Interstate 5, message in English and Spanish, and connect with a variety of recreationists through Web sites, social media, and online groups, or leverage stakeholders from each of these groups or forest-wide stakeholder groups, such as the Los Padres Forest Association, to assist with messaging. Managers should be mindful of research showing that Hispanic visitors prefer developed sites so are likely more affected by degraded facilities, and might lack personal transportation (Thomas, Sánchez, and Flores 2022). Thus, if public outreach needs to occur due to a closure, managers could identify alternative sites with developed facilities that public transportation can reach within a similar travel distance (White, Winder, and Wood 2023). A similar approach can be used for the findings of Polygons C and E. Managers could target Santa Barbara County residents, transmit messages bilingually (English and Spanish), and focus on groups that use trails (e.g., hikers, backpackers, trail runners, mountain bikers). Furthermore, for all the polygons, forest use is at its highest during the weekends. Managers could use this information to message more frequently as the weekend approaches.

Polygon F had the lowest median household income ($71,517.22), but Polygon B showed the highest median household income ($105,759.38). Managers could use this information when they need to identify alternative recreation sites outside of the LPNF. For example, visitors to Polygon F likely do not have the same ability to reach alternative recreation sites as visitors to Polygon B due to potential constraints including reliance on public transportation and insufficient resources (e.g., time, money) to visit alternative sites that are farther away (Ghimire et al. 2014; Whiting et al. 2020). Managers might also want to be sensitive to the geographical locations of Polygons B, C, and E. If a nearby area of LPNF is closed, recreationists do not have as much spatial latitude to go to alternative recreation sites because they are likely from Santa Barbara County (bound between LPNF and the Pacific Ocean). It might be more difficult for these forest visitors to substitute a recreational site within a similar travel distance. The most recent visitation data for LPNF showed that

Table 2. Analysis of mobile device data

Area	Race/ethnicity	Median household income	Primary home county	Primary day of use
A	45.7% non-Hispanic White 35.4% Hispanic 10.5% Asian 4.9% Black 3.5% other	$80,012.65	38.55% Los Angeles 30.05% Kern 6.17% Ventura	17.20% Saturday 15.80% Friday 13.94% Sunday
B	60.8% non-Hispanic White 25.6% Hispanic 7.6% Asian 2.4% Black 3.6% other	$105,759.38	53.71% Santa Barbara 18.34% Ventura 5.24% Orange	16.01% Saturday 15.88% Thursday 14.72% Sunday
C	51.9% non-Hispanic White 29.0% Hispanic 10.9% Asian 4.5% Black 3.7% other	$86,560.64	25.03% Santa Barbara 18.93% Los Angeles 10.43% Ventura	18.15% Sunday 15.95% Saturday 13.60% Monday
D	45.8% non-Hispanic White 35.2% Hispanic 10.4% Asian 5.0% Black 3.6% other	$81,451.51	36.69% Los Angeles 33.95% Kern 8.02% Ventura	23.37% Saturday 17.06% Sunday 15.91% Friday
E	53.0% non-Hispanic White 28.0% Hispanic 10.8% Asian 4.5% Black 3.7% other	$87,413.07	28.16% Santa Barbara 17.57% Los Angeles 10.88% Ventura	17.28% Sunday 15.88% Saturday 13.58% Monday
F	52.2% non-Hispanic White 32.3% Hispanic 7.7% Asian 4.1% Black 3.7% other	$71,517.22	44.25% San Luis Obispo 6.85% Santa Barbara 5.10% Fresno	18.28% Friday 17.74% Saturday 14.72% Sunday

48 percent of visitors had traveled less than twenty-six miles from their house to the recreation site within the forest. Furthermore, in the event that visitation to the LPNF was not possible, 58 percent of visitors said they would be willing to travel no more than twenty-five miles to an alternative recreational destination (U.S. Forest Service 2024).

Place attachment could influence the destination choice. Dandy et al. (2019) suggested that when distances are small, such as less than twenty-five miles, place attachment could be the primary driver when choosing a destination location. Social conditions, environmental conditions, emotional connections, and functional connections that formed attachments to a place could be sought at a destination location where those conditions are recognizable. These factors are important to consider when visitors are displaced by an environmental threat (e.g., wildfire, extreme heat, drought). Place attachment is often conceptualized as a bond to visitors' immediate surroundings, but it is valuable to understand how place attachment could influence destination choice.

