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Expulsive Greening: A Cross-Sectional Analysis of Resilience-Era Green Gentrification in Brooklyn, New York

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This project analyzes the impacts green gentrification in Brooklyn by evaluating the spatial coincidence between gentrification rates and urban greening from 2010 to 2020. Assets formed under the NYC Green Infrastructure Program were chosen as a proxy for urban greening to represent urban greening within the 21st-century climate change resilience paradigm of development. Methods: This is a mixed method approach to a natural experiment. First, five indexes measuring variations of economic and demographic conditions related to gentrification were applied to Brooklyn for comparative analysis: NOAA's Social Vulnerability Indicators of Gentrification Pressure, The NYC Heat Vulnerability Index, The Small Area Index of Gentrification, Typologies of Gentrification and Displacement, and The Housing Risk Chart. Then, for each index, a point-in-polygon count vector analysis was conducted using GIS software to determine the prevalence of green infrastructure assets within the varying gentrification categories. Then, using the method of dialectical materialism, close readings of theoretical, governmental, and corporate literature were used to examine the forces driving development practices during that time. Results: Gentrification varies per spatial unit with each index application, owing to varying index factors. However, the highest socioeconomic, gentrification, and ecological risk hot spots, regardless of index used, tend to be in northern Brooklyn, close to the border of Queens, while cold spots tend to be located in southern Brooklyn. Despite variability in gentrification hot and cold spots, every hot spot was highly associated with green stormwater infrastructure installed through the Green Infrastructure Program, while cold spots largely had few assets installed in their boundaries. A review of the quantitative results against the reviewed literature indicate that NYC's "green" planning and policies are related to ongoing green gentrification trends in the US.

Keywords

Brooklyn, Dialectical Materialism, Green Gentrification, Landscape, Proxy Representations, Resilience, Uneven Development, Urban Greening

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INTRODUCTION

Flowers and trees growing from rooftop gardens and street tree beds should be warmly welcomed bright spots in the Brooklyn hardscapes. But for many, ecological rejuvenation is perceived as a red flag for gentrification that threatens to disrupt their lives.

The purpose of this research is to evaluate the extent to which municipally sponsored urban greening is spatially linked to ongoing trends of this "green" gentrification by asking: What is the spatial relationship between urban greening practices and gentrification risk in Brooklyn over the last decade? To what extent do the landscape of urban greening and the landscape of gentrification coincide? While urban greening is necessitated in a coastal city planning paradigm of ecological resilience against the increase in both the magnitude and frequency of extreme weather events, greening is also marshalled by the real estate sector to increase community attractiveness to developers, raise property values, and earn tax breaks for new development. In turn, these things may exacerbate gentrification—or coconstitutive demographic shifts and economic transformations—possibly hurting longtime residents that cannot keep up with rising housing costs and other expenses.

Two themes in geographic theory speak to the issue: long-standing literature on the various city planning mechanisms that drive gentrification, and emerging literature on the burgeoning geography of "resilience." Herein, close reading of scholarly, corporate, and governmental literature is analyzed against themes from resilience planning to understand how urban greening practice correlates to the emergent gentrification crisis in Brooklyn.

Green Infrastructure for the CSO Problem

Responding to a 2005 order from the New York State Department of Environmental Conservation to reduce untreated combined sewer outfall (CSO) overflows, New York City (NYC) began deploying a new landscape of "green" stormwater infrastructure (GSI) in 2010. Raw sewage spilling into open waters from CSOs puts NYC out of compliance with Clean Water Act (CWA) Section 101(a)(2): "it is the national goal that wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water" (U.S. EPA 2002).

Green infrastructure is a stormwater management approach where structures that operationalize naturalistic elements (e.g., green roofs, permeable pavement, bioswales) capture and contain stormflow, preventing it from entering the sewer system. GSI reduces overflows, captures litter, increases permeable surface area, reduces urban heat island effects, contributes to the ever-increasing necessity for resilience against climate change hazards, and beautifies an area (Cherrier et al. 2016). However, the economic transformations and demographic shifts that accompany an increase in neighborhood attractiveness related to urban greening have been theorized to create "newly uneven socio-environmental riskscapes" (Colburn and Jepson 2012, 1).

