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Relational geographies of urban unsustainability: The entanglement of California's housing crisis with WUI growth and climate change

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One of California's most pressing social and environmental challenges is the rapid expansion of the wildlands–urban interface (WUI). Multiple issues associated with WUI growth compared to more dense and compact urban form are of concern—including greatly increased fire risk, greenhouse gas emissions, and fragmentation of habitat. However, little is understood about the factors driving this growth in the first place and, specifically, its relationship to urban–regional housing dynamics. This paper connects work in urban social science, urban and regional planning, and natural sciences to highlight the potential role of housing crises in driving displacement from the urban core to relatively more affordable exurbs, and with this, WUI growth. We analyze this relationship in California, which leads the nation in lack of affordable housing, scale of WUI growth, and many associated WUI hazards, including wildfire. We offer three related arguments: first, that California's affordable housing crisis, with its effect of driving migration to exurban areas, should be recognized as a significant urban form-related sustainability challenge; second, that to understand this challenge scholars must expand the spatial scale and analytic toolkit of both urban and WUI analysis through relational, mixed methods research; and third, that political and programmatic efforts to address California's housing crisis should undergird efforts to address WUI growth and climate change. Ultimately, we argue that expanding access to affordable urban housing can produce a more sustainable and just urban form that mitigates WUI-related climate and environmental impacts and reduces the vulnerability of growing numbers of WUI residents living in harm's way.

urban sustainability | housing crisis | climate change | wildlands urban interface | exurbanization

Urban Housing Unaffordability as a Sustainability Problem Far beyond Cities

In the context of climate change, critical attention is being paid to the environmental consequences of urban form, from concerns about the greater energy use of single-family homes to the increased emissions associated with car-dependent livelihoods (1, 2). This paper argues that another urban dynamic should be seen as a significant urban form-related sustainability challenge: the crisis of unaffordable urban housing. In prompting the growth of formal and informal housing in areas that are increasingly vulnerable to flood, fire, and other climate impacts, as well as in exacerbating these impacts, the political economy of housing markets is shaping urban form in ways that fundamentally challenge the pursuit of sustainability. One result of the siloing between natural scientific research on ecology, habitat and climate, and social scientific research on housing and urbanization is that little is understood about how patterns of housing investment, regulation, and (un)affordability are not just issues in the urban core but can have far-reaching, regional social and environmental effects.

A key example of these potentially interconnected dynamics, and their segregation in scholarship, is the unexamined relationship between California's affordable housing crisis and the growth of its wildland–urban interface (WUI). "The WUI" includes residential development located both within natural areas—known as "intermix WUI"—and adjacent to them—known as "interface WUI"—and is now the fastest-growing land use type in the coterminous United States, having grown rapidly from 1990 to 2020 in both number of houses (46%) and land area (31%) (3–5).* Since the 1990s California has seen the greatest scale of WUI growth in the United States and now has the nation's largest absolute number of WUI residents, with more than one out of every three California households located in the WUI. California saw nearly 1.5 million new WUI homes built in the last 30 y, with fellow sunbelt states of Texas and Florida each also seeing over one million new homes in WUI in this period (4, 6) (*SI Appendix*, Fig. S1). This growth has sparked public and scientific concern due in particular to its impact on wildfires—the risk of which inspired the coining of the term "WUI" in the 1940s (7). Again California has been at the center of this concern, as the state also leads the nation in wildfire activity. California fire ecologists have established WUI development as the leading cause of wildfires, independently and in combination with climate change, with the presence of housing in wildland areas now understood to alter fire frequency, severity, and its role in ecosystem functioning (8, 9). Meanwhile, housing in California's WUI is both the leading

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*Authors' calculations using data "State WUI Totals 1990 to 2020." For analysis from 1990 to 2010.

cause and casualty of wildfire, with destructive impacts on people and property far exceeding any other land uses in the state (10). While wildfire risk motivated the identification of the WUI as a critical site, and has trained public attention on it, this urban form is entangled with a wide range of climate-related problems that extend beyond fire, and also affect California in acute ways. These include, in particular, climate impacts associated with urban dispersion, sprawl, and greenhouse gas emissions (11). as well as habitat fragmentation in precarious, climate-change-impacted wildland areas (12).

Yet amid this attention, one key question has been gone unaddressed: What is driving WUI growth in the first place, in California and nationally? As a 2018 *New York Times* article summarized, "we know these lands are dangerous [but] it isn't easy to generalize why people are moving [to them]" (13). Studies allude to a "broad range of economic and lifestyle factors," or to the common sense notion that WUI migrants abandon cities out of "a desire to live closer to nature," with the assumptions of this continuous and quasi-natural "pull" of people from cities to WUI areas influencing WUI models, forecasts, and policy recommendations (14, 15). And while pandemic era remote work options and technological change have accelerated these trends since 2020, analyses of the latter have similarly failed to offer a clear understanding of this historic, multidecade shift.

Drawing on literature on urban displacement and migration from the urban social sciences and regional planning, we argue that rapid WUI growth since the 1990s should be understood in relation to another historically contemporaneous dynamic: the "push" factor of affordable housing crises in driving exurban development, particularly in California. Since the 1990s, the United States has experienced a persistent and growing lack of affordable housing in cities, and nowhere has this been more extreme than in California (16). Among urban social scientists, it is well known that housing unaffordability has displaced lower-income residents, disproportionately immigrants and people of color, from cities to relatively more affordable suburban and rural areas across the United States and Western Europe, while California coastal metros like Santa Cruz and San Francisco consistently top the list of housing unaffordability nationally and globally since the 1990s (17, 18).[†] These migration trajectories are highly uneven, reenforcing patterns of social and environmental inequality. More affluent migrants from California's coastal and "gateway" metropolitan areas—which include the Los Angeles, San Francisco Bay Area, San Jose-Santa Cruz, and San Diego regions—can move outside the state to other large and more affordable cities (19), to less costly but still well-established cities and suburbs further in inland California (20), and/or to affluent "favored quarter" exurbs in the state's famously desirable natural areas. Meanwhile, lower-income migrants are also moving from the coastal metros, but often to smaller suburban, exurban, and rural communities requiring lengthier commutes. Thus, in the Northern California urban megaregion, low-income residents are moving from more affluent coastal metros in San Francisco and Santa Cruz to exurbs in the more affordable areas surrounding Sacramento, Stockton, and Salinas, while to the South those priced out of Santa Barbara and Los Angeles move to inland empire cities and towns like Riverside and Redlands (21, 22).