Future research should collect social science data at recreation sites to further understand potentially displaced users. This information would be useful for validating mobile device demographic information and could be used to socially examine users, such as users' place attachment and behavioral intentions. For example, research shows that recreationists with higher place attachment will likely experience less satisfaction with alternative sites (Perry et al. 2021). It would be beneficial for managers to be aware of these characteristics. Also, LPNF receives visitation from diverse populations in which a variety of messaging languages might be beneficial (Schwab et al. 2020). These information types could assist with the formation of effective public outreach messaging. To aid with this type of data collection, a public participation geographic information system (PPGIS)

survey could be conducted. This type of survey allows visitors to identify alternative recreation sites and answer questions (e.g., user preferences) about specific locations (Riungu et al. 2018). This type of survey is effective at understanding the spatially conditioned process (Beeco and Brown 2013) of how visitors choose recreation sites and can be implemented using intuitive software (e.g., ArcGIS Survey123). Also, a PPGIS survey could be used to understand spatial locations across various temporal scales, such as seasonal or daily. For example, a visitor might choose recreation sites depending on the season (e.g., higher elevation sites in summer, lower elevation sites in winter). Additionally, visitors could use different sites throughout the week, but each of those sites might be perceived as important to a visitor. Thus, a recreation experience is not only spatially conditioned, but also spatiotemporally conditioned (Peterson et al. 2020). Additional social science data that support this study's findings could be useful for managers to preemptively design messaging and could help with overcoming limitations of this study.

There are several limitations of using MDD. Demographic data are inferred from the census block level. This is a limitation because forest users likely are not representative of their census block. This could be overcome by validating mobile device demographic data using other data sources such as past studies of the same study area. Also, the automated Spectus dashboard lacks age and gender data. Age data would be useful for understanding which public outreach messaging mediums could be useful (e.g., Instagram, Facebook, radio, news). Additionally, MDD is biased by people who approve of mobile device applications tracking their location. It is unlikely that these people are representative of national forest users. The SOC approach is a limitation because it might have excluded any visitors who recreated in the LPNF but never stopped for at least five minutes, such as a trail runner who entered LPNF from a trail that begins outside of the forest. Future research should use MDD with caution and be aware of limitations. There are also limitations associated with our fire modeling. Only one metric of high fire potential was used—burn probability. Modeling fire events is challenging and more sophisticated than relying on a single measure. Other considerations should include canopy cover, canopy height, flame length, heat per unit area, and existing vegetation types.

In conclusion, this study identified socioeconomic characteristics of potentially displaced forest users due to wildfire or fire risk. This information is useful for assisting with public outreach messaging, which should be coupled with other types of data, such as social science and communication data (Ham 2016). Managers might need to be aware of the challenges associated with public outreach messaging during closures and consider having preemptively formulated messaging strategies.

Disclosure Statement

No potential conflict of interest was reported by the authors.

Funding

Funding was provided by the U.S. Department of Agriculture Forest Service (Agreement 22-JV-11272131-011).

ORCID

Brian A. Peterson http://orcid.org/0000-0003-1488-9798
Elizabeth E. Perry http://orcid.org/0000-0002-7992-6345

References

Beeco, J. A., and G. Brown. 2013. Integrating space, spatial tools, and spatial analysis into the human dimensions of parks and outdoor recreation. *Applied Geography* 38:76–85. doi: 10.1016/j.apgeog.2012.11.013.

Cattau, M. E., C. Wessman, A. Mahood, and J. K. Balch. 2020. Anthropogenic and lightning-started fires are becoming larger and more frequent over a longer season length in the USA. *Global Ecology and Biogeography* 29 (4):668–81. doi: 10.1111/geb.13058.

Creany, N. E., C. A. Monz, A. D'Antonio, A. Sisneros-Kidd, E. J. Wilkins, J. Nesbitt, and M. Mitrovich. 2021. Estimating trail use and visitor spatial distribution using mobile device data: An example from the nature reserve of Orange County, California USA. *Environmental Challenges* 4:100171. doi: 10.1016/j.envc.2021.100171.

Dandy, J., P. Horwitz, R. Campbell, D. Drake, and Z. Leviston. 2019. Leaving home: Place attachment and decisions to move in the face of environmental change. *Regional Environmental Change* 19 (2):615–20. doi: 10.1007/s10113-019-01463-1.

Finney, M. A. 2006. An overview of FlamMap fire modeling capabilities. In *Fuels management—How to measure success: Conference proceedings*, ed. P. L. Andrews and B. W. Butler, 28–30. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Ghimire, R., G. T. Green, N. C. Poudyal, and H. K. Cordell. 2014. An analysis of perceived constraints to outdoor recreation. *Journal of Park and Recreation Administration* 32 (4):52–67.

Ham, S. 2016. *Interpretation: Making a difference on purpose*. Golden, CO: Fulcrum.

Jean, R., K. Naka, C. S. Christian, B. R. Gyawali, T. Bowman, and S. Hopkinson. 2022. Identifying primary drivers of participants from various socioeconomic backgrounds to choose national forest lands in the Southeastern Region of the US as a travel destination for recreation. *Land* 11 (8):1301. doi: 10.3390/land11081301.

