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Urban Ecology in the Time of Climate Change: Houston, Flooding, and the Case of Federal Buyouts

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Abstract

This study proposes a shift in sociology's approach to urban ecology. Rather than foreground the social ecologies that captivated the Chicago and Los Angeles Schools, we join and extend more recent efforts to engage *environmental ecologies* that successively intersect with those social ecologies over time. To ground our approach, we focus on areas of urban flooding where federally subsidized buyouts of residential properties have occurred over recent decades. Drawing on data from Houston, Texas, we locate where these buyout zones have emerged and how their social ecologies have changed in ways that feed back to influence the number of local buyouts that occur. Results indicate that Houston's buyout zones have an identifiable social ecology that has shifted over time, primarily from white to Hispanic working-class settlement as the city has grown and become more racially and ethnically diverse. Results also show that the extent to which this racial succession has occurred powerfully predicts subsequent numbers of buyouts in the area. Implications for developing an enhanced urban ecology for the twenty-first century are discussed.

Keywords

community and urban sociology, environment and technology, racial and ethnic minorities

This article joins calls for an updated sociological model of urbanization that better addresses a defining problem of cities in the twenty-first century: the socio-environmental consequences of climate change, especially repetitive flooding. Although urban-environmental concerns have galvanized other city-centric fields in the last two decades (Brenner 2014; Colten 2014), sociology lags behind, despite the fact that "urban ecology" is one of the discipline's founding frameworks (McKenzie 1925; Park 1936). In the present study, we contend that insights from this classical framework can be reformulated and extended to foreground links between cities and nature. In this reformulation, we propose starting with a local hazardscape—in this case, one tied to water—and analyzing how local social ecologies unfold in relation to it, alongside the use of new policies designed to intercede in this relationship. Our goal is not a new Chicago School exegesis but rather a framework that can build on basic propositions while incorporating critical insights from recent scholarship.

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In this effort, we bring forward from classical urban ecology the idea that urban areas differentiate socio-spatially to produce different zones as they grow. We also bring forward the idea that these zones change successively over time, as different residential groups of unequal status enter and exit them. Along the way, we incorporate understandings of racial oppression and the political economy of place-making, which intersect to shape these processes. We also, like our Chicago School predecessors, ground this effort in a rapidly urbanizing context: contemporary Houston. Much as twentieth-century Chicago provided a lens into that epoch's defining urban issues, twenty-first-century Houston offers researchers an important perspective on urbanization, socio-environmental vulnerability, and the repetitive flooding that climate change portends.

Houston, the fourth largest city in the United States, sits in a low-lying prairie cross-cut by a dense network of bayous and floodplains that render threats from water-related hazards a constant reality. Indeed, Houston is a city where successive interactions between nature, urban growth, and demographic change have forged a dynamic landscape deserving of study in its own right. Yet, at the same time, Houston is far from extraordinary. One of the biggest challenges that cities face with respect to climate change is flooding—the most common and costly of all natural hazards in the United States and globally (Fraser et al. 2003; Haney and McDonald-Harker 2017; Orsi 2004). This reality has already triggered a variety of urban policy recommendations and responses (Godschalk et al. 1999; Klinenberg 2016). Yet to acknowledge this fact is also to recognize a longstanding way that cities have adapted to flooding throughout much of their histories: by sorting and re-sorting different groups into harm's way.

To investigate how these dynamics come together, we highlight a particular component of Houston's hazardscape: "buyout zones" where targeted, technocratic efforts seek to contain risks of repetitive flooding. While other socio-environmental contexts might produce different kinds of policy zones, buyout zones—found not just in Houston but increasingly in cities across the United States—are areas where local experts and officials leverage public funds to purchase and demolish prior development, mostly in the form of private residences. According to local officials, "These are homes that were simply built in the wrong place, prior to the knowledge we have today of the boundaries of our floodplains and prior to building regulations imposed by the city and county on land development" (Harris County Flood Control District 2018:1).

It is here, in these zones, that a city's future stares down its past. In that past, the urbanization of local landscapes was driven by growth machines that remain in operation. Their successful intensification of local land uses pushed development outward, filling in swamplands and lining waterways as planners and developers cut new channels and added new reservoirs and spillways. In these efforts, new residential settlements, environmental risks, and policy interventions recursively intersected to produce—and now selectively address—growing hazardscapes produced by ongoing urbanization. In Houston, for example, earlier policies, which included not just lax local planning but also the National Flood Insurance Program (NFIP), helped build $13.5 billion worth of property within the city's current (and expanding) 100-year floodplain (Collette and Dempsey 2017). While repetitive flooding is an issue throughout this hazardscape, only some places within it become buyout zones. In Houston, these zones are noncontiguous and spread out across 15 different watersheds within Harris County alone—the central county of the nine-county Houston metropolitan region.

To investigate the shifting social ecology of these buyout zones and how such shifts influence subsequent policy use, we draw on data from the more than 3,000 buyouts that occurred in Harris County between 1985 and 2017, before Hurricane Harvey dropped its historic rains and led to increased discussion of local buyout programs. Results from descriptive and regression analyses indicate that despite the *spatial* fragmentation of buyout zones, an identifiable *social* ecology nonetheless exists.

Results also indicate that over time, this social ecology has shifted from white to Hispanic working-class residents, as the latter has replaced the former as the city's dominant demographic group. Finally, results indicate that the degree to which this residential succession has occurred powerfully predicts the number of buyouts eventually transacted. In other words, new mitigation policies designed to enhance urban resilience in the time of climate change depend a great deal on how the social, not just environmental, ecology of local areas have been changing.

Old and New Urban Ecologies

Today, if urban sociologists engage the classical Chicago School of urban ecology, it is typically for one of two reasons: to critique it for being blind to issues of power, including most prominently racial oppression (Hunter 2013; Loughran 2015) and growth-machine politics (Dear 2002; Logan and Molotch 1987) or to laud it for presaging the importance of neighborhoods for individual and inter-generational life chances (Abbott 1997; Sampson 2012; Sharkey 2013). In the present study, we chart a middle course through these well-worn paths with the aim of identifying key propositions that, with modification, can contribute to a better understanding of how local social, environmental, and policy dynamics intersect in and through cities facing socio-environmental challenges.

To start, we bring forth the foundational idea that cities differentiate as they grow, producing different zones of inhabitants that collectively comprise a city's social ecology. This proposition calls forth a systems perspective that views an urban area not as a randomly distributed, monolithic whole but rather as "a mosaic of little worlds" (Park 1925:40). Made famous by Burgess's (1925) concentric zone model and reinforced by racial segregation (Du Bois 1899) and opportunistic development (Logan and Molotch 1987), such zones (aka, natural areas) were originally conceptualized as constituting an "orderly and typical grouping of population and institutions" (Park 1925:1). The classical result was a central business district at the core, surrounded by a zone of transition, then working-class neighborhoods, and so forth, each identifiable by the social status of its inhabitants and shaped by its interactions with other, nearby zones.

The second idea that we pull forth from classical urban ecology is that of succession. For the Chicago School, succession was a central process by which groups change their geographic location, thus altering the socio-demographic composition of particular zones over time (McKenzie 1925; Park 1936; see also Burns 1980; Hawley 1944; Hernes 1976). The underlying point is that the social character and composition of different zones are not fixed; instead, they continually, if slowly, unfold in relation to what is going on around them and in relation to their own pasts. In these ways, spatial location and place history both matter together for how respective zones within cities develop, which they do successively through and atop earlier rounds of settlement.