The concern of this article is the fact that many parts of these growing exurban areas are also in the WUI, and as such are entangled with a host of other social and environmental challenges, in a vicious cycle that is increasing in scale and impact as both housing crisis and climate threats intensify (23). We lay this process out in Fig. 1 across five "moments," each of which is embedded within particular political economic and ecological contexts. Roughly, we are seeing urban housing crises, in the context of relatively less expensive housing in exurban areas, 1) leading to displacement to and growth of the WUI 2), which generates more hazardous land uses and social vulnerability, alongside fragmented habitat for wildlife. Increasing WUI housing and infrastructure like roads and powerlines then leads to a range of further socioenvironmental impacts 3), including increased commute sheds and greenhouse gas emissions, the displacement of rural and indigenous residents, as well as obstacles to land stewardship efforts, with the latter including efforts to reduce hazardous fuel loads through prescribed burns and other methods. In the context of climate change, WUI presence and related impacts can both cause and greatly exacerbate climate disasters like fires, floods, and landslides. 4) Following these disasters, the underlying inequality of the WUI also increases the likelihood of uneven postdisaster redevelopment 5), with some able to protect their homes, rebuild them, or build new homes on disaster sites, while others are displaced and live informally within the WUI, despite its danger, or attempt to move back to the city. The latter dynamic, meanwhile, further increase both WUI hazardousness and demand for affordable housing, thus exacerbating the original crisis.

With particular focus on the entanglements of moments 1 to 4, this paper centers urban housing affordability and land use questions within current discussions of WUI growth, the climate crisis, and urban and regional sustainability. We argue first, empirically, that California's affordable housing crisis, with its effect of driving migration to exurban areas, should be recognized as a significant urban form-related sustainability challenge in itself. Second, methodologically, we contend that to understand this relationship—between urban and WUI housing dynamics, as well as between housing and broader sustainability challenges—scholarship on WUI growth must expand the spatial scale, historic frame, and analytic toolkit of its analysis. And third, politically and programmatically, we argue that understanding and addressing the factors affecting housing affordability in the urban core should undergird efforts to address WUI growth, climate change, and climate-related disasters in California and more broadly.

Recognizing Metropolitan Drivers of Exurban WUI Growth. In the foundational natural science literature on WUI growth, its origins typically go unexplained, or else reasons given for it lack evidence or analysis. The most common assumption is in-movers' desire to "live closer to nature," including nature-based lifestyles and/or amenities. For instance, to explain the recent finding that "from 1940 to

[†]We note that this "relative affordability" is itself a question, given added costs associated with commuting and climate risks.

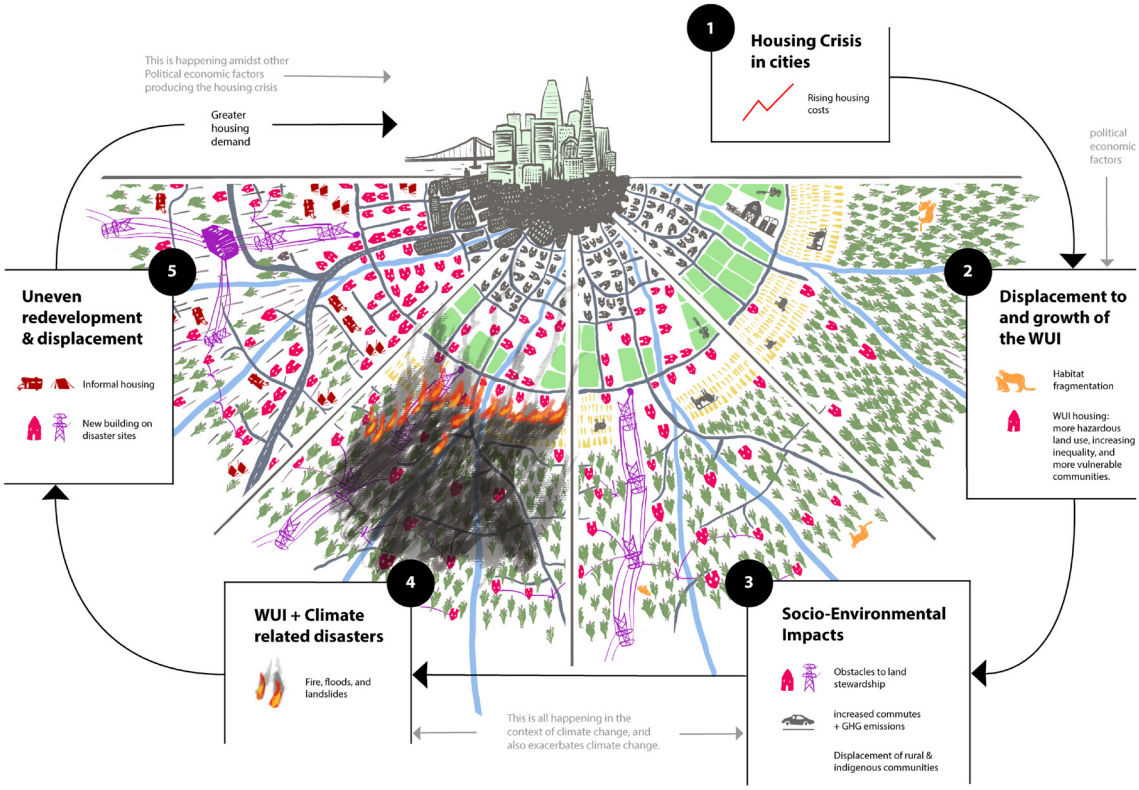

Fig. 1. Entanglements of the housing crisis with WUI growth and the environment. The conceptual diagram displays a vicious cycle of five "moments": (1) the housing crisis in cities that can intensify (2) displacement to and growth of the WUI, which leads to (3) a variety of socioenvironmental consequences of WUI growth, and (4) WUI and climate-related disasters. This can result in (5) uneven redevelopment and further displacement, which can in turn exacerbate the housing crisis.