Jenkins, J., J. Abatzoglou, E. Wilkins, and E. E. Perry. 2023. Visitation to national parks in California shows annual change and seasonal adaptation during extreme drought and wet years. *PLoS Climate* 2 (8):e0000260. doi: 10.1371/journal.pclm.0000260.

Keane, R. E., S. A. Drury, E. C. Karau, P. F. Hessburg, and K. M. Reynolds. 2010. A method for mapping fire hazard and risk across multiple scales and its application in fire management. *Ecological Modelling* 221 (1):2–18. doi: 10.1016/j.ecolmodel.2008.10.022.

Lawson, S., C. Monz, and A. Larkin. 2023. Passive mobile data analysis of visitor use in parks and protected areas: Prospects and challenges. *Journal of Park & Recreation Administration* 41 (4):95–104.

Liang, Y., J. Yin, B. Pan, M. S. Lin, L. Miller, B. D. Taff, and G. Chi. 2022. Assessing the validity of mobile device data for estimating visitor demographics and visitation patterns in Yellowstone National Park. *Journal of Environmental Management* 317:115410. doi: 10.1016/j.jenvman.2022.115410.

Los Padres ForestWatch. 2013. Fire in our region. Accessed December 27, 2023. https://lpfw.org/fire/.

Manning, R. E., M. Budruk, K. Goonan, J. Hallo, D. Laven, S. Lawson, R. Stanfield McCown, L. Anderson McIntyre, B. Minteer, P. Newman, et al. 2022. *Studies in outdoor recreation: Search and research for satisfaction*, 4th ed. Corvallis: Oregon State University Press. https://osupress.oregonstate.edu/book/studies-in-outdoor-recreation-1.

Monz, C., N. Creany, J. Nesbitt, and M. Mitrovich. 2021. Mobile device data analysis to determine the demographics of park visitors. *Journal of Park & Recreation Administration* 39 (1):123–30.

National Park Service. 2018. Wildland fire in chaparral: California and southwestern United States. Accessed December 27, 2023. https://www.nps.gov/articles/wildland-fire-in-chaparral.htm#:~:text=One%20chaparral%20plant%2C%20ceanothus%2C%20has,and%20resins%20in%20their%20leaves.

Perry, E. E., X. Xiao, J. M. Nettles, T. A. Iretskaia, and R. E. Manning. 2021. Park visitors' place attachment and climate change-related displacement: Potential shifts in who, where, and when. *Environmental Management* 68 (1):73–86. doi: 10.1007/s00267-021-01480-z.

Peterson, B. A., E. E. Perry, M. T. Brownlee, and R. Sharp. 2020. The transient nature of concentrated use at a national park: A spatiotemporal investigation into visitor behavior. *Journal of Outdoor Recreation and Tourism* 31:100310. doi: 10.1016/j.jort.2020.100310.

Riungu, G. K., B. A. Peterson, J. A. Beeco, and G. Brown. 2018. Understanding visitors' spatial behavior: A review of spatial applications in parks. *Tourism Geographies* 20 (5):833–57. doi: 10.1080/14616688.2018.1519720.

Rollins, M. G. 2009. Landfire: A nationally consistent vegetation, wildland fire, and fuel assessment. *International Journal of Wildland Fire* 18 (3):235–49. doi: 10.1071/WF08088.

Schwab, K., W. W. Hendricks, J. B. Greenwood, M. Goldenberg, B. Greenwood, and L. Higgins. 2020. Connecting with nature in the digital age: Intentions of adolescents in California urban areas. *Journal of Park and Recreation Administration* 38 (1):29–49.

Scott, J. H., and R. E. Burgan. 2005. Standard fire behavior fuel models: A comprehensive set for use with Rothermel's surface fire spread model. Gen. Tech. Report RMRS-GTR-153, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Spectus. 2023. Turning location data into actionable intelligence. Accessed January 2, 2024. https://spectus.ai/.

Thomas, A. S., J. J. Sánchez, and D. Flores. 2022. A review of trends and knowledge gaps in Latinx outdoor recreation on federal and state public lands. *Journal of Park and Recreation Administration* 40:24–43. doi: 10.18666/JPRA-2021-11064.

Thompson, M. P., K. C. Vogler, J. H. Scott, and C. Miller. 2022. Comparing risk-based fuel treatment prioritization with alternative strategies for enhancing protection and resource management objectives. *Fire Ecology* 18 (1):26. doi: 10.1186/s42408-022-00149-0.

U.S. Census Bureau. 2023. Santa Barbara County, California. Accessed January 3, 2024. https://data.census.gov/profile險g=050XX00US06083.