Political Ecology and Green Gentrification in Brooklyn

Gentrification is a process where, first, a pattern of neglect and divestment from poor neighborhoods exacerbates vacancies and drives down land value, which is then followed by a period of reinvigoration by private investors encouraged by governmental and private financial incentives that increase the attractiveness of an area (Glass 1964; Smith 1979; 1987). It can be quantified through demographic shifts coupled with economic transformations, showing sharp changes in land value from low to high (Colburn and Jepson 2012; CDC 2017), where the socioeconomic environment changes to appeal to the new, typically wealthier, residents. Gentrification negatively impacts the health of existing residents by limiting access to affordable housing, healthful and culturally appropriate food, transportation, well-funded schools, bicycle and walking paths, exercise facilities, and social networks, while also potentially changing stress levels, injuries, violence and crime, mental health, and social and environmental justice (CDC 2017; Comber, Brunsdon, and Radburn 2011; Maguire et al. 2017).

Political ecology highlights "the dynamics among actors involved in environmental governance—including the state, civil society, and the public," which manifests as public-private partnerships for greening. Greening "campaigns can be understood as strategies used by competitive, global cities investing in environmental quality as part of city image-making, within a political-economic context of rescaled, post-industrial, neoliberalism,"[1] (Campbell 2015, 243).

In the two-phase "spatio-temporal fix," capitalists invest in an area, effectively affixing the capital to a certain place at certain times, "to build a fixed space (or 'landscape') necessary for its own functioning at a certain point in its history only to have to destroy that space (and devalue much of the capital invested therein) at a later point in order to make way for a new 'spatial fix' (openings for fresh accumulation in new spaces and territories)" later (Harvey 2001, 25). In the first phase—the spatial phase—of the spatial fix in the resilience paradigm, where the city government and developers are tied to greening obligations, and up-and-coming neighborhoods seek to green their space, GSI investments are *the* place to affix capital.

As projected in the 1990's, ecologism[2] is now an economic boon—found everywhere from designated government offices to research institutions to clean-up crews and mitigation companies (Latour 2005). While environmentalism is still far from politically ubiquitous, it is theorized that global competition to be the "greenest" city and the need to comply with government rules like the CWA, combined with the post-modernist/resilience paradigmatic need for a green aesthetic are central to "boost[ing] political salience and financial feasibility" for GSI (Shokry, Connolly, and Anguelovski 2020, 1). The Federal Emergency Management Agency suggests that stormwater management solutions be funded partially through residential utility fees and leveraging state-specific grant programs (FEMA 2021). GSI development[3] is funded in

[1] Here, neoliberalism refers to capitalist practices in the United States that encourage government deregulation coupled with strategies to reduce government spending. This is "spatially manifested in the fragmentation of space at multiple scales, from the body to international borders," (Oza 2011, 256).
[2] Ecologism is a political ideology where there is a moral obligation take the ecosystem and non-human world into account in social, economic, and political systems (Baxter 2000).
[3] This includes site selection, geological examination, environmental impact assessment, design, architecture, construction, and ongoing maintenance.

many ways but, in particular, private entities that fund infrastructure have their own financial interests to maintain. So, "for a relatively small price, corporate capitalists buy the good will, averted glance, and forgiveness, as well as patronage, of much of the population, with changes in packaging and "tokenistic 'green' gestures" (Katz 2005, 50).

In the second phase—the temporal phase—of the spatial fix, the capital investments displaced into long-term projects take "many years to return their value to circulation through the productive activity they support" (Harvey 2003, 88; cf. Oza 2011). In the planning era of green climate resilience orthodoxy, investors affix their money to GSI in up-and-coming neighborhoods where property values are assured to rise, as stated in driving design principles and long-term city plans (NYC Department of City Planning 2011; Fekete and Rosenzweig 2018). The promise of property value rise is what actually manifests the investment that raises the property value.