2000, significant housing growth occurred in suburban and rural areas (of the United States), especially in and near forests," Stewart et al. note simply: "homeowners want to be near open space and in close contact with nature" (14). Such conventional wisdom also enters into models of future residential growth in the WUI and WUI policy and management (15). Yet no empirical research on drivers and demographics of WUI growth supports this claim. In our review of WUI literature, we only found one article, from 2014, to cite any evidence substantiating the assertion that natural amenities drive current moves to exurbs (15).[‡] And even here, while the distinction between amenity and affordability drivers is noted, it is asserted the former applies to exurbs and the latter to suburbs, even though the secondary source cited to make this point rests on a single case study and literature from the 1960s and 1970s, and thus is of limited relevance to the contemporary context of rapid exurban growth (24, 25).

At the same time, in the critical social sciences, relational approaches to the studies of cities and hinterlands are growing. Human geographers and sociologists have approached such work under the rubric of "planetary urbanization"—a framework which considers growth of urban cores in connection with the "extended" landscapes of food, energy, and infrastructure on which they depend, as well as urban–agrarian entanglements more broadly (with research on zoonotic disease transfer a prime example of the latter) (26–29). This dovetails with urbanists' understanding that gentrification drives displacement within cities and on the urban fringe, as people are priced and pushed out of unaffordable urban areas, or as would-be urban migrants, attracted to cities for jobs, school, or community, remain on the outskirts for the same reason (30, 31). The unevenness in who is relegated to urban peripheries—in Northern cities as well as across the global South—is well established, as are the environmental impacts of these dynamics, from increased emissions and energy use to increased exposure to environmental risks such as pollution, flooding, and wildfire (32–35). Research on urbanization and urban displacement, with no reference to wildlands interface, remains for the most part separate from natural science studies of interacting forms of environmental impact of and risk. But its holistic, relational approach to the study of interface zones is an essential resource for understanding current affordability-driven transformations, their implications for people and the environment, and the degree to which policy and planning will need to address the complex of factors shaping housing markets in order to mitigate them.

The silo-ing of natural and social science fields points to the legacy of field-specific methods and the challenge of defining "interface" zones amid rapid urban transformation on a planetary scale. "The WUI" as a framework, designed as it is for forestry and fire management, is akin to other efforts to define expanding interface zones—e.g.,: the "wildlife–livestock–human interface" designed by epidemiologists to track zoonotic disease, or the use of "peri-urbanization" within public health to understand the growth of informal settlements—but many of these do not expand to sites far beyond

[‡]The authors cite Crump et al. from 2003 to generalize from the single case of Sonoma County, California. The latter builds on residential preference literature in rural sociology and behavioral economics from the 1960s and 70s, asserting continuity in these trends. Yet since then, urbanization dynamics have increased at such a rate and scale as to erode distinctions between many suburbs and exurbs, while urban unaffordability and inequality have intensified.

interface zones (whether within central cities or in far-flung peripheries) where risks, diseases, or displacements originate (31). In addition, there is the empirical challenge of WUI data itself, which combines USGS National Land Cover Data with US Census housing data at the block level (36). Since standard sociospatial data representing the various dynamics of the affordability crisis—including demographic, housing, and commute data—are captured at the larger block group, tract, or county level, simple integration of datasets is complex. Further, no social survey data are incorporated in WUI analysis to assess the motivation for migration, such as from the Current Population Survey (CPS) or American Community Survey (ACS). Census survey data are also quite coarse in this regard, since neither CPS nor ACS specifically address the motivation for moves to wildland adjacent areas, while more detailed housing surveys are captured sporadically by private industry groups. And finally, it is likely that a large and growing proportion of WUI development is itself "informal"—e.g., trailers permanently parked behind a main house illegally connected to water and sewer lines, or "self-help" homesteads hastily built alongside farm fields—all of which goes undetected by standard survey methods (37, 38).

Our research team at UC Santa Cruz is in the initial stages of conducting the kind of robust mixed methods analysis—including the refining of survey tools and integration of census and WUI data—that will enable analysis of the drivers, demographics, and dynamics of WUI growth. Here we lay the conceptual groundwork for this broader analysis, putting natural science research on the WUI in conversation with literature in urban social sciences, planning, and demography. To begin, we highlight the relationship between affordability-driven urban displacement and ex-urban growth on the one hand and, on the other, correlations between these exurban dynamics and the WUI growth of 1990 to 2020. We argue that changing dynamics in the WUI should be understood in the context of exurban development, including its political economic and demographic drivers and dynamics, even while subjective motivations for moves to these areas undoubtedly entail nuanced combinations of push and pull factors.

Since the 1980s, urban sociologists, planning scholars, and geographers have documented the impact of "neoliberal" or market-oriented policies and plans in generating gentrification, housing crises, and displacement in urban areas of the United States, all of which have particularly impacted low-income and non-White communities. These dynamics were both rooted in and a break from prior housing dynamics. The federal housing policy that emerged following the Great Depression of the 1930s and continued through the 1960s was never fully inclusive, given the racial segregation it also enshrined (39, 40). It nonetheless had the potential, much like contemporaneous policy in Europe, Asia, and Latin America, to support urban forms—including publicly subsidized, dense, multifamily rental housing in core urban areas—that were relatively expansive, affordable, and environmentally sound (41).[§] This potential was never embraced due to a number of factors. The first was the role of anti-urban and racially biased federal urban policy enacted by agencies like the Federal Housing Authority, which worked to expand private, single-family homes (SFHs) in majority White suburbs, all of which fueled the boom in population and sprawled housing in the "Sunbelt" of the South and West (42).[¶] The second, beginning in the 1970s, was state and federal retrenchment from urban and publicly subsidized housing altogether, further driving "White flight" and "capital flight" to suburbs. Since the 1980s and 90s, with the speculative "return of capital" to cities and gentrification of core areas, poor, working-, and middle-class residents, disproportionately communities of color, were increasingly displaced to under-resourced urban areas, declining suburbs, as well as far-flung exurbs. The relative affordability of these areas was itself due to lax land use regulations and the entrepreneurialism of urban, rural, and exurban growth machines—landowners and speculators, real estate developers and agents, politicians, and planners—seeking to attract new investment and tax revenue. Thus, since the 1990s supply-side factors have interacted with demand of those displaced from unaffordable cities—and, we suggest, been key in accelerating growth of the WUI during the same time period.