Subsequent urban theorists have not disputed these basic propositions, but they have challenged their spatial configuration, especially the idea that urban areas have just one core, in relation to which all other zones and processes of succession unfold. The Los Angeles School of urban studies of the 1990s and early 2000s, for example, has argued for a multinodal, politically fractured approach to understanding urban regions, which have become less mono-centric over time (Dear 2002; Garreau 1991; Soja 2000). We accept this argument and take it a step further to highlight not just the spatial fracturing of local social ecologies but also their interactions with local environmental ecologies that tend to be more physically anchored in place.[1] These interactions, along with new policies aimed at mitigating the risks that result, are the focus of our modified urban ecology.

In this updated framework, the environmental landscape that entwines with the local social ecology becomes a dynamic force in the latter's formation and change. When we scope this environmental landscape downward to focus on a particular type of hazard—for

example, repetitive flooding—we might talk of a particular hazardscape. In some cases, this hazardscape might be spatially contained or contiguous, say, in the form of a coastline prone to storm surge. In other cases, it might be more spatially fragmented, say, in the form of a tangle of creeks, rivers, and bayous prone to inland flooding that characterizes much of the South, where urbanization has accelerated dramatically over recent decades (Colten 2014). The latter illustrates how the local environmental ecology of cities can become spatially disjointed, just as the social ecology does, as local growth machines push urbanization outward across the local landscape (Loughran 2016; Wachsmuth 2014). It also draws attention to how different types of residents shift and settle in relation to these evolving hazardscapes, that is, how local social and environmental ecologies change and intersect over time, creating and exposing new vulnerabilities.

The Social Vulnerabilities of Intersecting Ecologies

Highlighting these intersecting social and environmental ecologies brings us into conversation with ongoing research on environmental injustice and social vulnerability. Work on the former has traditionally focused on chronic risks to health posed by industrial hazards (e.g., Bullard 1993; Cole and Foster 2001; Crowder and Downey 2010; Elliott and Smiley 2017; Stroud 1999; Taylor 2014), whereas the latter has focused more generally on acute risks posed by natural disasters and the environmental hazards that trigger them (e.g., Cutter, Boruff, Shirley 2003; Tierney 2014). Both literatures, however, emphasize common points that are useful for our modified urban ecology. One is that the risks associated with local environmental ecologies are not natural but rather socially produced. The other is that this production involves processes that operate at multiple, overlapping scales within urban areas (Bulkeley, Edwards, and Fuller 2014).

At the more immediate scale and in pursuing their own priorities (e.g., productivity gains, profits, and regulatory freedom), discrete organizations and institutions commonly fail to prioritize the long-term safety of other residents, which, intentionally or not, can result in risk build-up within urban centers. At the scale of local government, which has primary authority over land development and flood control in the United States, elected officials and established agencies often privilege such development over other considerations, such as local quality of life. Third, these multi-scalar dynamics often conjoin to produce risk unevenly, and as a result, some people and places become more threatened than others, with people of color and lower income groups often suffering disproportionate burdens due to circumscribed social, political, and economic resources.

Thereafter, when these ongoing, overlapping processes manifest in a large-scale disaster, efforts to recover from them can further exacerbate related vulnerabilities. As Gotham and Greenberg (2014) have shown, this tendency often evolves out of "crisis" narratives that emerge in the aftermath of urban disasters, which allow political leaders and other power brokers to circumvent normal channels of governance in the name of "recovery." These efforts often end up directing resources to wealthy areas, white communities, and tourist districts at the expense of poor communities and communities of color (Loewenstein 2015; Mutter 2015). And, in the time of climate change, these stratifying dynamics promise to intensify—and new ones likely to emerge—suggesting that risk buildup, disaster recovery, and resilience should also be understood within the framework of "climate justice," which draws explicit attention to the types of rights, responsibilities, distributions, and procedures required to respond justly to climate change (Bulkeley et al. 2014; Walker and Burningham 2011).

Collectively, these dynamics might suggest that environmental ecologies of risk map neatly onto social ecologies of vulnerability, as racial segregation, working-class clustering, and other stratifying forces that shape cities also steer people at the bottom of intersecting race and class hierarchies into the riskiest zones of a city's evolving hazardscape (Bullard 1993). In some instances, however, such

overlap may not be so clean or absolute. We suspect that this may be the case when it comes to spatially fragmented urban flooding for two reasons. One is that in order for a group to reside disproportionately in such a spatially fragmented zone, members must have sufficient status to spread across different areas of the city. Historically, this has not been the case for African Americans, who because of extreme marginalization, have tended to be much more residentially confined than other groups (Drake and Cayton 1945; Du Bois 1899). Another reason that the mapping of social vulnerabilities onto areas of dispersed urban flooding may not be so rigid is that related risks can open opportunities for discounted housing in centrally located areas of the urban core. As such, it may not always be the most socially vulnerable, or marginalized, groups that shift and settle into a risky flood zone. Instead, it may be groups that are growing in number and positioned more toward the middle of the local social hierarchy, between more and less advantaged groups.

Risk Containment and Federally Funded Property Buyouts

When environmental risks and social vulnerabilities collide within urban areas, they generate a variety of responses. At the household level, they may trigger considerations of whether to stay or move, and in the case of large-scale disasters even set off waves of displacement that have been shown to amplify local residential instability (Elliott and Howell 2017) as well as larger systems of regional migration (Curtis, Fussell, and DeWaard 2015). In these ways, environmental ecologies can contribute to the successive remaking of local social ecologies, as groups that once settled within given areas of a particular urban hazardscape exit and others replace them. At a more structured level, governments, too, respond to the collisions of evolving social and environmental ecologies. Historical efforts have included, for example, not just long-running investments in massive engineering and mitigation projects but also Presidential Declarations of Disaster that began formally in 1953, and the NFIP that began in 1968. In the present study, we focus on a more recent policy initiative, known formally as the Federal Emergency Management Agency's (FEMA) Hazard Mitigation Grant Program.

Established in 1985 but now increasingly prominent, this initiative distributes federal funds to local governments to pursue voluntary home buyouts in targeted areas of repetitive flooding. The rationale behind the program is to reduce mounting financial pressure on the NFIP by buying out property owners in the most precarious areas and returning their developed parcels to nature in ways that can better absorb or otherwise redirect excess water in the future (Fraser et al. 2003). From a policy perspective, such buyouts constitute a rational, cost-effective urban planning tool. They are market-based, nominally voluntary, and deferential to property owners who are allowed to make an economic determination about the offered buyout price relative to the appraised value of their lot, and to take into account probable future costs associated with repetitive flood loss. Buyouts may also be conceptualized as a migration-based mitigation strategy in that, in addition to undoing prior development, they also move residents elsewhere (see Koslov 2016).

In our modified urban ecology, we conceptualize this policy tool as one of risk containment (Elliott and Frickel 2015) because it does not eliminate risk but rather intercedes strategically into specific areas where intersecting social and environmental ecologies have become particularly pressing. Here, public officials are producing a new type of zone within the twenty-first urban ecology: the buyout zone. In this zone, new mitigation policies intersect with ongoing social and environmental ecologies already in motion, which are likely to influence how widely that policy is implemented.