U.S. Forest Service. 2023. Campground camping. Accessed January 3, 2024. https://www.fs.usda.gov/activity/lpnf/recreation/camping-cabins/險 recid=10902&actid=29.

U.S. Forest Service. 2024. Visitor use report: Los Padres National Forest, USDA Forest Service, Region 5. National visitor use monitoring data collected FY2019. Accessed August 24, 2024. https://apps.fs.usda.gov/nvum/results/ReportCache/2019_A05007_Master_Report.pdf.

U.S. Forest Service. n.d. Picnicking. Accessed August 30, 2024. https://www.fs.usda.gov/activity/lpnf/recreation/picnickinginfo/險recid=10902&actid=70.

Westerling, A. L., D. R. Cayan, T. J. Brown, B. L. Hall, and L. G. Riddle. 2004. Climate, Santa Ana winds and autumn wildfires in southern California. *Eos: Transactions of the American Geophysical Union* 85 (31):289–96. doi: 10.1029/2004EO310001.

White, E. M., S. G. Winder, and S. A. Wood. 2023. Applying novel visitation models using diverse social media to understand recreation change after wildfire and site closure. *Society & Natural Resources* 36 (1):58–75. doi: 10.1080/08941920.2022.2134531.

Whiting, J. W., L. R. Larson, C. Greenwood, and S. Lankford. 2020. Public parks and sno-parks help diverse populations in California's Central Valley negotiate constraints to winter recreation. *Journal of Park and Recreation Administration* 39 (4):41–62. doi: 10.18666/JPRA-2020-10161.

Whitney, P., W. L. Rice, J. Sage, J. M. Thomsen, I. Wheeler, W. Freimund, and E. Bigart. 2023. Developments in big data for park management: A review of mobile phone location data for visitor use management. *Landscape Research* 48 (6):758–76. doi: 10.1080/01426397.2023.2198762.

Winter, P. L., J. J. Sánchez, and D. D. Olson. 2021. Effects of climate change on outdoor recreation in the Sierra Nevada. In *Climate change vulnerability and adaptation for infrastructure and recreation in the Sierra Nevada*, ed. J. E. Halofsky, D. L. Peterson, L. Buluç, and J. Ko, 181–244. USDA Forest Service, Gen. Tech. Report GTR-PSW-272, Pacific Southwest Research Station, Albany, CA.

Xiang, L., M. Gao, and T. Wu. 2016. Extracting stops from noisy trajectories: A sequence oriented clustering approach. *ISPRS International Journal of Geo-Information* 5 (3):29. doi: 10.3390/ijgi5030029.

BIJAN GURUNG is a PhD Candidate in the Department of Horticulture and Natural Resources at Kansas State University, Manhattan, KS 66502. E-mail: bijangurung@ksu.edu. His research interests include applying geospatial science to parks and forest management, as well as using discrete choice experiments in forest recreation.

BRIAN A. PETERSON is an Assistant Professor in the Department of Horticulture and Natural Resources at Kansas State University, Manhattan, KS 66506. E-mail: brianpeterson@ksu.edu. His research interests include the integration of social, spatiotemporal, and geographic data to understand human behavior and experiences in parks and protected areas.

SEAN FLEMING is a U.S. Department of Agriculture Forest Service ORISE Research Fellow at the Pacific Southwest Research Station, Riverside, CA 92507. E-mail: Sean.Fleming2@usda.gov. His research focuses on using GIS and remote sensing to analyze forest disturbance.

STACY DRURY is a Research Fire Ecologist with the U.S. Department of Agriculture Forest Service Pacific Southwest Research Station, Forestville, CA 95436. E-mail. stacy.a.drury@usda.gov. His research focuses on modeling fire behavior and fire effects with an emphasis on understanding the drivers of fire severity to predict fire severity of future wildfires.

ALYSSA THOMAS is a Social Science Analyst with the U.S. Department of Agriculture Forest Service Pacific Southwest Research Station, Riverside, CA 92507. E-mail: alyssa.thomas@usda.gov. Her research focuses on public outreach communications during severe weather events including how people interpret and respond to messaging.

JOSÉ J. SÁNCHEZ is a Research Economist with the U.S. Department of Agriculture Forest Service Pacific Southwest Research Station, Riverside, CA 92507. E-mail: jose.sanchez2@usda.gov. His research focuses on outdoor recreation and how forest disturbances affect recreation demand.

ELIZABETH E. PERRY is an Assistant Professor in the Department of Community Sustainability at Michigan State University, East Lansing, MI 48824. E-mail: eeperry@msu.edu. Her research addresses sustainable protected area management, outdoor recreation, and local community connections with both, assisting decision-makers in addressing challenges in and beyond parks, such as relevance and inclusion, collaboration, and climate change.