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Intensifying Fire Season Aridity Portends Ongoing Expansion of Severe Wildfire in Western US Forests

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ABSTRACT

Area burned by wildfire has increased in western US forests and elsewhere over recent decades coincident with warmer and drier fire seasons. However, *high–severity fire*—fire that kills all or most trees—is arguably a more important metric of fire activity given its destabilizing influence on forest ecosystems and direct and indirect impacts to human communities. Here, we quantified area burned and area burned severely in western US forests from 1985 to 2022 and evaluated trends through time. We also assessed key relationships between area burned, extent and proportion burned severely, and fire season climate aridity. Lastly, using the strong relationships between fire season aridity and both area burned and area burned severely, we predicted future fire activity under ongoing warming. While annual area burned increased 10-fold over our study period, area burned severely increased 15-fold. Disproportionate increases in severe fire occurred across a wide range of forest types from 1985 to 2022. Importantly, we found that the proportion of area burned severely increased with fire extent at the scale of individual fires and total annual area burned. The relationships between fire season aridity and fire were strong, and our models predicted further increases in fire activity, leading to 2.9- and 4-fold increases in area burned and area burned severely, respectively, under mid-21st century climate. Without a substantial expansion of management activities that effectively reduce fire severity (e.g., thinning of understory and fire-intolerant trees combined with prescribed fire), wildfires will increasingly drive forest loss and degrade ecosystem services including carbon storage, biodiversity conservation, and water yield, with major impacts to human communities.

1 | Introduction

Increasing fire activity associated with climate warming threatens ecological and human communities across many regions of Earth (Nolan et al. 2022). Annual area burned by wildfire has expanded rapidly across western US forests and elsewhere in North America over recent decades (Donovan et al. 2023; Hanes et al. 2019; Jain et al. 2024; Parks and Abatzoglou 2020). Large and fast-growing wildfires are increasingly impacting people through fatalities, excessive smoke, loss of homes and infrastructure, diminished water quality, and massive economic costs (Balch et al. 2024; Burke et al. 2023; Higuera et al. 2023; Kramer et al. 2019). Although metrics such as annual area burned and fire size are important indicators of fire activity—and often capture media attention—they may not reflect the effects of fire on ecosystems, which depend largely on fire severity.

High–severity fire, as defined here and in numerous other studies (e.g., Williams et al. 2023), is a fire that kills all or most trees, while a low–severity fire is one in which most trees survive (Figure 1). Many western US forests historically experienced frequent, low–severity fire (e.g., ponderosa pine