Demographers and geographers have commonly described urban out-migration beyond the outer suburban ring as "exurbanization," with exurbs understood as desirable, low-density neighborhoods on the fringe of suburbs and rural areas that are still within commuting distance of major cities for affluent urbanites (43).[#] The phenomenon has gained attention in the era of Covid-19 (2020 to 2023), when scholars in the United States and internationally noted an "exodus" of white- and blue-collar workers able to escape overpriced metros for small towns and rural areas beyond the urban and suburban fringe, causing what some termed an historic "reverse urban–rural migration" (44). In 2021, for instance, the largest urban counties in the United States all lost population for the first time in 50 y, while over 80% of exurban counties gained population, with the biggest increases seen in California's Inland Empire, the Mountain West and eastern Texas (45).[||] Yet while recent trends are extreme, similar exurban dynamics have been observed over the past 30 y in the United States and many other parts of the world. In the United States, alongside overall decline in domestic migration since the 1990s—due in part to affordability pressures preventing people from moving for new jobs in larger high-price cities (46)—"housing-related reasons" have driven a growing number of moves out of these metros to smaller cities, towns and rural areas, in particular those within 1 to 2 h driving distance of major metropolitan areas (47).

We use the term exurb in this paper in line with demographers and urban planners' spatial understanding of exurbs as low-density areas beyond suburbs that have experienced

[§]Schwartz highlights three main housing policy shifts of the 20th century: from public to private financing; federal support for rental housing to homeownership; and zoning for dense, multifamily housing to single-family homes, noting all of this signaled a move away from the social housing ideal.

[¶]Policies include the Homeowners Loan Corporation's "red-lining" of credit ratings in racially diverse urban markets while "green-lining" those in "homogenous," white suburban areas; the FHA's exclusionary mortgage lending mostly to SFHs in greenlined areas; Fannie Mae's standardization of these mortgages; the IRS's concomitant expansion of mortgage interest deductions, privileging SFH-owners over renters; and massive federal subsidy of suburbs via car-centric highway infrastructure at the expense of urban mass transit.

[#]The term exurbia was coined by Auguste Spectorsky in his book *The Exurbanites* from 1955—prior to large-scale affordability-driven urban out-migration.

[||]The article indicates that in 2021, the 78 large urban counties in the United States (with more than 250,000 people and including an urban center) experienced a net loss of 863,000 residents, the first time this group experienced negative growth in aggregate in the past 50 y.

demographic growth (48–50). We see cultural geographers' emphasis on amenity-driven migration as a continued feature of exurban development (51–53), while also drawing attention to the more pronounced bimodal distribution of WUI growth (i.e., both amenity and affordability-driven) that results, we hypothesize, from housing crises in urban cores today. Observations of exurban growth between 1990 and 2000, which found small exurban areas growing at a faster pace than the major cities they were connected to for the first time, noted the coexistence of amenity and affordability-related moves (43). Researchers found that many exurban moves, especially on the east and west coast, were motivated by the lack of availability and affordability of homes in urban areas, with workers making a conscious trade-off between a shorter commute time and lower-priced homes. But these motivations coexisted with other established and emerging interests in natural amenities. Thus they juxtaposed the rise of "affordable exurbs" with "recreation exurbs"—resort towns becoming year-round homes—and a smaller number of "favored quarter exurbs" selected by the wealthy to build large estates, often in pristine natural areas, as a "perceived refuge from the economic and social distress that afflicts their far-away central cities." California and the Mountain West were leading locations for all three types of exurb (43).

Uniting the exurban and the WUI literature, we hypothesize three contemporary dynamics. First, we anticipate that motivations for WUI migrants have shifted over time. While from the 1960s to 1990s, these moves were found to be primarily "amenity-driven," i.e., rooted in a desire to live near nature for recreational, familial, or other cultural reasons, by the 1990s to 2020s, moves have likely become increasingly "affordability-driven," i.e., a result of the need to find housing within commuting distance of "out-of-reach" metros.

Second, we find an increasingly convincing relationship between this growing housing demand and the political economic and property market forces currently shaping WUI growth dynamics, including distinct dynamics in "intermix" vs. "interface" WUI areas. Building on fire ecology research that emphasizes regional heterogeneity in terms of hazardousness across these WUI types (9), we would add an emphasis on heterogeneity in terms of land use policy and demand that helped produce housing markets in intermix vs. interface areas in the first place. Based on observations in our study area, we hypothesize that relatively lax land use regulation and less community resistance and/or influence in formerly agricultural areas allows for large-lot middle-income commuter sprawl within interface WUI. Intermix WUI, however, likely emerges in or around areas designated restrictive "greenbelt" in the 1980s, where residential communities are built beyond the urban services line, thus driving up development costs. This likely results in an eclectic housing mix, e.g.: large gated mountaintop estates for the affluent; more modest infill and rehabbed homes in mountain towns; and informal, "off the grid" housing, including trailers, vans, and vehicles, parked on others' properties or public lands. While interface areas are far more prevalent—constituting 90% of all WUI development—both bring with them particular risks. The proximity and scale of housing in interface areas leads to particular risk of property damage in fire, while dispersed intermix housing, far from urban services and roads, is more difficult to protect from fire and more consequential in impacting ecosystem processes on a per house basis (9).

Finally, we expect that affordability migration has grown alongside amenity migration, resulting in a bimodal class distribution of WUI residents, and with this, intensifying inequality in the WUI. This includes an increase in what some scholars call the Affluence Vulnerability Index [AVI]. Building on Mike Davis' famous essay "The Case for Letting Malibu Burn," the emphasis here is on high-profile cases of wealthy urbanites' voluntary movement to, and luxury home building in, "favored quarter" WUIs that are also extremely hazardous and resource depleting (54–56). The AVI likely has remained steady or increased since the 1990s, as wealth has grown at the top of the income and "asset class" spectrum (57). Yet we also expect it has been matched by increasing and greater vulnerability among those involuntarily displaced from unaffordable cities. While Davis's essay contrasted fire risk in coastal Malibu for wealthy, well-insured homeowners to that of renters in poorly maintained, high-density apartment buildings in downtown L.A., today we find both wealthy and poor living in WUI areas. Though in theory both are exposed to the same risks, they have very different abilities to prepare for, mitigate, and recover after fire and other climate-related events.