Summary and Hypotheses

To summarize the modified urban ecology sketched previously, we offer the heuristic in Figure 1. The left-most panel depicts the

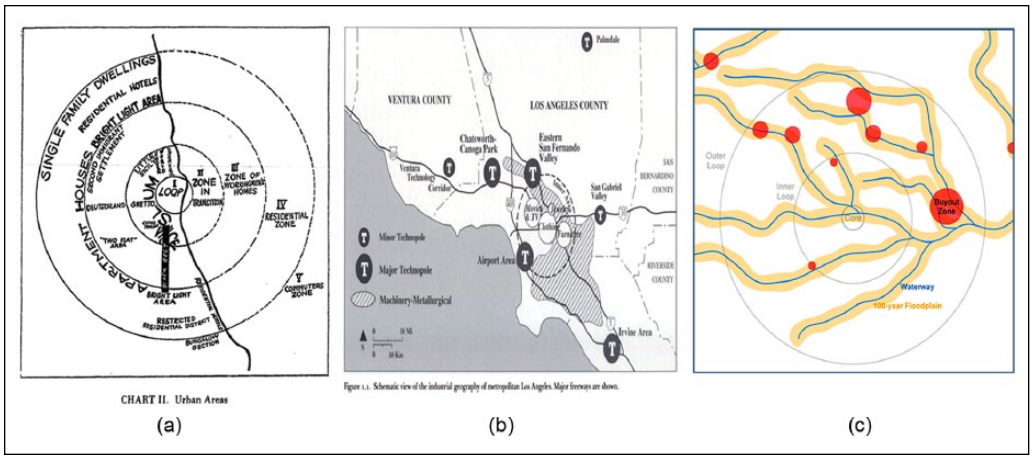

Figure 1. (a) Urban ecology of Chicago School (Burgess 1925: 55) (b) Urban ecology of LA School (Scott and Soja 1997: 13) (c) Modified urban ecology of present study, image by authors.

de-natured, de-watered ecological model of Burgess's Chicago. In it, Lake Michigan, the Chicago River, and smaller floodplains and waterways are intentionally rendered invisible to emphasize the city's socio-spatial center and the zones that form and emanate from that center, in orderly but clearly racialized ways. The middle panel illustrates the LA School's theory of a spatially fragmented social ecology, wherein a particular type of zone, say a technopole of innovation, is shown to emerge in different areas of the sprawling urban region, but local environmental ecologies still remain secondary. The right-most panel begins instead with local waters. In it, community areas and highways are abstracted away to emphasize a local hydrological structure. What emerges around this structure is the focal hazardscape—indicated here by, say, a city's 100-year floodplain (itself an evolving social production)—and within that, the spatially fragmented buyout zones, where this hazardscape intersects with changing social ecologies and policy interventions. As indicated by the greyed-out concentric zones, traditional models cannot easily account for the ecology of buyout zones. From this heuristic and the discussion earlier, we posit several foundational hypotheses for investigation.

Hypothesis 1: Within a given urban area, a particular demographic group will settle disproportionately within areas of environmental risk and eventual policy intervention (e.g., buyout zones), regardless of how spatially diffuse those zones become.

Hypothesis 2: Over time, this social ecology—which need not consist of the most socially vulnerable or marginalized group—will shift in accordance with general principles of residential succession.

Hypothesis 3: The extent and direction of local residential succession will influence subsequent risk containment efforts, especially those privileging individual choice (e.g., federally subsidized buyouts).

Case Study of Houston: Flood and Buyout Capital

To test our hypotheses and refine our framework, we study Houston because it is reflective of the conceptual, empirical, and policy challenges faced by cities and urban researchers in the age of climate change. Like the Chicago encountered by Park and Burgess in the 1920s, contemporary Houston is a place that has experienced rapid urban development and demographic diversification over recent decades with little in the way of centralized planning (Emerson et al. 2012; Feagin 1988). Like early Chicago, too, this urbanization has generated stark inequalities and relied heavily on a "drain and reclaim" approach to local wetlands in

conjunction with massive mitigation projects. Now excess water and its broad distribution present a growing threat. Data from National Oceanic and Atmospheric Administration (NOAA's) National Centers for Environmental Information indicate an average of four to five flood days per year over the past decade (Erdman 2017). This regularity along with three major flood events in the past three years—the Memorial Day Flood (2015), the Tax Day Flood (2016), and Hurricane Harvey (2017)—has led reporters in outlets as diverse as *Scientific American* and the Weather Channel to dub Houston "Flood Town" and "Flood Capital" of the United States.

As such, Houston offers a strategic research site from which to empirically engage a modified urban ecology of water and flood hazards. Over recent decades, Houston has grown rapidly, generating local residential zones and inequalities that continue to expand and shift over time and space in accordance with broad principles of classical ecology. At the same time, this development has intersected with a vast and growing number of repetitive flood zones, which remain not only geographically fixed, by comparison, but also sites of growing policy intervention aimed at undoing prior development for the sake of future resilience. The fact that these areas do not line up neatly along a major coastline or river adds further analytical benefit. Indeed, the waterscape of Houston includes 22 bayous that, along with constructed channels, run nearly 2,500 miles. Surrounding those bayous is a floodplain that forms a fragmented hazardscape, where different types of residents and policy interventions not only intersect but change in relation to one another over time.

Data and Method

Drawing from the earlier discussion, we use federally subsidized buyouts to identify areas of the local flood hazardscape where social, environmental, and risk-containment dynamics intersect.[2] As a subset of the local flood hazardscape, we acknowledge that not all waterways or stretches of waterways are equally hazardous, even if they flooded sometime in the past. For purposes of the present study, we are specifically interested in areas where officials have deemed current engineering projects and flood insurance programs to be insufficient and, therefore, in need of other types of intervention, including buyouts. It is here that public resources are being deployed deliberately to undo past development that they once helped to support. After a buyout, all structures on the purchased site are cleared, leveled, and returned to open space along with a promise that the site will never be residentially or commercially occupied again. It will instead offer a porous surface to absorb and occasionally channel excess water or become part of a larger flood mitigation infrastructure.

In addition to examining who demographically has resided in these areas recently and in the past, we test whether and how such residential succession influences the number of subsequent buyouts in a given area.[3] To date, most public discussions around buyouts have emphasized two themes: their voluntary, market-based administration, pending federal funds, and local approval; and the idiosyncratic decision making of local property owners who vary widely in personal resources, life plans, and place attachment. Missing from these discussions is the local context in which such deliberations unfold.