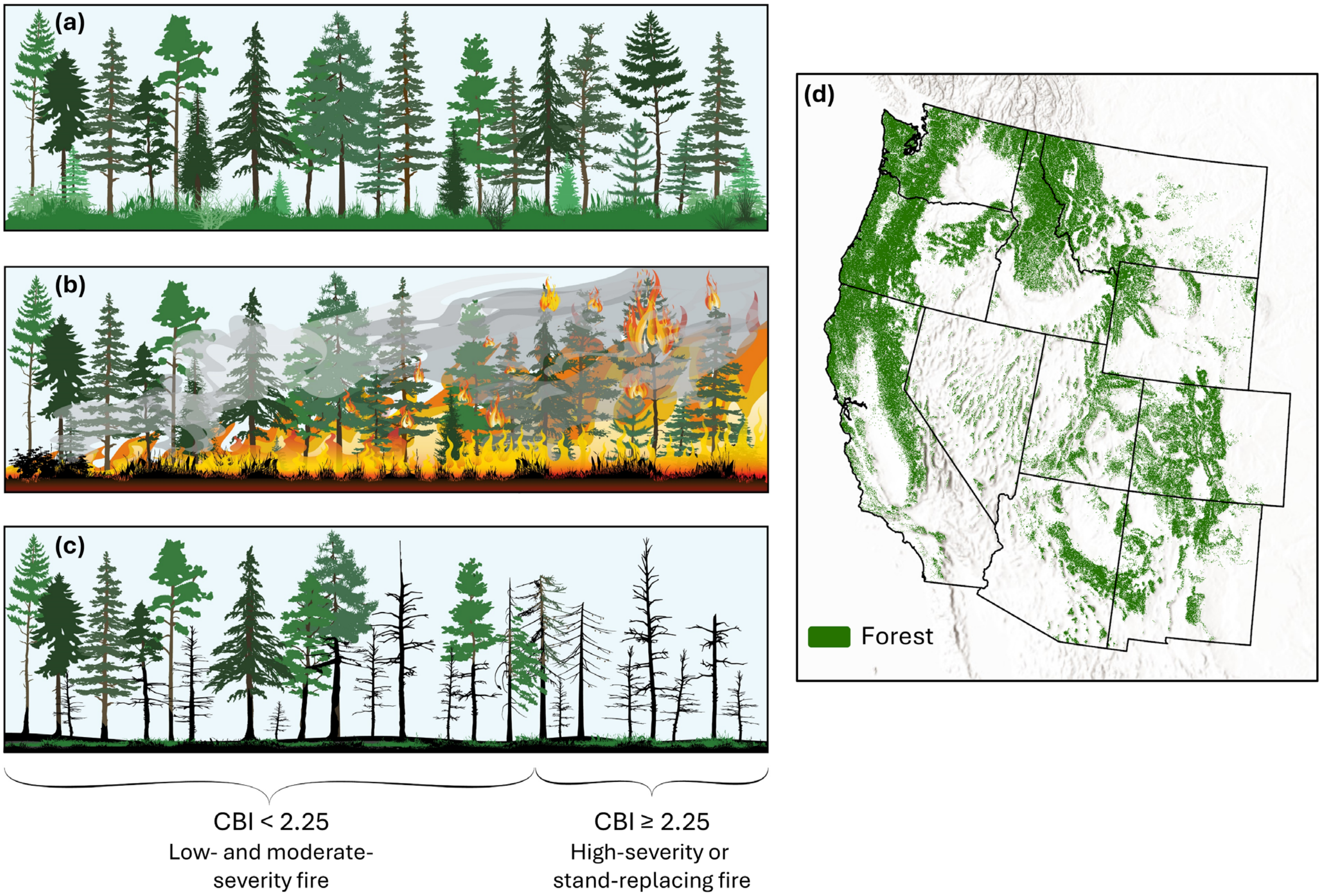

FIGURE 1 | Graphical depiction of high–severity fire, or stand-replacing fire, in the context of our study (a–c). Here, the forest (a) experiences increasing flame lengths from left to right, corresponding with increasing canopy fuel consumption, tree mortality, and fire severity (b). High–severity fire corresponds to a composite burn index (CBI) ≥ 2.25 (c). Study area showing forests in the western US (d).

and dry mixed-conifer forests), which can increase resistance to drought, insect outbreaks, and the inevitable next wildfire (Coppoletta et al. 2016; Hood et al. 2015; Norlen et al. 2024), thereby serving as a strong foundation for implementing prescribed fire (Davis et al. 2024). High–severity fire in these forest types can lead to long-term forest loss or conversion (Coop et al. 2020; Falk et al. 2022). In other forest types (e.g., spruce-fir forests), fire was historically infrequent and high-severity, but even in these systems, more frequent fire and arid post-fire climate can overcome forest resilience (Busby et al. 2020; Hansen and Turner 2019; Hoecker and Turner 2022; Whitman et al. 2019). Accordingly, understanding trends in high-severity fire is critical to assessing fire's growing impact on mature and old-growth trees, carbon storage, watershed function, ecosystem transformation, and habitat for threatened, forest-dependent species (Liang et al. 2018; Moody et al. 2013; Steel et al. 2022; Tepley et al. 2017). Furthermore, projections of future area burned severely could inform pre-fire management needs such as ecologically based forest thinning (i.e., removal of understory and fire-intolerant trees) and prescribed fire, and post-fire restoration needs relative to capacity (Dobrowski et al. 2024; Francis et al. 2023; Hurteau, North, et al. 2019; Keenan 2015).

Models predict that area burned by wildfire in western US forests will roughly double by mid-21st century (Abatzoglou, Battisti, et al. 2021; Coop et al. 2022). Likewise, annual area burned by high–severity fire (hereafter 'area burned severely') increased 8-fold in western US forests from 1985 to 2017 (Parks and Abatzoglou 2020). Despite clear links to climate (Mueller et al. 2020), however, there have been no studies that project area burned severely into the future. Increasing aridity and extreme fire weather promote not only more extensive fire but can also produce more severe fire (Abatzoglou and Williams 2016; Parks, Holsinger, et al. 2018). Thus, we might expect disproportionate increases in high–severity fire as area burned increases under warming. Regional studies indicate that high–severity patch size scales with total fire size (Buonanduci et al. 2023) and that annual proportion burned severely increases with annual area burned (Reilly et al. 2017) in the Pacific Northwest. Whether or not these relationships hold up over broader extents (e.g., all western US forests) remains unknown, but if so, would indicate that predictions of expanding area burned under future climate in fact understate the potential ecological impacts of future fire.

The availability of cloud-based computing and satellite imagery (Gorelick et al. 2017), code to automate fire severity calculations (Parks, Holsinger, et al. 2019), and gridded climate data (Abatzoglou et al. 2018) facilitate analysis of trends in and projections of wildfire activity over large temporal and spatial extents. As such, the specific goals of this study are to: (1) quantify trends of area burned and area burned severely from 1985 to

2022 for western US forests, (2) assess key relationships between area burned, extent, and proportion burned severely, and fire season climate aridity, and (3) based on observed fire–climate relationships, project mid-21st century annual area burned and area burned severely. A better understanding of high-severity trends through time, relationships to climate, and mid-21st century projections will help land management agencies and society better prepare for future wildfires and their effects on forest ecosystems and people.