This juxtaposition, in turn, likely contributes to what we've seen elsewhere in disaster-prone urban areas under conditions of increasing precarity and wealth inequality: "uneven landscapes of risk and resilience" (58), i.e., in the face of mounting hazards exacerbated by WUI growth itself, greater social, economic, and structural vulnerability in certain areas coincides with greater capacity to fortify structures, insure property, and protect lives in other areas. This helps explain increasing forms of vulnerability to fire and other WUI hazards along lines of class, as fire frequency is increasingly correlated to lower socioeconomic status in WUI areas, as well as to far greater fire damage (59, 60). Critical observers have recognized the unsustainability of these unequal dynamics overall, referring to high-end fortification as a "facade of safety" and access to insurance as a "perverse incentive" for the wealthy and real estate industry to continue to develop in these areas (61, 62). Thus, if demographic and political economic dynamics continue in the WUI as they have in cities, the result will be a bimodal distribution of increasing WUI risk for some and resilience—however illusory—for others.

Relational Geographies of Housing Crisis, WUI Growth, and Fire Risk in the Northern California Megaregion. The housing dynamics we see in California and its urban megaregions are an extreme case of a national crisis. To choose a common measure of US rental markets, in its 2023 "Gap" report, the National Low Income Housing Coalition (NLIHC) estimates that none of the 50 largest metropolitan areas in the United States has an adequate supply of affordable and available housing for low-income renters (63). Yet coastal California metros are the least affordable overall, with six of them in NLIHC's "top 10 most expensive jurisdictions," including all of the top five. (Of these, the top four were in Northern California; the bottom two in Southern California) (64).[**] This domination of NLIHC lists by coastal California

[**]The 2023 "least affordable metros" include, in order: Santa Cruz-Watsonville, San Francisco HMSA, San Jose-Sunnyvale-Santa Clara, Salinas-Monterey, and Santa Barbara, at #'s 1-5, and Santa Ana-Anaheim-Irvine at #8.

metros dates back to their beginning in 1998, indicating an endemic issue.[††] To establish its rankings, NLIHC estimates each jurisdiction's "housing wage," i.e., the wage full-time workers would need to earn to afford a modest rental at HUD's fair market rent (FMR) without spending more than 30% of their income on rent, which is the accepted standard for affordability. At the state minimum wage of $15.50/h, this means that California tenants in these top metro areas would need to work, on average, close to four full-time jobs to be able to afford the FMR for a two-bedroom apartment.[‡‡]

Beyond overcrowding, living in informal or substandard housing, or homelessness, current or would-be residents survive such extreme rent burdens by relocating in search of greater affordability, typically to smaller metros as well as lower-priced suburbs, small towns, and rural areas (see, e.g., ref. 65). These dynamics have resulted in a lack of "jobs-affordable housing fit" in cities; the rise of "extreme" or "super commutes" for those driving more than 60 or 90 min for jobs in the city; the "suburbanization of poverty" as many pushed out of urban areas lack access to networks and services that might provide economic mobility; and the "re-segregation" of California, as lower-income exurban migrants are disproportionately African American and Latinx (22, 66, 67).

However, while journalists highlight stories of Californians priced out of metro areas and into the state's hotter, more hazardous interior (see, e.g., ref. 68), there is no systematic, scholarly literature linking these housing market dynamics to WUI growth, nor to fire danger and other climate-related environmental risks. This is concerning since, as noted above, WUI growth and hazardousness have increased in tandem with the housing crisis in urban areas, and it is very likely that these phenomena are related, i.e., that out-migration from unaffordable metros is a significant factor driving these dynamics. Nowhere are the costs of ignoring this question more consequential than in California, a state distinctive not only for the intensity of its affordable housing crisis but for the rapid rate and scale of its WUI development and associated risk of climate disasters.

Fig. 2 juxtaposes these two patterns. On the left is a map of housing wages in 2023, showing the six California coastal metropolitan areas currently listed as the top 10 least affordable in the United States (and which, with the exception of Salinas, have appeared in the top 10 consistently since the NLIHC began publishing these reports in 1998). On the right, we see the surge in WUI growth across California since 2000, nearly all of which was due to housing development in wildland areas as opposed to spread of wildland vegetation (4). Beyond spatial WUI expansion, these 30 y also saw significant densification of housing and population in existing WUI areas and commute sheds. We see this with the WUIs growing in proximity to the Northern and Southern California multicounty "megaregions," which constitute 80% of the WUI growth in the state (69, 70. See also ref. 71).[§§]

As noted, not all "exurbs" are in the WUI. Some of the fastest growing small towns are along the rural fringe but not adjacent to areas defined by USGS as wildlands—such as much of California's Central Valley. All WUI areas, however, are urban, suburban, or exurban, i.e., located within or impacted by expanding metropolitan areas. This is evident in the 21-county Northern California Megaregion (NCM), including its four subregions: the nine-county San Francisco Bay Area, the six-county Sacramento Area, the three-county Monterey Bay Area and three counties of Northern San Joaquin Valley (Fig. 3). The NCM has seen both the fastest rate of urban growth as well as the fastest rise in median home values and associated rents in California, with the latter steepest in the coastal San Francisco and Monterey Bay Areas (Fig. 3). The region is home to 12.7 million people, nearly 5.8 million jobs in industries from tech in Silicon Valley to agriculture in the Salinas Valley, and an economy which, on its own, would rank as the sixth largest in the world. Yet the core urban areas of the Bay Area, where this economy is centered, have since the 1990s attracted hundreds of thousands more jobs than there is housing to support. This is an issue not simply of supply/demand mismatch, but also of lack of housing that is affordable for most working people, which is due to opposition to the production and preservation of social housing as well as to meaningful tenant protections. Thus, while exclusionary zoning curbs supply, an unregulated, financialized rental and property market also drives up costs. The result has been one of the most extreme housing crises in the United States, and the world, as well as one that is not evenly experienced throughout the region. From 1990 to 2020, median housing costs in these coastal areas have been two to three times higher than in the interior areas around Sacramento and Northern San Joaquin Valley (Fig. 3), with the hourly wage needed to rent a two bedroom at the fair market rate reaching over $60 in coastal counties, more than twice that of interior counties (Fig. 3).