For both sets of analyses, we draw on a unique dataset from the Harris County Flood Control District (HCFCD). This dataset contains the addresses and payouts for every one of the 3,076 federally subsidized buyouts in Harris County between 1985 and 2017, pre-Harvey. Harris County, with a residential population of more than 4.5 million, is the central county of the City and Metropolitan Area of Houston. For analysis, we aggregate site-level buyout records to the level of census tracts and combine them with demographic data from the U.S. Census and the American Community Survey (ACS) between 1970 and 2014. For all years, respective tracts are standardized to 2010 boundaries, which means that analyses are conducted for the same, fixed spatial units over time. These spatially standardized data come from the GeoLytics'

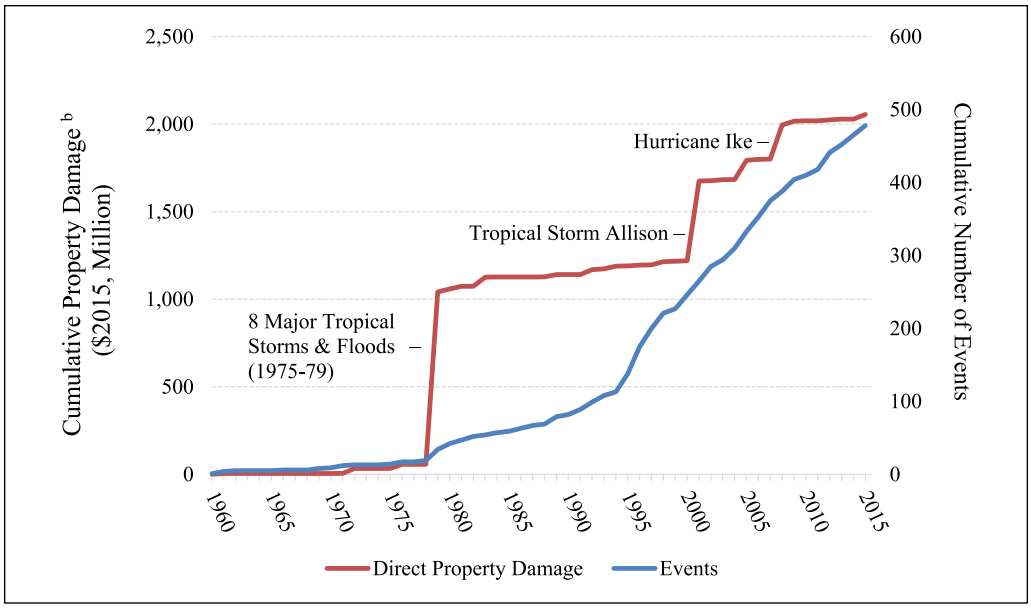

Figure 2. Cumulative number and property damage (in $2015) for floods, storms, and hurricanes in Harris County, Texas, 1960–2015[a].

Source. SHELDUS version 15.2.

[a]These include only events that caused at least $50,000 in direct property damage or one fatality. (They do not include damages and events associated strictly with lightening, hail, and tornados.)

[b]Property damage is measured at the county level using SHELDUS's accounting of direct losses to (noncrop) property. These values do not include indirect disruptions to commerce or production, nor do they include fire assistance grants for mobilizing equipment and personnel. Thus, they provide a conservative measure of direct, local damages to property (Gall, Borden, and Cutter 2009). All values are adjusted to 2015 dollars before cumulative accounting.

Neighborhood Change Data Base (NCDB) developed in partnership with the Urban Institute (GeoLytics 2016). The database draws from the decennial Census of Population and Housing between 1970 and 2010 and from the ACS (five-year sample) for 2014 (U.S. Census Bureau [USCB] 2016).

Results

Flooding and Areas of Eventual Federal Buyout

First and as background, Figure 2 shows the cumulative number of rain storms, floods, and hurricanes—aka, water events—that caused at least $50,000 in property damage or one fatality in Harris County from 1960 through 2015. These results and running totals for direct property damage indicate nearly 500 such events triggering more than $2 billion in cumulative damages, not including lost wages and profits. These totals equate to an average of nine events causing $36 million in direct damages per year (not including the Tax Day Flood of 2016 or Hurricane Harvey of 2017).

Next, Figure 3 displays a running total of federally subsidized buyouts in Harris County since 1985, when the program first began locally. Results show light use prior to Hurricane Allison in 2001, after which local officials began to pursue it more aggressively throughout the area. Table 1 shows that by the summer of 2017, just before Hurricane Harvey, property buyouts had occurred in 15 different watersheds, 71 different Super Neighborhoods,[4] and 148 different census tracts within Harris County. Supplemental analyses indicate that 100 percent of these census tracts incurred residential damage during Hurricane Harvey,

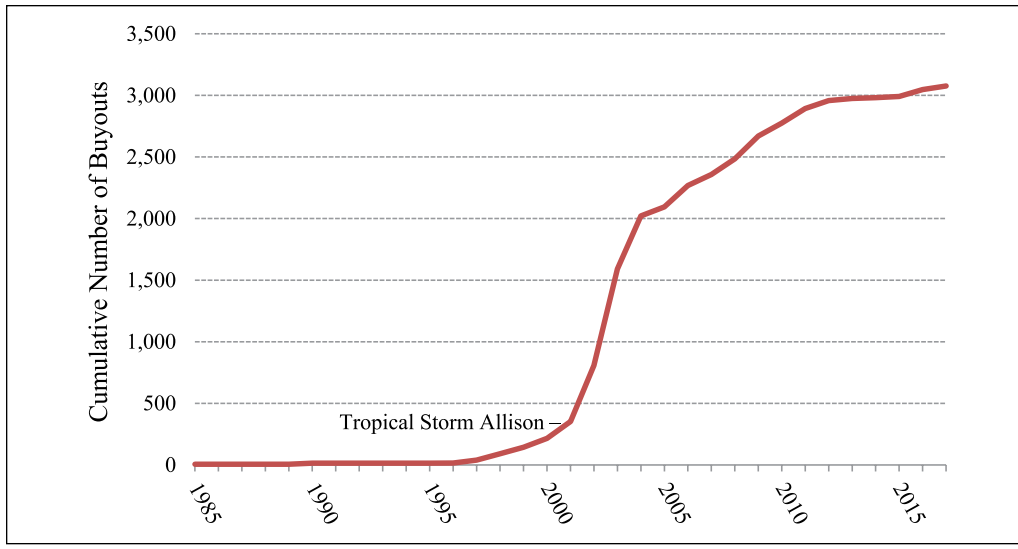

Figure 3. Cumulative number of federally assisted buyouts in Harris County, by year.
Source. Buyout data from Harris County Flood Control District, pre-Hurricane Harvey.

according to the City of Houston Harvey Damage Assessment (City of Houston 2018a).

Historical Residential Clustering

In this section, we test the hypothesis that, despite Houston's geographically scattered buyout zones, certain types of residents nonetheless tend to cluster in them. To assess historical patterns of such clustering, we first estimate regression equations using census data for 1970, when the NFIP was just beginning. In these equations, census tracts serve as the unit of analysis and are reconfigured to 2010 boundaries to standardize comparisons with more recent data analyzed below. Consistent with a long line of sociological research on the racial and class segregation of American cities and research linking such segregation to place-based vulnerabilities, we focus on the racial composition of respective tracts in addition to two indicators of class status: educational attainment, measured as the percentage of residents 25 years and older who have less than a high school education, and homeownership, measured as the percentage of occupied housing units that are owner occupied. All models statistically control for the size and density of the tract's population—two baseline features of local urban ecology—and for the percentage of residents who are under 18 years of age, which serves as a proxy for the presence of families.

Results appear in Table 2. Model 1 indicates that in 1970 and net of other factors, black and Hispanic residents were significantly *less* likely to cluster in areas of eventual buyout than white counterparts (who serve as the reference category). Conversely and net of these racial differences, results also indicate that less-educated residents and families with (more) children were significantly *more* likely to cluster in areas of eventual buyout. By contrast, results show no statistically significant variation with regard to homeownership.

To further examine the racial and class dimensions of this historical clustering, we estimated a series of additional regression equations that included interaction terms among respective variables. Model 2 in Table 2 offered the best statistical fit. In it, the racial composition of a tract is simplified to percentage white, and this variable is interacted with the percentage of residents with less than a high school degree. Here, we see a strong, positive interaction. We also see that the presence of children remains strongly positive, as well.