2 | Methods

2.1 | Fire and Climate Data

Gridded fire severity data (resolution = 30 m) for all fires ≥ 400 ha (Picotte et al. 2020) that burned from 1985 to 2022 in the western US (Figure S1) were produced in Google Earth Engine (Gorelick et al. 2017) using the code developed and distributed by Parks, Dobrowski, et al. (2019). Briefly, this Earth Engine procedure uses pre- and post-fire Landsat satellite imagery to map the predicted composite burn index (CBI) using a model developed with field-derived CBI data from > 250 fires across North America. The field-based CBI was developed as a composite measure of fire severity that rates > 20 individual factors such as duff consumption, char height, and canopy mortality (Key and Benson 2006). Modeled CBI closely replicates this field-based measure of fire severity across a variety of forest types; the cross validated $R^2 = 0.72$ across 263 fires (8075 CBI plots) spanning the United States and Canada (Parks, Holsinger, et al. 2019). Prescribed fires, which generally do not burn severely, were included in our study because they are an important component of the contemporary fire regime, and we did not want to bias our study toward a higher proportion burned severely. Prescribed fires represent 2.2% of the total area burned in this study.

We masked out non-forested pixels across all fires using two criteria. First, those pixels not classified as conifer, hardwood, hardwood-conifer, or conifer-hardwood according to the Biophysical Settings (BpS) gridded product produced and distributed by Landfire (www.landfire.gov) were excluded. Second, pixels with < 10% canopy cover according to the Rangeland Analysis Platform's (RAP) (Jones et al. 2021; www.rangelands.app) gridded annual tree cover product were excluded. For this step, the annual tree cover from the year prior to the fire was used. We used both Landfire BpS and RAP canopy cover to reduce the effect of misclassification errors in each dataset; this is intended to reduce the probability that non-forest pixels are included in our analyses. However, as RAP tree cover datasets were not available for 1984 and 1985 (as pre-fire screening for 1985 and 1986 fires, respectively), we used the mean pre-fire NDVI value that corresponded to 10% RAP canopy cover for fires that burned from 1987 to 2021; we then applied this pre-fire NDVI threshold to fires from 1985 and 1986 to mask out non-forest pixels. As such, we excluded all pixels with a pre-fire NDVI ≤ 0.32 for fires in 1985 and 1986; these years (1985 and 1986) account for only about 1% of total area burned from 1985 to 2022. Following Miller, Knapp, et al. (2009), we then labeled burned pixels with CBI ≥ 2.25 as *high–severity fire* (or stand-replacing fire); this threshold corresponds to ≥ 95% overstory canopy mortality (Figure 1).

Climate for each fire season across the western US was characterized using three variables: vapor pressure deficit (VPD), mean maximum monthly temperature (T_{max}), and climatic water deficit (CWD), all averaged over the June–August time period across the western US. These gridded climate variables were obtained from TerraClimate (Abatzoglou et al. 2018), which distributes monthly data from 1958 to present. The annual values were then converted to standardized z-scores using the mean and standard deviation of the 1961–1990 reference period. Following previous studies (Abatzoglou and Williams 2016; Coop et al. 2022), we developed a single synthetic variable by averaging the VPD, T_{max}, and CWD z-scores for each year. In doing so, we recognize that multiple temperature and moisture variables shape fire activity through distinct influences on fire season length, fuel moisture, and atmospheric conditions during fire. Combining these into a single synthetic predictor accounts for how variation in each may enhance or diminish the effects of others (e.g., warm and dry vs. cool and dry fire seasons). Hereafter, this synthetic variable is referred to as 'fire season aridity'.

Monthly climate representing mid-21st century conditions was also acquired from TerraClimate (Abatzoglou et al. 2018). These data reflect a 2°C increase in global mean temperature above pre-industrial levels that is likely to manifest by mid-21st century without immediate and massive changes in international climate policies (Friedlingstein et al. 2014). TerraClimate uses the observed interannual variability from 1986 to 2015 to produce multi-model mean monthly projections for 30 individual years representing mid-21st century climate as defined by a 2°C increase in global mean temperature (Qin et al. 2020). We then averaged the three annual mid-21st century climate metrics from June–August, converted them to z-scores based on the 1961–1990 reference period, and averaged these annual z-scores to project future fire season aridity.

2.2 | Analyses

To evaluate trends in area burned and area burned severely over time, we annually summarized the area of all forested pixels burned at (a) any severity (CBI 0–3) and (b) high severity (CBI ≥ 2.25). Trends and significance (two-sided Mann–Kendall test) were evaluated using the Theil-Sen slope estimator using a combination of the 'zyp' and 'trend' packages in the R statistical platform (R Core Team 2020). Area burned and area burned severely were log transformed for the trend analyses because they are well understood to be log-normally distributed (e.g., Higuera et al. 2023); this approach also mimics previous studies (Abatzoglou, Juang, et al. 2021; Parks and Abatzoglou 2020). Trend lines were backtransformed for visualization purposes. Using the Theil-Sen intercept and slope, we quantified increases from 1985 to 2022 by dividing the modeled 2022 value by the modeled 1985 value. We also conducted trend analyses on each Landfire 'fire regime group' (FRG) (Blankenship et al. 2021). Here, fire regime group 1 (FRG1) corresponds to a historical fire regime characterized by frequent (≤ 35-year fire return interval [FRI]), low–severity fire; fire regime group 3 (FRG3) corresponds to a historical fire regime characterized by infrequent (36–200-year FRI), mixed–severity fire; fire regime group 4 (FRG4) corresponds to a historical fire regime characterized by infrequent (36–200-year FRI), stand-replacing fire; fire regime group 5 (FRG5) corresponds to a historical fire regime characterized by very infrequent (200+ year FRI), stand-replacing fire. The results for individual FRGs are presented in Figure S2.