What has this meant for WUI growth? We observe multiple dynamics. The wealth generated in Silicon Valley has accelerated the acquisition and development of large properties in the WUI in the above-mentioned coastal counties, as well as favored quarter areas further inland, such as around Lake Tahoe, which have seen the most increase in the WUI area (Fig. 3). We might expect to see dynamics in line with the AVI hypothesis in areas like Lake Tahoe, the Santa Cruz Mountains, and the Oakland Hills, which are becoming simultaneously richer, more costly, and more hazardous (56). Meanwhile, ACS data show higher growth in the share of super commuters in the lower-cost interior counties relative to coastal areas (Fig. 3). These counties also have seen significant population increases across the same period, implying workers may be moving in search of housing affordability, while keeping jobs elsewhere at the expense of long commutes. While some workers manage to remain in high-cost coastal areas of the Monterey and San Francisco Bay Areas, many more are moving to the outlying parts of the region

[††]In reviewing rankings from 1998 (the earliest *Out Of Reach* report) to the present, we find an average of five California metros in the top 10 for the last 25 y. Note: "housing wages" are based on HUD's annual fair market rents, the metrics for which change over time.

[‡‡]Housing researchers deem two-bedroom fair market rents the most reliable metric with which to measure affordability since they are the most prevalent bedroom-size rental units in the US HUD's own methodology for determining FMRs uses these units. See https://www.huduser.gov/portal/datasets/fmr/fmr2023/Federal_Register_notice_07132022.pdf.

[§§]As Brenner argues, the move toward governance of urban megaregions, dubbed "new regionalism" in the 1990s, emerged amid neoliberal restructuring in that era and may be seen as a new "politics of scale," i.e., an attempt to govern rapidly expanding urban areas facing new large-scale challenges—like housing crises—that exceeded the capacity of individual cities and counties, while confronting federal and state retrenchment.

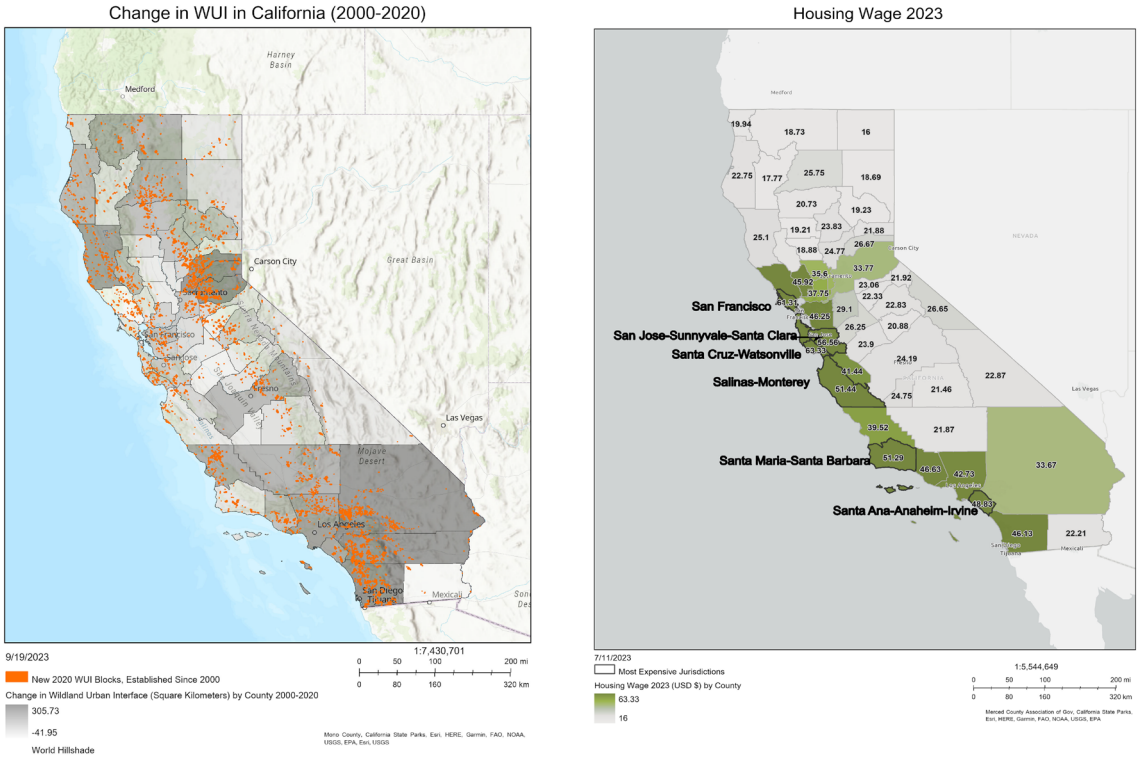

Fig. 2. California out of reach metros 2023 and WUI growth, 2000 to 2020. The map on the *Left* shows 1. orange-colored polygons representing new WUI Census Blocks since 2000 and 2. magnitude of change in the WUI area (square km) in grayscale by county. The green choropleth map on the *Right* shows the 2023 housing wage (hourly wage necessary to afford a modest rental at HUD's fair market rent by county). The metropolitan areas that are part of the 10 most expensive in the United States are labeled and their counties outlined. All data from National Low Income Housing Coalition (NLIHC) https://nlihc.org/oor.

further inland around Sacramento and the northern San Joaquin Valley, which accounts for more than 60% of growth in the region overall, and where housing wages are 30 to 50% lower. First-tier valley areas closer to the coast, including San Benito County to the south and Sonoma County to the north, are also relatively affordable and areas of some of the most rapid growth; combining these counties with the interior regions accounts for 70% of growth in the megaregion (20).

The NCM is also home to some of the nation's most rapidly growing WUI areas, which adjoin or intermix with a region of vast, biodiverse, and ecologically sensitive wildland areas—making them also extremely hazardous. As noted, we suspect there are distinct property dynamics in intermix and interface WUI, as these different types of exurban form are produced by different urban development policies and politics, and also shaped by the forementioned residential income disparities.