Table 1. Watersheds of Harris County, Texas by Descending Order of Federal Buyouts, 1985–2017 (before Hurricane Harvey).

Local watershed[a]	Number of super neighborhoods[b]	Number of census tracts[c]	Number of buyouts	Buyout acreage (000)[d]	Buyout costs ($million)[e]
Buffalo Bayou	23	111	1,110	203.2	143.7
San Jacinto River	18	88	431	102.4	28.5
Brays Bayou	19	128	388	229.5	66.8
Greens Bayou	14	76	266	56.8	20.3
Hunting Bayou	11	62	185	71.2	26.2
Armand Bayou	4	28	183	47.8	16.4
Spring Gully/Goose Creek	4	32	134	61.6	17.9
Cypress Creek	12	62	90	96.3	9.2
White Oak Bayou	16	69	90	85.8	11.0
Cedar Bayou	3	25	64	56.0	7.7
Clear Creek	5	28	57	34.5	6.0
Addicks Dam	4	33	30	55.0	4.6
Sims Bayou	5	13	9	14.5	1.0
Barker Dam	3	19	4	16.7	0.9
Carpenters Bayou	1	7	1	3.7	0.1
Harris Co. Total	142	781	3,042	1,135	360.3

[a]Excludes Spring Creek watershed, which county records indicate had 2,641 acres bought out at no cost. Water sheds are distinguished by the Harris County Flood Control District.
[b]Super Neighborhoods include all officially recognized Super Neighborhoods and independent municipalities in Harris County. According to the City of Houston: "A super neighborhood is a geographically designated area where residents, civic organizations, institutions, and businesses work together to identify, plan, and set priorities to address the needs and concerns of their community. The boundaries of each super neighborhood rely on major physical features (bayous, freeways, etc.) to group together contiguous communities that share common physical characteristics, identity, or infrastructure. The super neighborhood elects a council comprised of area residents and stakeholders that serves as a forum to discuss issues and identify and implement priority projects for the area" (http://www.houstontx.gov/superneighborhoods/ accessed 12/24/2017).
[c]Census tract are defined using official 2010 boundaries, which hold for all subsequent analyses.
[d]Nominal payouts recorded at time of buyout. If adjusted for inflation, the Harris Co. Total would be closer to $440 million in 2017 dollars.
[e]Based on calculations from shapefiles using Geographic Information Software.

Thus, the historical picture that emerges from 1970 is not one of racial injustice in which people of color were disproportionately concentrated into eventual buyout areas, nor is it one of under-development. Results consistently indicate that in 1970, eventual buyout tracts were more populated than other tracts. Instead, the evidence points to two intersecting ecologies, one environmental and the other social. The social ecology is one of early settlement by white, working-class families unable to access wealthier white neighborhoods but also less socially and spatially constrained by intense racial segregation imposed on black and Hispanic counterparts. This scenario is a social ecology of the middle—one positioned below more-advantaged white counterparts but above less-advantaged minorities. The other ecology, the environmental one, is also of the middle. It is geographically fixed in areas with relatively central access to urban employment but also temporally sandwiched between past flood events and future risks. That was in 1970. Since then, these two ecologies, social and environmental, have continued to shift as ongoing urbanization, racial diversification, and new policies designed to address rising flood costs fan out across the growing urban area.

Table 2. Logistic Regression Results Predicting if a Tract Eventually Had One or More Buyouts (Yes/No) in Harris County (Standard Errors in Parentheses).[a]

Census tract variables	Model 1 1970	Model 2 1970	Model 3 2014
Population (000)	0.293*** (0.073)	0.289*** (0.074)	0.038 (0.037)
Population density (000)	−0.166** (0.064)	−0.174** (0.064)	−0.258*** (0.047)
% White	—	−1.740 (1.173)	—
% Black	−1.907** (0.559)	—	0.450 (0.521)
% Hispanic	−3.952** (1.368)	−1.283 (1.292)	2.530** (0.935)
% Asian	−2.085 (4.725)	−1.643 (4.850)	0.549 (2.705)
% Less than high school	3.918*** (0.628)	−0.664 (1.890)	—
% Owner occupied	0.507 (0.823)	0.657 (0.825)	0.832 (0.525)
% Under 18 years old	5.710* (2.393)	4.732* (2.282)	−0.639 (1.980)
% Foreign born	—	—	−2.306 (1.909)
% White × % less than high school	—	4.417* (2.008)	—
Constant	−5.520*** (0.943)	−3.647** (1.376)	−1.452* (0.628)
N (tracts, 2010 boundaries)[a]	744	744	744
Log likelihood	−325.2	−327.2	−331.5

[a]Includes only census tracts with 25 or more residents in 1970. Tract boundaries in 1970 and 2014 are standardized to the same 2010 boundaries. All racial and ethnic composition variables are mutually exclusive; whites, blacks and Asians are all non-Hispanic.
*$p < .05$. **$p < .01$. ***$p < .001$ (two-tailed tests).

Contemporary Residential Clustering

In this section, we test the hypothesis that the socio-demographic composition of eventual buyout areas changes as the aforementioned forces successively intersect over time. For this assessment, we use data from the 2014 ACS (with the same 2010 tract boundaries used for 1970) but with two changes. First, we no longer include the variable for the proportion of residents with less than a high school education because, over time, this variable has become almost completely collinear with a tract's proportion of Hispanic residents ($r = 0.9, p < .001$). Second, and as a result, we substitute a variable indicating the percentage of residents who are foreign-born, which increased from approximately 2 percent in 1970 to approximately 26 percent in 2014. In this way, just as education stratified the largest ethnoracial group in Harris County—whites—in 1970, nativity now stratifies the largest ethnoracial group in Harris County—Hispanics—today, with roughly 40 percent being foreign-born. With these analytical changes, our central questions are twofold: Is socio-demographic clustering still identifiable after four decades of rapid urbanization and racial diversification? And if so, has it changed?

Results in Model 3 of Table 2 indicate that the answer to both questions is yes. Overall, findings show that buyout zones are now disproportionately populated by Hispanic residents, above and beyond what we might otherwise expect from their demographic growth in the area as a whole. Indeed, solving Model 3 indicates that, all else equal, the predicted probability of a tract having a buyout property in 2014 increases from 7 to 30 percent as the share of Hispanic residents increases from 10 to 75 percent. Moreover, there are 119 tracts in 2014 where the proportion of residents who are Hispanic is 75 percent or higher, and all but two of these tracts have more native-born than foreign-born residents. Examples of such tracts with buyouts include those in Galena Park along Hunting Bayou, in Pasadena along Vince Bayou, and in the Jensen area along Halls Bayou—all of which are more than 80 percent Hispanic and 70 percent native-born, in addition to being areas of federal buyout.