To gain a better understanding of expanding fire activity and its outcomes (i.e., severity) under a warming climate, we conducted subsequent analyses. For example, as it is still unclear how area burned relates to fire severity, we produced a model explaining annual proportion burned severely as a function of annual area burned, which we tested using linear regression. We then showed proportion burned severely (with interquartile range) as a function of binned fire size and illustrated how annual median fire size has changed through time from 1985 to 2022, which we statistically analyzed using the Theil-Sen slope estimator as described above. We also illustrated the relationship between fire season aridity and median fire size using linear regression.

To make predictions of annual area burned under continued climate warming and reflective of mid-21st century climate, we built a linear model of annual area burned (logged) as a function of fire season aridity for the 1985–2022 time period. We then used this model to predict annual area burned under the mid-21st climatic conditions. We compared the mean of mid-century predictions to mean model predictions from 1985 to 2022. We used the same approach for area burned severely.

As the observed fire data reflects that recently burned areas are less likely to burn again in short succession (e.g., Parks, Parisien, et al. 2018), predictions of mid-21st century fire activity implicitly incorporate recent feedbacks that may dampen future fire activity as area burned increases. Even though such feedbacks are unlikely to have substantial effects on future area burned over broad spatial extents (Abatzoglou, Battisti, et al. 2021; Buma et al. 2020; Hurteau, Liang, et al. 2019), they could have impacts on *forest* area burned and area burned severely given that increasing fire activity may erode forest extent (Parks, Dobrowski, et al. 2019; Rodman et al. 2022). As such, we also produced parallel models of annual percent forest area burned and burned severely under recent climate, and used these to predict these same metrics under mid-21st century climate conditions using the 'betareg' package (Zeileis et al. 2016) in R. Annual forest cover is defined by Landfire Biophysical Setting (landfire.gov) and the annual tree cover product from the Rangeland Analysis Platform (Jones et al. 2021), as previously described.

3 | Results

Annual area burned and area burned severely have increased markedly from 1985 to 2022 in western US forests (Figure 2; $p < 0.001$). In fact, annual area burned exhibited a 10-fold increase and area burned severely a 15-fold increase from 1985 to 2022. Strikingly, over 16,000 km^2 of forest in the western US burned in each of 2020 and 2021; of which, 46% and 36% burned severely, respectively (Figure 2). We also quantified these trends for each ‘fire regime group’ (FRGs) (Figure S1a) to gain a better understanding how these trends may vary among broad forest types. In doing do, similar increases in area burned and area burned severely were observed across each FRG over the study period, with disproportionate increases in area burned severely (Figure S2).

We found that annual proportion burned severely across western US forests increased with annual area burned (Figure 2b). This relationship is mirrored at the scale of individual fires: as fire size increases, so too does the proportion burned severely (Figure 3a). Annual median fire size also increased through time (Figure 3b) and with fire season aridity (Figure S3). Collectively, these relationships indicate that not only are warmer, drier conditions linked to increasing fire size, but additionally, these larger fires are associated with a larger proportion burning severely (Figure 3a,c,d). Finally, we found strong positive