We see these dynamics play out, for example, in the Monterey Bay Area, including the coastal zone of the Santa Cruz Mountains and Gabilan Range. The Santa Cruz Mountains and adjacent cities encompass a rapidly growing and increasingly unequal urban region, as well as one with significant wildland areas—including approximately 2,500 km^2 of grassland, coastal chaparral, redwood, and mixed conifer/hardwood forests. It is also variegated almost entirely by differing levels of intermix and interface WUI. In the more mountainous intermix areas, strict greenbelts were established in the 1980s, leading to less development as well as greater housing and income disparities. This pushed more affordable housing to lower-lying interface areas to the south, where the less regulated rural valleys of the Gabilan became sites for growing sprawl. This further fragmented vital habitat for wildlife populations requiring wide ranges, such as the native puma, which have experienced a marked loss of genetic diversity and are now provisionally listed as a state-threatened species under the CA endangered species act (72). Meanwhile, the CZU Lightning Complex Fire lasted 37 d between August and September 2020 in the intermix WUI areas of the Santa Cruz Mountains to the northwest. Burning over 85,000 acres, destroying close to 1,500 structures, displacing 10,000 people, and costing one life in the immediate aftermath, the slow and highly unequal ability for residents to rebuild demonstrated the intertwined climate, fire, and housing problem for the entire region. This is increasingly apparent as people both remain in and move to burned-out areas, which, paradoxically, became relatively more affordable for renters and opportunistic sites for informal and ever riskier dwellings (31).

In the foothills of the Sierra Nevada surrounding Sacramento, where pine forests and chaparral have been especially vulnerable to a warming climate, nearly all new housing units are located in the WUI. A prominent chain of intermix WUI areas can be seen in the foothills, while interface WUI grows beyond the already sprawling Sacramento metro area (6). Although the number of units is modest compared to the populous Bay Area and Southern California, the spatial extent of the resulting WUI is massive, leading the region to become a hotspot for mountain lion depredations in the state (12, 72). The region experienced steady growth of amenity migrants in the late 20th century and has seen unprecedented increases of in-migration in the last decade. While net exits from San Francisco in 2020 increased from 5,200 in 2019 to 38,800 in 2020, counties in the Sierra Nevada mountains saw huge increases in moves from former Bay

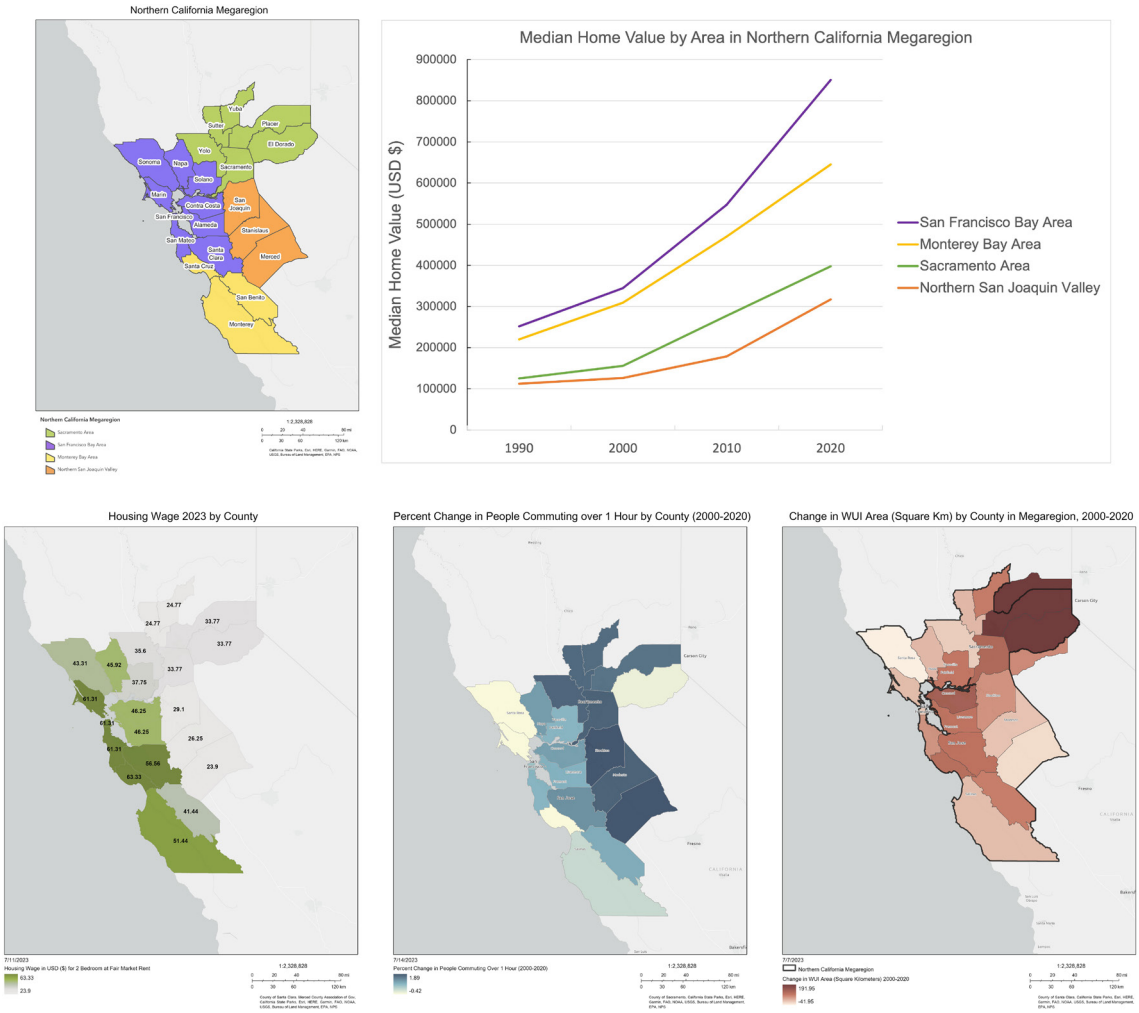

Fig. 3. Housing costs, WUI growth, and commutes in Northern California Megaregion (NCM). The map in *Upper Left* corner shows the four subregions within NCM: six-county Sacramento Area, nine-county San Francisco Bay Area, three-county Monterey Bay Area, and the three-county Northern San Joaquin Valley. Counties are labeled. The line graph shows the trend in median home in each subregion in the NCM from 1990 to 2020 using data from the ACS. The green choropleth map shows the NLIHC housing wage for a modest rental at HUD's fair market rent by county in NCM in 2023. Housing wage ($) labeled for each county. The blue choropleth map shows percent change in people commuting over 1 h between 2000 and 2020 by county in NCM. Data from ACS. The brown choropleth map shows the change in WUI area (square km) between 2000 and 2020 by county in NCM. Displays counties in NCM and two adjacent counties, Nevada County and Amador County. Data from SILVIS Lab.

Area residents, with 50 to 100% more in-migrants in 2020 than in previous years (73). The areas of fastest growth in the region were small towns and rural areas on the border between the Bay Area and Central Valley.