To further examine this clustering in 2014, we estimated a series of additional regression equations that included interaction terms among all independent variables in Model 3. None of these interactions proved statistically significant

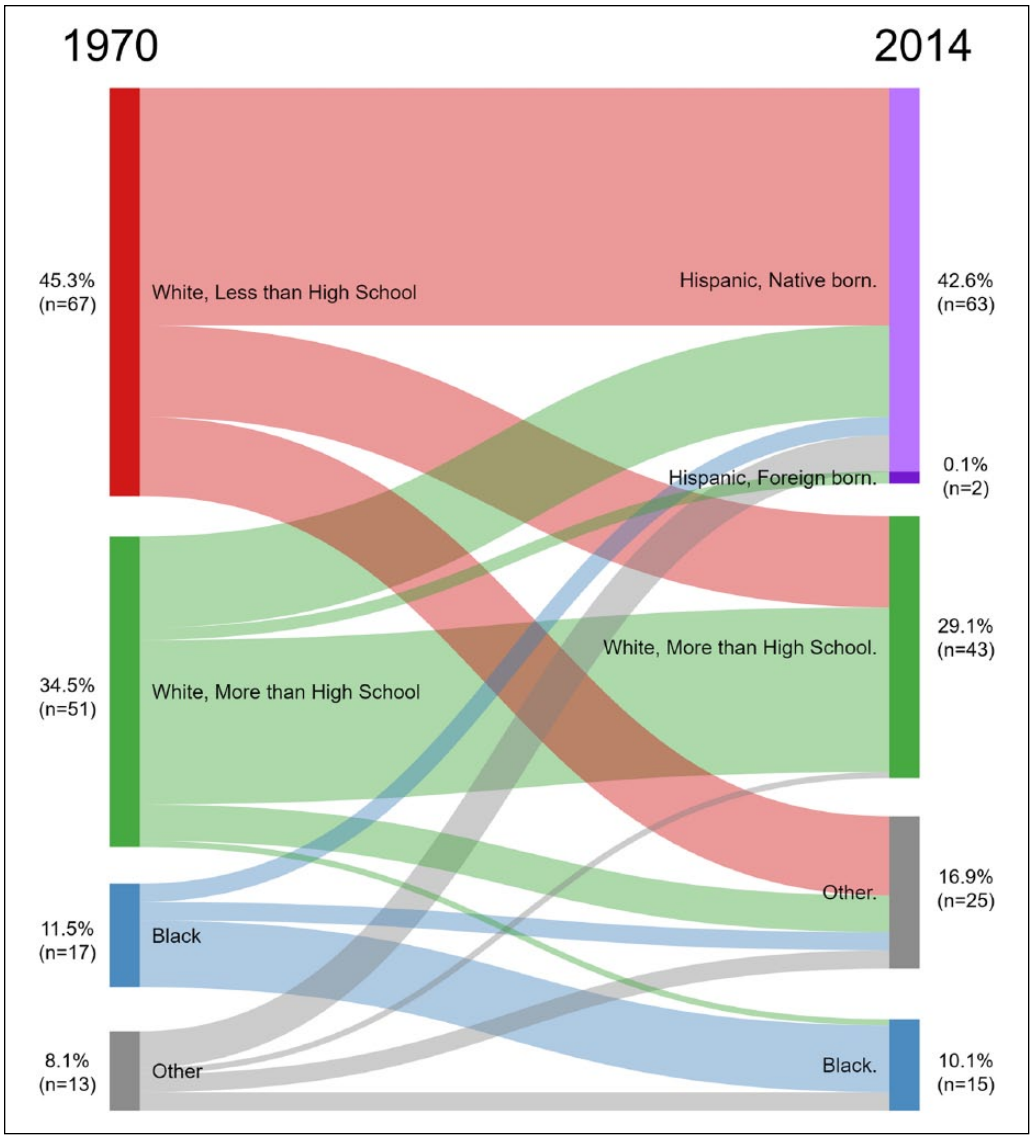

Figure 4. Sankey diagram depicting stocks and flows of buyout tracts by demographic type, 1970–2014.
Note. $N = 148$ tracts with at least 25 residents in 1970. White, Less than High School refers to majority-white tracts in which a majority of residents aged 25 years and older had less than a high school education. All 67 of these tracts in 1970 converted to some other type by 2014, with 58 percent ($n = 39$) converting to majority-Hispanic, majority-Native Born tracts. White, More than High refers to majority-white tracts in which most residents aged 25 years and older had attained at least a high school degree. Black refers to majority-black tracts, regardless of educational attainment. Hispanic, Native born refers to majority-Hispanic tracts in which most residents are also native born, regardless of race/ethnicity. No such tracts existed in 1970; by 2014, 63 such tracts existed. Hispanic, Foreign born refers to majority-Hispanic tracts in which most residents are also foreign born, regardless of race/ethnicity. No such tracts existed in 1970; by 2014, two such tracts existed.

at the 0.05 level. Thus, overall, the findings from Table 2 are quite straightforward. They indicate that over time, white working-class settlement in eventual buyout zones has given way to Hispanic working-class settlement. Indeed, supplemental analyses show that the percentage of Hispanic residents in today's buyout zones has increased nearly eightfold since 1970.

To help visualize this residential succession, we present a Sankey diagram in Figure 4.

For this diagram, we leverage findings from Table 2 to divide all buyout tracts into a handful of types. In 1970, there are four types: (1) less-than-high-school, majority-white tracts; (2) more-educated, majority-white tracts; (3) majority-black tracts; and (4) other tracts, which include all tracts with no racial majority. Because there were relatively few Hispanics living in Harris County in 1970 and because Hispanics did not comprise a majority of residents in any eventual buyout tract at that time, they do not contribute to a meaningful neighborhood type in 1970. By 2014, however, that situation changes dramatically alongside the disappearance of less-educated, white neighborhoods. For these reasons, in 2014, we shift the neighborhood typology. We drop the less-educated, majority-white category because there are no longer any of these tracts present in Harris County. We then add majority-Hispanic, majority-native-born and majority-Hispanic, majority-foreign-born as categories.

Once these shifts are made, the Sankey diagram in Figure 4 allows us to see more clearly the succession, or flow, of buyout tracts from one type to another over time. For example, we can see how the majority of white, working-class tracts in 1970 became Hispanic, native-born tracts by 2014. We can also see that other types of buyout tracts in 1970 also became Hispanic, native-born buyout tracts by 2014, as indicated by the bands stemming from the three other neighborhood types in 1970.

Thus, buyout zones have not been abandoned over recent decades. Instead, they have been increasingly handed over to Houston's newest and now largest working-class group—native-born Hispanics. Interestingly, this group, like its white working-class predecessor, also occupies a middle ground between more affluent whites who have remained in Harris County and a more segregated black working class, whose racial expansion and neighborhood succession has been much more limited by comparison.

Succession as a Predictor of Use of Local Buyouts

Next, we test the hypothesis that the extent to which buyouts are used depends as much if not more on local demographic succession as on market logics or the racial and class composition of neighborhoods before buyouts began. For this assessment we restrict analyses to census tracts in which at least one buyout occurred between 2000 and 2017, just before Harvey ($n = 148$ tracts). We then predict the number of buyouts that occurred, which administrators widely consider to be a measure of programmatic success (de Vries and Fraser 2012). Specifically, we fit a series of negative binomial regression equations that estimate the count of buyouts completed in a tract, conditional on having at least one buyout occur. Results appear in Table 3.

To start, we predict the count of buyouts by the mean payment per buyout acre in the tract, controlling for the size and density of the tract's population in 2000, the year before buyouts began to increase dramatically in Harris County. Logically, we would expect this relationship to be positive and statistically significant, indicating that the higher the payment for buyouts, the more of them that occur. Model 1 provides no evidence to support this logic. Next, Model 2 adds a control variable for a tract's income per capita in 2000. Still, the relationship is statistically insignificant. Model 3 then enters the proportion of white residents in the tract in 2000, just before buyouts began to increase. Again, none of the predictors in the model are statistically significant at the 0.05 level.