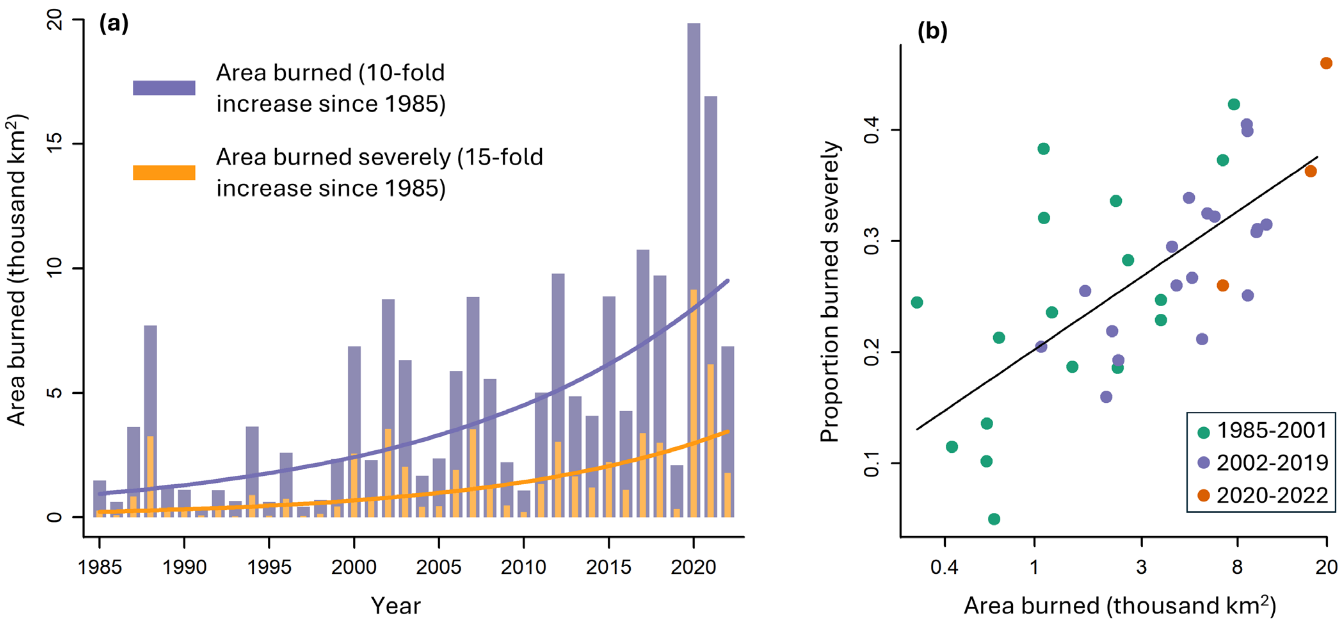

FIGURE 2 | Area burned and area burned severely from 1985 to 2022 in western US forests (a). Smooth lines show the Theil-Sen model fit (back-transformed) which is used to calculate the overall increase in area burned and high–severity area burned from 1985 to 2022. Proportion burned at high severity as a function of annual area burned (b).

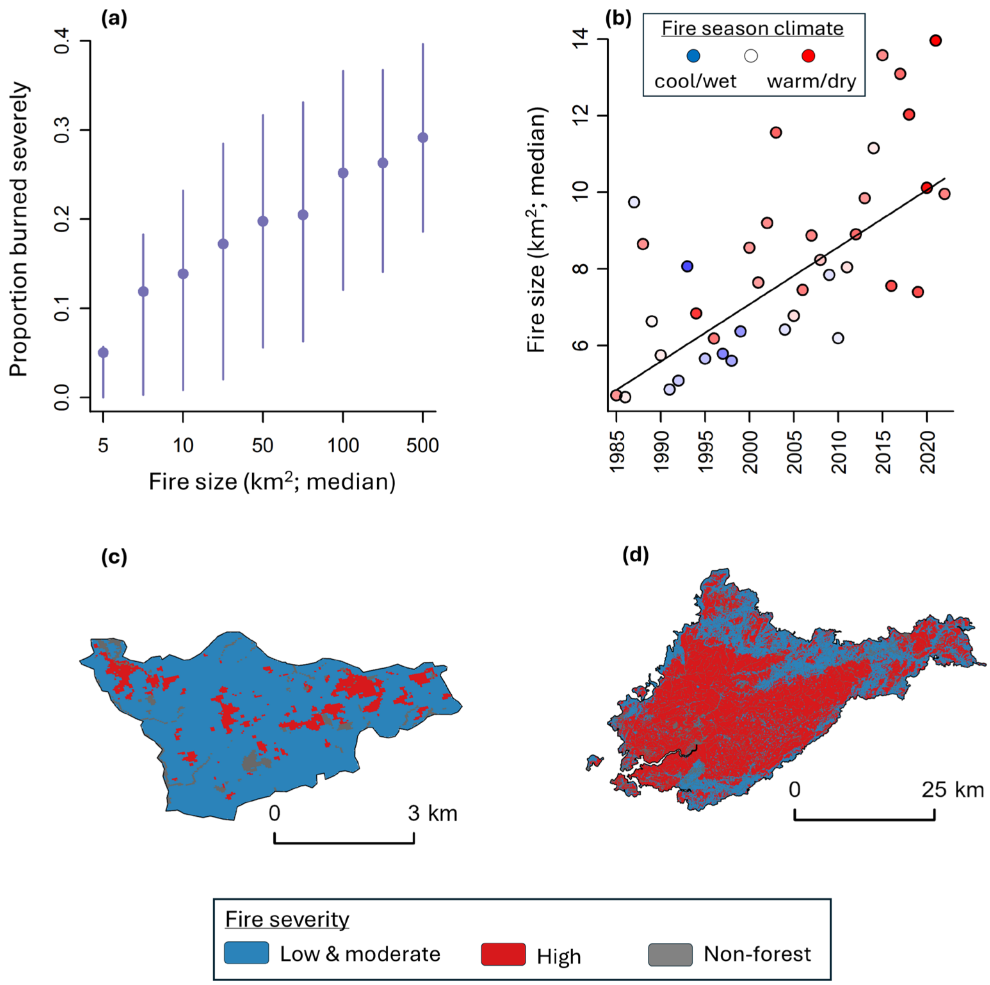

FIGURE 3 | Key relationships among fire size, proportion burned severely, and time. Proportion burned at high severity as a function of fire size (binned; interquartile range shown by vertical lines) (a) showing how larger fires tend to have proportionally more high–severity fire. Median fire size by year (b); fire size increases through time ($p < 0.001$). Only forested pixels are used in the calculation of fire size, thereby maintaining consistency among all analyses; fires with < 100 ha (1 km^2) of forest cover are excluded. Example of a smaller fire with low proportion burned severely (0.11): The 1999 High Complex Fire burned 1332 ha in California (c). Example of a very large fire with high proportion burned severely (0.59): The 2020 North Fork Complex burned 128,101 ha in California (d).

relationships between fire season aridity and both annual area burned and area burned severely (Figure 4; Figure S4).