Integrated greening is an alternative to modernist "urban renewal" processes that involve razing of communities and rebuilding, calling for integration of green space in the landscape as part of the "urban fabric" rather than fully segregating different land use types, partially to avoid severe overcrowding in zones that would otherwise be for discrete residential use (Jacobs 1992, 207). However, the compromises that occur during these processes leave residents with the fraught paradoxical and "painful choice of either resisting environmental improvements altogether or of being priced out of their neighborhoods," (Checker 2020, 82). These "green locally unwanted land uses" are often indicators to socially vulnerable groups that they either have to modify their relationship with their neighborhood or risk having to move (Shokry, Connolly, and Anguelovski 2020, 2).

Creation or restoration of green amenities in conjunction with rapid economic and demographic transformation in an area constitutes environmental or "green" gentrification (Gould and Lewis 2016). Green gentrification is a process of ecological clean-up that follows the onset of gentrification in an area, which accelerates community changes or displacement, especially for the most economically and socially vulnerable (Maantay and Maroko 2018; Maantay 2002a; 2002b). For example, in the northern Brooklyn area near the Gowanus Canal, water quality improvement efforts were the result of gentrification already taking place, making the city consider the area "'worth' cleaning up" (Miller 2016). Suddenly making an area or resource more "amenable" may negatively impact longtime residents that find themselves surrounded by wealthier neighbors, and often is followed by people being slowly displaced by either eviction, being priced out of their homes[4], coerced to sell properties, or general antagonism towards them from new, more affluent residents (Nir 2017; Rosenberg 2016; Martinez 2017).

The dwindling Brooklyn marine fisheries economy was an early catalyst of widespread socioeconomic change resulting from an ecology of deteriorating water quality in NYC. From the 1960s through the 1990s, the coastal economy shifted and many fishery workers[5] migrated north to New England or south to Virginia and the Carolinas, (Jeffries 2011; Dvorak 2012;

[4] The affordable rent rate in an area is determined by the area's median income. When wealthier people move into the area, the median income may rise as well, and the options for government-designated affordable housing are unattainable.
[5] Largely based out of Sheepshead Bay.

Grachek and Hall-Arber 2011; Kvilhaug 2005; Allerdt 2011). Rising housing costs and comparatively strict State fishing regulations related to the Long Island Sound, (Ruhle 1987), permanent and seasonal job opportunities (Scavone 2011; Roche 2010; Pederson 2008; Rogers 1997), or for ports with space for bigger or more technologically advanced boats (Dawson 2005; Ulrichsen and Ulrichsen 2017) made these moves attractive. Subsistence fishing became untenable and the inability to safely eat their own catch was a final straw for many families living and working near the Long Island Sound (Tursi 2016). Brooklyn fisheries work on the southern coast became untenable around the same time the garment and manufacturing industries largely housed on the northwest Brooklyn coast declined. Pollution overload and waste management were also a great contributor to shifting economies related to reduced manufacturing and fishing (Merchant 1996; Bryant 2020; Bernice et al. 2016).

Community (Re)Branding

Rezoning and planning are as much about exclusion as they are about inclusion. The union between culturally dominant newcomers and “profit-oriented place entrepreneurs” (Logan and Molotch 2007) creates a discourse that “brands” a place, and that brand shapes new zoning laws for development (Zukin 2011). Rezoning influences and is influenced by the branding and rebranding of Brooklyn and Brooklyn neighborhoods (Table 1).

Table 1. Rezoning in Brooklyn, 1992-2010. Source: Vision 2020 Appendix C

<table>
<tr><th>Original Zoning</th><th>Area Code</th><th>Area Name</th><th>Rezoning</th></tr>
<tr><td rowspan="13">Non-Residential[6]</td><td>B1</td><td>Greenpoint/Williamsburg</td><td>Residential/Mixed Use/Commercial</td></tr>
<tr><td>B2</td><td>The New Domino</td><td>Residential/Commercial</td></tr>
<tr><td>B3</td><td>Williamsburg Bridge</td><td>Non-Residential and Commercial</td></tr>
<tr><td>B4</td><td>Kedem Winery</td><td rowspan="2">Residential/Commercial</td></tr>
<tr><td>B5</td><td>Schaefer Brewery</td></tr>
<tr><td>B6</td><td>Rose Plaza on River</td><td>Residential and commercial</td></tr>
<tr><td>B7</td><td>Vinegar Hill</td><td>Residential/Mixed Use/Commercial</td></tr>
<tr><td>B8</td><td>DUMBO</td><td>Mixed Use</td></tr>
<tr><td>B9</td><td>Main Street</td><td>Residential/Commercial</td></tr>
<tr><td>B10</td><td>Dock Street</td><td rowspan="2">Mixed Use</td></tr>
<tr><td>B11</td><td>Red Hook Stores</td></tr>
<tr><td>B12</td><td>Ikea</td><td>Non-Residential (Commercial)</td></tr>
<tr><td>B13</td><td>363-365 Bond Street</td><td>Residential/Mixed Use</td></tr>
<tr><td rowspan="3">Low-Density Residential</td><td>B14</td><td>The Home Depot</td><td rowspan="3">High-Density Residential and Commercial</td></tr>
<tr><td>B15</td><td>Coney Island</td></tr>
<tr><td>B16</td><td>Gateway Estates/Fresh Creek</td></tr>
</table>