Next, Model 4 adds a variable for the racial succession of a tract during the three decades preceding significant federal buyouts in 2000. This variable is computed as a simple change score between the proportion of residents who are white in 1970 and the proportion of residents who are white in 2000, which offers greater statistical reliability than more disaggregated racial measures over the same span. Here, we find a strong, *negative* result. That is, the less a tract's white population declines over time, the *fewer* subsequent buyouts occur. Results in Model 5 show that this relationship is even stronger after controlling for concurrent changes in per capita income, which exerts a counter influence. Residential succession along racial and income lines, in other words, is a, if not *the*, major driver of eventual buy-in for buyouts.

Table 3. Negative Binomial Regression Results Predicting Number of Buyouts in Tracts with at Least One Buyout (Standard Errors in Parentheses).

	Model 1	Model 2	Model 3	Model 4	Model 5
Buyout market incentives					
Mean payment per buyout acre ($000)	−0.001 (0.005)	−0.001 (0.006)	−0.002 (0.006)	0.003 (0.006)	0.001 (0.001)
Tract traits at start of buyouts, 2000					
Population (000)	0.096 (0.070)	0.096 (0.074)	0.097 (0.074)	0.154* (0.078)	0.218** (0.079)
Population density (000)	−0.047 (0.069)	−0.053 (0.071)	−0.053 (0.078)	−0.089 (0.080)	−0.037 (0.077)
Income per capita ($000)[a]		−0.004 (0.013)	0.004 (0.020)	−0.004 (0.020)	−0.117** (0.038)
% White			−0.034 (1.002)	0.413 (0.963)	1.452 (0.918)
Tract changes, 1970–2000					
Δ in % White[b]				−1.543** (0.488)	−1.923*** (0.494)
Δ in per capita income ($000)[c]					0.137*** (0.037)
Constant	2.747*** (0.418)	2.844*** (0.510)	2.841*** (0.517)	1.475* (0.649)	2.242*** (0.639)
Ln(alpha)	0.794 (0.101)	0.794 (0.100)	0.794 (0.100)	0.749 (0.101)	0.692 (0.101)
N (buyout tracts)	148	148	148	148	148
Log likelihood	−564.15	−564.09	−564.09	−559.48	−553.66

[a]Per capita income is adjusted to 2014 dollars for all values.
[b]Change in % White is measured as % white in 2000 minus % white in 1970 (e.g., 0.60 − 0.90 = −0.30).
[c]Change in Per Capita Income is measured as per capita income in 2000 minus per capita income in 1970, both adjusted to $2014 dollars (e.g., 50,000 – 25,000 = 25,000).
*$p < .05$. **$p < .01$. ***$p < .001$ (two-tailed tests).

To visualize the importance of racial succession in Model 5, Figure 5 graphs the predicted number of buyouts in a tract holding all other variables in the model, including income, constant at their sample means. Here, we see a strong downward slope, indicating that areas where white flight occurred most aggressively during the 1970s, 1980s, and 1990s became areas of greatest subsequent buyout, all else equal.

Finally, to probe this trend more deeply, we identified three buyout zones that have experienced particularly strong transitions from white working-class to Hispanic working-class settlement: the Pasadena, LaPorte, and Channelview areas. We then consulted public tax records available online through the Harris County Appraisal District to locate property records linked to buyout addresses in each zone. Once these links were made, we recorded the name of the last legal owner before the buyout occurred. Of the 125 properties we were able to clearly link, we estimate that about 22 percent had pre-buyout owners with Spanish surnames. If one compares this estimate to the roughly two thirds of residents in these areas who now report Hispanic ethnicity, it suggests that it is not Hispanics who sold out, but rather outgoing whites.

Conclusion

The impacts of climate change in urban areas present new challenges that require updated ways of understanding and predicting social phenomena that occur in their wake. These efforts, in turn, can open doors to better recognizing and mitigating climate injustices that will increasingly define many urban contexts in the years ahead. The present study sought to contribute to these broad efforts by narrowing our empirical gaze to focus on a particular type of policy response—property buyouts—to a particular type of impact—repetitive flooding. Overall, findings support our three foundational hypotheses: (1) that buyout zones, despite their spatial fragmentation across a sprawling urban area, have a distinctive social ecology; (2) that over time this social ecology changes as government officials implement new mitigation policies aimed at containing local flood risk; and (3) that how these changes occur at the neighborhood level influence use of subsequent risk containment policies, especially when these policies are largely voluntary. Collectively, these findings support efforts to resurrect and reformulate an updated urban ecology that centers on how socio-spatial ecologies intersect with more geographically fixed environmental ecologies, as well as how

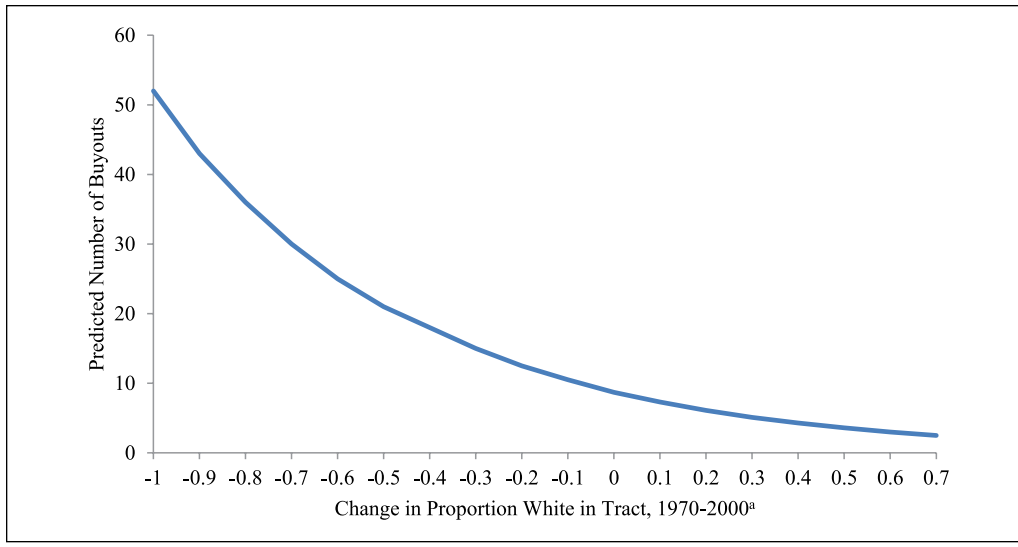

Figure 5. Predicted number of buyouts in a buyout tract by change in proportion white during 1970–2000, all else equal.

Source. Model 5 of Table 3 with all other variables held constant at sample means.

[a]The value −1 refers to a shift from 100% white to 0% white between 1970 and 2000; the value 0.7 refers to a shift of 70 percentage points in the proportion white between 1970 and 2000, for example, from 0.2 to 0.9, or from 20 to 90 percent. These lower and upper values constitute the full observed range of this variable among tracts in Harris County during 1970–2000.

policies intended to manage those evolving intersections come to unfold in relation to those intersections. Moving these efforts forward can take several paths. We focus here on those tied most directly to flood-related buyouts.