The strong relationships between fire season aridity and both area burned and area burned severely ($r^2 = 0.61$ and 0.63, respectively) allowed us to make predictions under mid-21st century climate. The models predict continued growth in fire activity, leading to a 2.9- and 4-fold increase in average annual area burned and area burned severely by mid-21st century, respectively, compared to modeled burned area averages from 1985 to 2022 (Figure 5), noting there is uncertainty in the observed relationships and mid-21st century predictions (Figure S4). The average predicted area burned and area burned severely under mid-21st century conditions are approximately equal to that observed in 2020 and 2021 (Figure 5a,c), suggesting that years like these will potentially become a 'new normal'. Further, area burned and area burned severely during exceptionally warm and dry fire seasons under mid-century climate are predicted to far exceed anything observed even in 'record-breaking' years of recent decades (Figure 5b,d). To account for any fire-catalyzed forest loss that may influence these projections, we also produced parallel models of annual *percent* forest burned and burned severely as a function of fire season aridity (Figure S5). We used these models to predict these same metrics under mid-21st century climate conditions. These models also predict continued growth in fire activity, leading to a 2.4- and 2.6-fold increase in average annual percent forest burned and burned severely by mid-21st century, respectively (Figure S6).

4 | Discussion

Annual area burned and area burned severely have increased 10- and 15-fold, respectively, from 1985 to 2022. As these increases are themselves nonlinear (Figure 2a; Figure S2) and result from non-linear relationships with fire-season climate (Figure 4; Figure S7) (Abatzoglou, Battisti, et al. 2021), our models predict that continued climate change is expected to drive additional growth in fire activity, potentially leading to a 2.9-fold increase in area burned and a 4-fold increase in area burned severely by mid-21st century (relative to 1985–2022 averages) (Figure 5). Extraordinary fire years like 2020 and 2021 (Francis

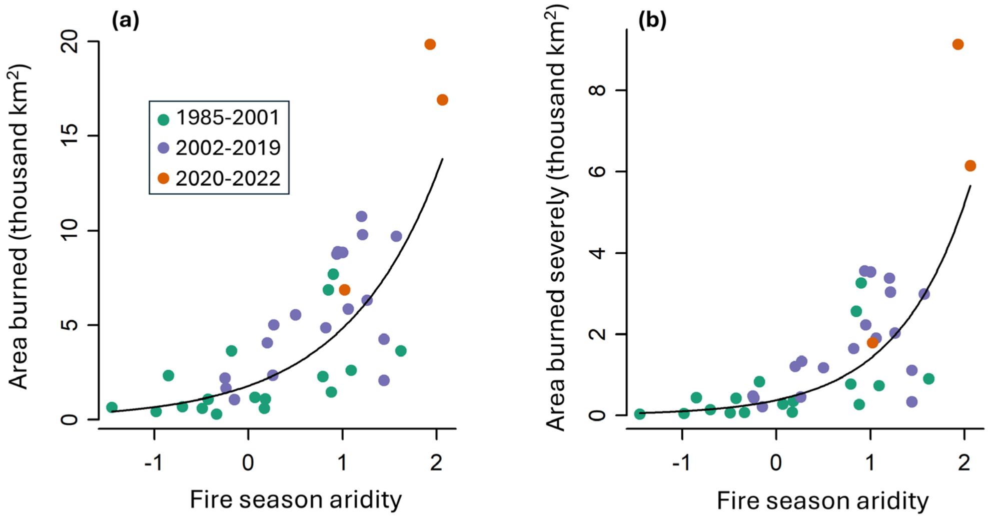

FIGURE 4 | The relationships between area burned and fire season aridity (a) and area burned severely and fire season aridity (b). Smooth black lines (a, b) show back-transformed model fit between log-transformed area burned (and area burned severely) and fire season aridity. These models were used to project mid-21st century outcomes (Figure 5).

et al. 2023; Higuera and Abatzoglou 2021; Jain et al. 2024) are expected to represent average fire years by mid-21st century, with some years projected to produce far more area burned and area burned severely than anything experienced in recent decades (Figure 5). Given that communities, firefighters, emergency services, and post-fire restoration capacity are not currently equipped to respond to years like 2020 and 2021 on an annual basis (Dobrowski et al. 2024; Spearing and Faust 2020; Thompson et al. 2023), our findings imply major challenges in years ahead.

As annual area burned increases, the annual proportion burning at high severity also increases (Figure 2b), thus amplifying the social and ecological impacts resulting from fire and forest loss. Previous research has shown that fire growth rates are increasing (Balch et al. 2024) and faster growing fires also burn more severely (McFarland et al. 2025). This is likely because the same kinds of fires that burn forests most rapidly, running crown fires, are also the most lethal to trees. Here, we found that relationships between fire size and severity scale from individual fires to annual area burned across western US forests. As we also show that fire size increases with fire season aridity (Figure S3) and through time (Figure 3b), our results highlight a potential mechanism as to why area burned severely may increase at a faster rate than area burned (Figure 2a; Figure S2): increasingly fire-conducive conditions favor more rapid fire expansion (leading to larger area burned) and canopy fuel consumption (increasing fire severity). Taken together, it is logical to conclude that proportion burned severely will continue to increase as climate change drives increases in large fire events (Buonanduci et al. 2023; Coop et al. 2022) and area burned (Figure 5) without substantial investments in ecologically based fuel reduction treatments (Hessburg et al. 2021; Prichard et al. 2021) (see below) intended to restore surface fire regimes. Overall, our findings also support previous studies showing that proportion burned severely has increased in specific regions of the western US, like California's Sierra Nevada (Miller, Safford, et al. 2009), the northern Rocky Mountains (Harvey et al. 2016b), and the southwestern US (Singleton et al. 2019). Increases in area burned severely and proportion burned severely will have major detrimental impacts on forest persistence and recovery, particularly under more arid postfire climates (Coop et al. 2020; Davis et al. 2020, 2023; Stevens-Rumann et al. 2018) and, subsequently, the essential ecosystems services provided by forests (e.g., biodiversity, carbon sequestration, timber, water provisioning) (Rocca et al. 2014; Turner et al. 2013).