In Williamsburg, a neighborhood in north Brooklyn, the closure of seaports, Brooklyn Navy Yard, and factories in the area throughout the fiscal crisis of the late 1960s and 1970s drew

[6] There are multiple types of non-residential zonings within this category.

in a population of artists and musicians occupying warehouse space in the area for community building, work space, shelter, music performances, and parties that continued through the new millennium (Zukin et al. 2009, 53). But, from 1990 to 2005, these spaces were slowly bought and converted to condominiums, stores, and bars.

In 2005, the New York Times[7] said rezoning the East River waterfront from industrial to residential, "would transform the long-crumbling waterfront into a residential neighborhood complete with …luxury apartment buildings…and manicured recreational areas," including 54 acres of parkland, "…to capitalize on… miles of neglected waterfront, while also protecting a neighborhood that has long been a repository for unpopular projects like power plants, waste transfer stations and porn shops," (Cardwell 2005, 1). However, you could argue that this area was not neglected. "Young people seeking an alternative to Manhattan" (p. 1) fueling a nightlife boom, working-class communities, and subculture communities were caring for the neighborhood, inadvertently propelling the housing market there. But only the new private developments are eligible for 25-year tax exemptions and public esplanade grants. Neglect of the area was only on a municipal level. These diverse grassroots community uses (like underground punk rock and hip-hop music venues, art warehouses, or fruit vendors) were largely using the otherwise abandoned buildings without authorization. So, when the investors came in, they had to get out. The cultural contributions of these grassroots collectives may do more for the community directly than the transformations of their tax contributions might do.

Rezoning in Brooklyn is also related to rezoning in other areas, essentially displacing certain environmental issues without eliminating them. Fishing moved to other coastal states, and much manufacturing moved overseas. Even within NYC, expulsive rezoning practices show growing manufacturing zones[8], and the pollution associated with them, growing in low-income and racialized areas, like the Bronx, are linked to the shrinking pollutive zones in Brooklyn and Manhattan (Maantay 2002a). Environmental "negatives" are not simply removed from areas with GSI installation, they are picked up and dropped elsewhere.

Economic and Racial Demographics in Brooklyn Neighborhoods

Brooklyn is ~70.82 mi^2 of land housing 2.7 million+ people (U.S. Census 2020). This population is highly racially and economically segregated. Based on application of 2010 United States Census data to indexes of segregation, NYC has a score of 56.9% on the Isolation Index of Segregation, which here measures the percentage of non-Hispanic Black individuals compared to the general population, and a score of 82.2% on the Index of Dissimilarity, which measures the social segregation between non-Hispanic white and Black populations in the borough. Gini coefficients for each neighborhood vary (0.39 to 0.53). Gini coefficients measure the level of wealth disparity within each spatial unit (in this case, neighborhoods). However, the difference in wealth between neighborhoods varies greatly, with the top earnings of $195,000 per year in

[7] It is important to note what is said in popular publications like this because they are consumed by the public and shape public perceptions and social dynamics.
[8] "Manufacturing" zoning code refer not only to manufacturing of items but also waste transfer stations, bus depots, warehouses, wastewater treatment plants, recycling facilities, etc.

East New York, but top earnings ~$1 million per year in Brooklyn Heights, while they have almost the same Gini score (0.483 vs. 0.526) (Figure 1)[9].