One path involves more direct research on what buyouts mean and do in different types of neighborhoods. Given that buyouts reveal local vulnerabilities and the sorting of social groups into different areas, it would make sense to investigate more directly the processes of social inequality that contribute to this sorting, which have long racial histories in the United States. Redlining, restrictive covenants, Jim Crow, Federal Housing Administration policies, and racial violence all conspired to delimit areas of black settlement in the twentieth century (Drake and Cayton 1945; Kruse 2005). Despite progress, black residential attainment remains circumscribed (Pattillo 1999), and other groups of color, including Hispanics, face similar constraints (Quillian 2012). Therefore, the residential choice sets and mobility options afforded to property owners considering if and when to accept federal buyouts is likely to differ for different ethnoracial groups. Relatedly, buyouts represent a political process, one that requires property-owners to interface with local and possibly federal officials (de Vries and Fraser 2012; Shriver, Adams, and Messer 2014). Not all property owners deemed eligible for FEMA funds are eager to participate: satisfaction with current residential attainment could foreclose interest in moving elsewhere, as could a lack of faith in government bureaucracies or an unwillingness to navigate them—including perceptions that the particular policy mechanism is a mode of racialized displacement (Lynn 2017).

Indeed, although the modal succession in buyout zones we observed in Harris County has been from white to Hispanic working class, this finding does not imply that other groups, particularly African Americans, have not also found themselves in buyout zones. A particularly contentious case occurred in Houston's Kashmere Gardens neighborhood, where the HCFCD pursued its Hunting Bayou Project (Lynn 2017). These types of cases are

important to consider because they can provide clues as to how the challenges facing different racial groups over time shape residents' abilities to move into as well as sell out of risk-prone areas. In this way, such cases can illuminate the overlapping dynamics in play and how predominantly black neighborhoods are not only much less likely to undergo racial succession once they are established (Pattillo 1999) but how this dynamic in turn shapes future risk mitigation strategies.

Attending to such dynamics might also extend more deeply into investigations of who *within* respective areas is digging in and who is leaving. These questions would benefit from expanding into broader questions of land tenure: Who owns the properties being bought-out? Are they owner-occupied, or rented? Where do residents go when they are bought out? These questions might then extend conceptually into how we think about areas of extensive flooding and subsequent buyouts: Do they represent the stark curtailment of residential succession in that they reduce local housing stock? Or, do they represent a different phase in which housing does not diminish in number but instead shifts to different, less flood-prone parts of the established community? The answer may rest not just on numbers of local buyouts but also on how the cleared parcels are later used.

For example, in preliminary field investigations for the present study, we surveyed a number of buyout sites in two very different neighborhoods: one an affluent white neighborhood, and the other a largely black, lower-income neighborhood. In our observations, buyouts were becoming parts of the new local ecologies in different ways. In the affluent white community, the handful of buyouts were functioning as local recreational and aesthetic amenities: they presented as FEMA-owned pocket parks where well-tended flowers and trees mixed with occasional patio furniture or a soccer net. A real-estate advertisement for an adjacent property even boasted, "BIG PLUS: The vacant lot behind the property is a HCFCD/FEMA-owned lot which can never be built on, per current federal law." Conversely, in the less-affluent black neighborhood, buyout sites had a different character. The planning processes that created them seemed less idiosyncratic and more institutional. A large swath of buyouts along the neighboring bayou resulted in open fields dotted with large-scale flood infrastructure. Other buyout sites in the neighborhood, while newly mowed, often contained trash and other debris, and sometimes abutted other vacant lots and abandoned homes. Beyond their apparent value as flood-control, it was difficult to imagine these sites serving as local amenities.

Regardless of the specific path taken, the broader, concluding point is that ongoing development of a new urban ecology can help inform and contextualize emergent urban-environmental concerns. The Chicago School laid forth an urban ecology structured by forces of population concentration, centralization, segregation, invasion, and succession. These were the forces that contributed to a city's dynamic growth, division, and ongoing reorganization. Our efforts retain these social-ecological forces as well as the mediating determinants of race, class, and land values, but we re-insert a critical factor: environmental ecologies and, specifically, water hazardscapes.

Indeed, in thinking about the applicability of this integrated framework, the wide-ranging impacts of climate change on cities across the world give a heightened importance to critical reassessments of urban-environmental links. Beyond improving social scientists' ontologies of cities and nature as well as risk and adaptation, the urgency of environmental crises and their associated social inequalities calls for a broad, interdisciplinary scope. Our new urban ecology can aid in such efforts. Elite-led "risk containment" efforts intervene not only in environmental hazards of various kinds but in the social ecologies that form recursively in and around hazardous sites. Scholars investigating climate justice should not only attend to the environmental changes—such as rising water levels and desertification—that bring the droughts, floods, and other crises that tend to most severely impact groups at the bottom of social hierarchies but also critically examine the

policies that claim to intervene in such changes and how the resulting social impacts may exacerbate, or diverge from, expected inequalities along lines of race, class, gender, and other domains.

In a similar way, researchers focusing on buyouts should continue to extend beyond the analysis of "best practices" to consider the social context in which buyouts are occurring. Importantly, this should encompass the current socio-demographic character of buyout zones as well as historical processes of local demographic change, which our research suggests are extremely important: a key factor distinguishing neighborhoods that sold out most to government agencies was not the absolute number of minority residents or flooded units but the rate at which minority populations were *growing*. This deserves more direct and ongoing attention, and we contend that this issue must be understood at the metropolitan scale. This is particularly pressing work for places where most humans now live: in sprawling urban regions threatened by encroaching water.

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Notes

1. Here, we are foregrounding the absolute "landscape dimensions" of places—that is, their discrete geospatial location. The more relational "sense of place"—that is, the social construction of community and the production of local cultures (Brown-Saracino 2015)—is not disregarded. It simply shifts to the background. Future work may emphasize how local cultures and new subjectivities form and shift in relation to hazards linked to the landscape dimensions of places.
2. One potential shortcoming of focusing on buyouts is that they only involve the decision making of property owners. Renters, who make up a slight majority of Houston residents, are not directly included in this decision making. They can, however, occupy rental housing that owners sell to a buyout program. They also contribute to the social ecology of local buyout zones. But renters' omission from our sample may suggest that the most vulnerable local residents are omitted; given the importance of understanding the most marginalized from a climate justice standpoint, future work should more directly investigate how renters (and the homeless) are implicated in these top-down risk-containment policies.
3. Buyout criteria are, "1. The property must be located in a community that participates and is in good standing in the National Flood Insurance Program (NFIP) and has a Federal Emergency Management Agency (FEMA)-approved Hazard Mitigation Action Plan. 2. The property's purchase must be cost beneficial. A property is considered cost beneficial if the cost of acquiring and demolishing the property is less than the cost of the estimated future flood damages to the property. 3. The property must have a current flood insurance policy to meet the requirements for certain types of FEMA grants, such as Severe Repetitive Loss (SRL) and Flood Mitigation Assistance (FMA)" (https://www.hcfcd.org/media/1730/voluntary-buyoutprogramfema.pdf, accessed 11/15/2017).
4. According to the City of Houston (2018b), "A super neighborhood is a geographically designated area where residents, civic organizations, institutions, and businesses work together to identify, plan, and set priorities to address the needs and concerns of their community. The boundaries of each super neighborhood rely on major physical features (bayous, freeways, etc.) to group together contiguous communities that share common physical characteristics, identity, or infrastructure. The super neighborhood elects a council comprising area residents and stakeholders that serves as a forum to discuss issues and identify and implement priority projects for the area." In addition to the 88 officially recognized super neighborhoods, we also count smaller municipalities in Harris County as super neighborhoods, since they too serve many of the same functions (e.g., West University and Galena Park).

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