The extent to which fire-generated fuel limitations will reduce future burning (self-regulate) under future climate remains an open question. Because observed fires analyzed here already reflect any self-regulation that occurred from 1985 to 2022, such fuel constraints imposed by previous fires are theoretically incorporated into models, including our mid-21st century projections. Previous investigations have concluded that self-regulating feedbacks may not substantially influence future projections of area burned over broad regions (Abatzoglou, Battisti, et al. 2021). For example, Hurteau, Liang, et al. (2019) found that fuel constraints imposed by previous fires reduce area burned by only 14% compared to climate-only models that do not incorporate bottom-up fuel constraints. Even in systems that historically burned at long intervals, we are increasingly seeing shorter fire intervals (Buma et al. 2020; Harvey et al. 2016a, 2023). Nevertheless, as our data and models are relevant to *forested* area burned and *forested* area burned severely, it is possible and even probable that conversions to non-forest associated with high–severity fire and climate warming will erode forest extent in the future, particularly in the warmer and drier forests (i.e., the trailing edge) (Meigs et al. 2023; Rodman et al. 2022). For example, it is estimated that 30% of forest in the southwestern US is at risk of fire-catalyzed conversion to non-forest (Parks, Dobrowski, et al. 2019). Forest loss due to high–severity fire and climate change would therefore be expected to affect our projections, as less available forest may reduce the amount of forest area burned and area burned severely in future decades. However, our parallel analyses of percent (rather than area) of forest burned and percent forest burned severely is independent of the amount of available forest, yet still project ~2.5-fold increase in both metrics by mid-21st century (Figure S6). Nevertheless, several previous studies