These two regional examples correspond to our hypothesized bimodal distribution of WUI residents, particularly in intermix WUI, and intensification of these dynamics in the aftermath of Covid, with the growing opportunities of remote work, particularly in tech—proximately located for both in Silicon Valley. As we describe above, we expect an increase in "affordability migrants" relative to "amenity migrants" has occurred in recent decades. I.e. affluent homeowners continue to move to desirable areas by choice and at increasing cost in terms of home hardening, while precariously housed renters will select WUI locations primarily on the basis of cost, with fire risk often contributing to their relative affordability. Meanwhile, this migration itself pushes up home values in these outer ring counties, driving further cycles of displacement for existing rural and indigenous populations into yet undeveloped reaches of rural and wildland areas, if not back to cities, thus intensifying housing pressures.

Conclusion: Integrating Affordable Housing within Regional Land Stewardship and Climate Resilience

California represents a "perfect storm" of unsustainabilities, all of which are more extreme than elsewhere in the United States and interact with one another in complex and compounding ways. This includes affordable housing crisis and related inequality, exurban WUI growth, climate change-related disasters like wildfire and floods, as well as habitat fragmentation and the decline of endangered species. In this exploratory article, we posit an increasing relationship between these dynamics. In particular, we hypothesize that the affordability of California's hinterlands relative to urban areas, particularly in noncoastal and non-Bay Area regions, combined with political economic dynamics of housing and land use, are driving the extreme rate of WUI growth and related environmental impacts in these regions.

Thus, first and foremost, we argue that insofar as the affordable housing crisis is having the effect of driving migration to exurban and WUI areas, it should be recognized as a

significant urban form and climate sustainability challenge in itself. For researchers and policymakers, recognizing and responding to this relationship will require "expanding the frontiers of urban sustainability" (74) to link housing unaffordability in the urban core to regional sustainability problems including in the exurban interface zones that are currently experiencing the greatest rate and scale of housing growth. Most research on urban displacement makes no reference to this growth, nor engages environmental studies and sciences more broadly, while research on unsustainable political ecologies and environmental justice generally does not address fundamental questions of urban political economy and housing as such. Bringing these concerns and fields together is particularly urgent now, given the interacting sustainability challenge of continuing sprawl and informal development in the face of climate change, which both exacerbates the hazardousness of these areas and places more people at risk.

To accomplish this goal, we must also expand the spatial scale and analytic framework of urban and exurban research to capture the regional and relational housing and land use dynamics underlying WUI growth. WUI researchers should consider the role of housing market dynamics in proximal urban areas, the context of ongoing ex-urbanization, and the relative influence of affordability vs. desirability as drivers of growth, as well as the change in these motivations over time. Environmental work on the dangers of the WUI has largely ignored these urban shifts, while urban social science literature, including in housing and urban sustainability, has largely ignored their ecological and WUI context. Recent journalistic accounts have provided evidence for housing cost "push" factors (75), but there is currently very little empirical research, in part due to the challenges of integrating WUI and standard socioeconomic data, as well as in obtaining data from WUI residents who are mobile, informally housed, and/or undocumented. To understand whether the relationship between the housing crisis and WUI sprawl is causal and to what extent, new data and methodologies are needed, including mixed method, regional, and community engaged approaches.

Assuming this relational analysis is correct, solutions to these problems will need to integrate local, state, and federal housing policy and planning with climate policy. Such a holistic understanding of the pursuit of sustainability and these linked urban-environmental dynamics will create opportunities for novel alliances between organizations focused on urban housing and those concerned with sustainable land use—from agricultural and wildland conservation to indigenous land stewardship. This analysis also suggests that state and federal policy, like research, should begin to integrate putatively environmental (e.g., fire- or habitat-related) and social (housing-related) issues in its design. In California, as elsewhere, urban housing policy and politics is a terrain of considerable debate and struggle, often fixated on particular, narrowly defined policy interventions—such as increased housing production *or* stronger tenant protection— with these policies themselves considered in isolation from state climate policy. While we don't have space here to explore these debates, we concur with planning scholars who argue for a combination of policies covering the "3P's" of housing production and preservation alongside protection of tenants. This includes in particular greatly increased production and preservation of dense affordable housing with strong tenant protections to prevent displacement and redress the decades of anti-urban and racially biased housing policy noted earlier (76). We would add that these often costly and contested urban form-related policy interventions will need to be supported at multiple scales, from the local to the state and federal, and understood as key to the widely embraced pursuit of urban sustainability. Advancing these approaches becomes only more urgent when considering the stakes of continued WUI growth, particularly for vulnerable communities and ecosystems increasingly living in harm's way.

We recognize that addressing the urban housing crisis will not, in and of itself, solve the problem of WUI growth nor its entanglements with fire, habitat loss, and climate change. Affordable urban housing will need to be combined with interventions targeting the WUI itself—from local land use planning that deters WUI development to cultural easements that allow the expansion of indigenous land stewardship practices; from collective hazard mitigation strategies in existing WUI communities to "managed retreat" from some of the most fire-prone areas (77–79). Nonetheless, our analysis suggests that such innovative and vital local efforts, which are the focus of an emerging WUI resilience literature, will themselves be insufficient without—and could be greatly aided by—a simultaneous focus on the urban housing crisis and affordability-driven migration. This is the aim of our research moving forward. In the short term, such a relational approach will allow us to develop a more complete understanding of the drivers, demographics, and dynamics of WUI growth, with the goal of enhancing local scale WUI management and stewardship efforts, including as these may differ across WUI landscapes variegated by social and environmental factors. Meanwhile, such an approach can inform more equitable and sustainable housing and land use planning on a regional scale, including in urban areas, with the goal of curbing WUI growth itself over the long term.

In sum, it is increasingly apparent that addressing the climate and wildland conservation crisis will require addressing the housing crisis in cities. In California, and regions across the United States and the world, this must begin with understanding the fundamentally relational and entangled dynamics between urban, rural, and WUI areas and the role of chronic lack of affordable housing in WUI growth and hazardousness. This can then inform more integrated and equitable approaches to policy and planning—enabling more people to live and thrive in cities as a means of confronting the major socioenvironmental challenges of our time.

Data, Materials, and Software Availability. All study data are included in the article and/or *SI Appendix*.

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