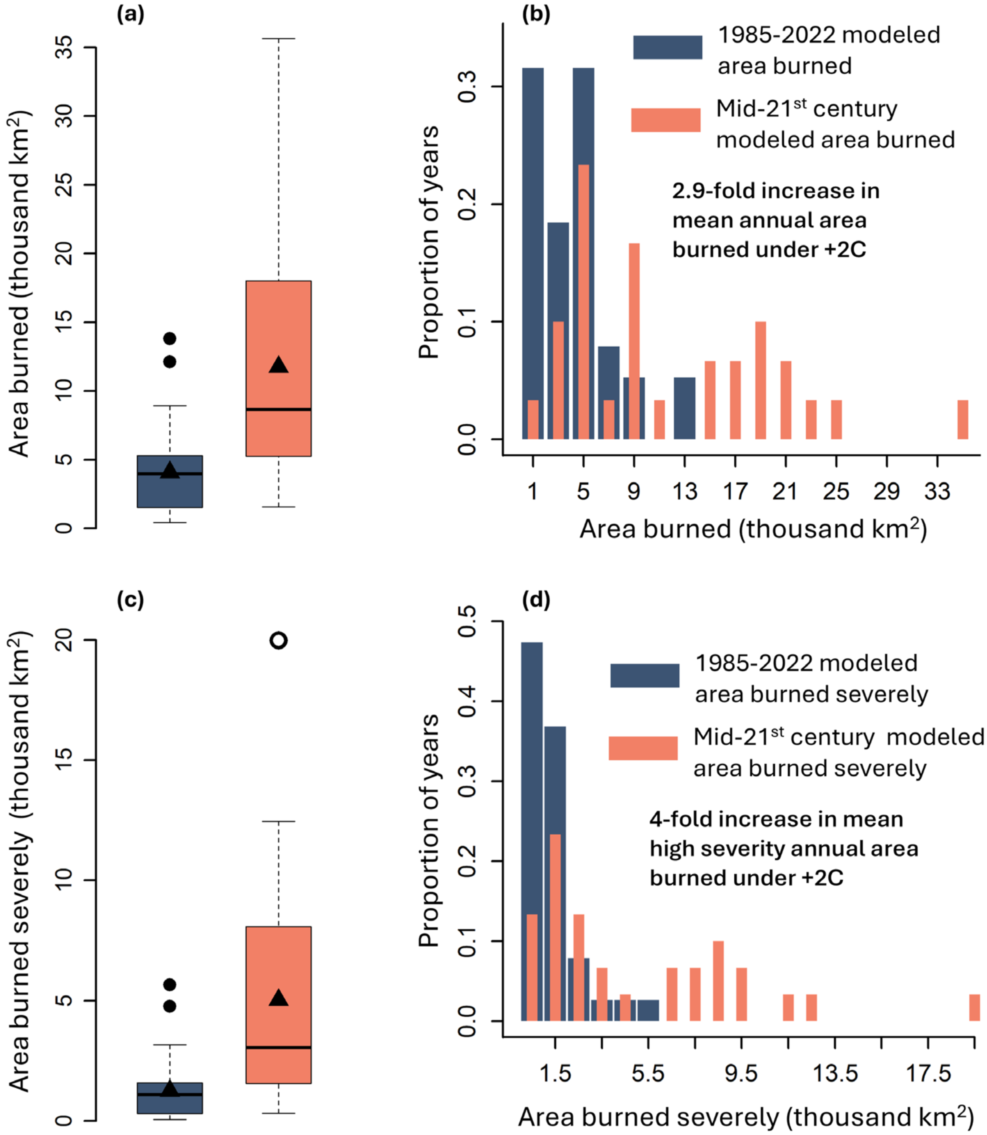

FIGURE 5 | Modeled recent (1985–2022) and mid-21st century area burned (a, b) and area burned severely (c, d). In panels (a, c), the black triangles and horizontal lines represent the mean and median, respectively; the black dots show 2020 and 2021 predictions, and the open circle (d) represents an outlier for the mid-21st century area burned severely prediction. Note that the modeled mid-21st century mean annual area burned and mean annual area burned severely approximately matches fire activity in 2020 and 2021 (a, c).

across the western US have concluded that low–severity fire begets low-severity fire and high-severity fire begets high–severity fire (Cansler et al. 2022; Coppoletta et al. 2016; Harris and Taylor 2017; Harvey et al. 2016a; Parks et al. 2014). These studies further suggest that area and proportion burned severely will maintain high levels unless land managers can promote and perpetuate cycles of repeated, lower–severity fire.

A broad body of literature demonstrates that fire was historically far more common in the western US and elsewhere compared to the modern time period (e.g., Margolis et al. 2025; Marlon et al. 2012; McClure et al. 2024), and the area burned during fire years like 2020 and 2021 would have been about average when compared to historical fire regimes (Parks et al. 2025). However, as evidenced by tens of thousands of fire-scarred trees in the western US and elsewhere (Margolis et al. 2022), the frequent and widespread fire that occurred during the historical period often burned at low- and moderate-severity, meaning that most of the mature trees survived, particularly in frequent-fire, dry conifer forest types (represented by FRG1 in this study; Figure S1). These historical fire effects, in which the proportion burned severely was relatively low, contrast sharply with the modern fire effects reported here (Figure 2) and in other studies demonstrating the high proportion of area burned severely by many contemporary fires (McClure et al. 2024; Parks et al. 2023; Williams et al. 2023). Paradoxically, changes in fire severity between historical and contemporary time periods result in part from the exclusion of fire and associated changes in fuel loads and forest structure that promote high–severity fire (Calkin et al. 2015; Hagmann et al. 2021; Kreider et al. 2024).

Although we project a substantial increase in annual area burned and area burned severely by mid-21st century (Figure 5), we can better contextualize, prepare for, and potentially mitigate this future by incorporating knowledge of historical (~1600–1880) fire regimes. Specifically, historical fire regimes, which were significantly influenced by Indigenous fire stewardship (Long et al. 2021; Roos et al. 2022), show that it is possible to have a large annual area burned yet a low proportion burned severely, therefore informing efforts aimed at reducing fire severity. Specifically, restoring forest conditions that were historically resilient to frequent fire, particularly in warmer and drier forest types (FRG1 and some FRG3 forests; Figure S1), would reduce area and proportion burned severely if these restoration actions were implemented on a meaningful scale (Hessburg et al. 2015; Kolden 2019). Ecologically based forest thinning followed by prescribed fire is generally the most effective restoration treatment in forests with historically frequent to moderately frequent low– and mixed–severity fire (Davis et al. 2024). Recognizing that such restoration treatments are not feasible on all landscapes (e.g., designated wilderness), managing fire as an ecosystem process in locations and times of year when it is safe to do so could help increase the pace and scale of restoration (Jones et al. 2025; North et al. 2012). Without a substantial expansion of such measures, our findings indicate that we can expect fire to increasingly drive forest loss and degrade ecosystem services provided by forests (e.g., carbon sequestration, biodiversity conservation, water supplies), with major impacts on human communities.

Author Contributions

Sean A. Parks: conceptualization, data curation, formal analysis, investigation, methodology, visualization, writing – original draft. **Jonathan D. Coop:** conceptualization, methodology, writing – review and editing. **Kimberley T. Davis:** conceptualization, methodology, writing – review and editing.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are openly available in FigShare at http://doi.org/10.6084/m9.figshare.29485736. Climate data were obtained from TerraClimate at https://www.climatologylab.org/terraclimate.html. Annual tree cover data were obtained from the Rangeland Analysis Platform at https://code.earthengine.google.com/c4cebca6a3d6a153c136095abeef67b0 (version 3). Fire regime group and Biophysical Settings (BpS) were obtained from the United States. Department of the Interior, Geological Survey, and U.S. Department of Agriculture's Landfire database at https://landfire.gov/data/lf2020.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Figures S1–S7:** gcb70429-sup-0001-FigureS1-S7.pdf.