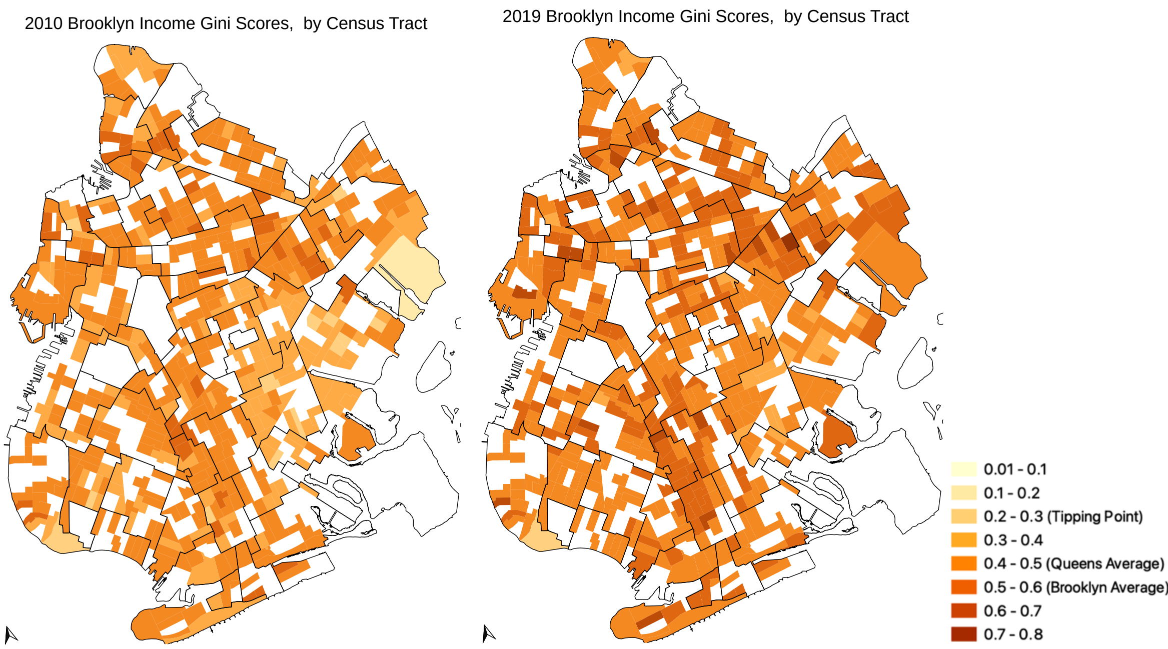

Figure 1. Brooklyn Gini Scores, by Census Tract, 2010 vs. 2019. Gini scores of 0.25 are typically the "tipping point" for acute inequality. Source: U.S. Census Bureau.

There are distinct wealth and property value disparities within and between Brooklyn neighborhoods, which greatly impacts rent and mortgage rates, in-turn impacting the demographics (economic, racial, ethnic, age brackets, etc.) of the residents in that neighborhood, and eventually the brand of the neighborhood, too (Jacobs 1992). This enacts something of a "power-geometry." This is a space-time condition where many neighborhoods are only permeable in one direction: the wealthiest people can move into or shop in any neighborhood they wish, while the poorest people must stay put (Massey 1993).

Likely owing to the immense size, heavily concentrated population density (38,634 people per square mile), and high rates of racial and economic segregation, many research projects on Brooklyn geography are conducted at the neighborhood level. Common themes in neighborhood-specific studies include land taken over after being stewarded by grassroots groups, closures of mom-and-pop shops, changes in bicycle access, and stakes for specific local waterbodies. Some areas are extremely socially and spatially different even if they are directly adjacent to one another (Miller 2016; Curran and Hamilton 2012; Naphtali 2006; Freeman 2015; Lipton 1959).

Neighborhood-specific studies have shown that gentrification manifests differently in each neighborhood, though sharing the sentiment that gentrification and sustainable dilapidation

[9] Neighborhoods delineated by Neighborhood Tabulation Areas—administrative areas used by NYC

"chang[e] the essential character and flavor of a community" (Yagley et al. 2005, 1). Transportation and evaluation of the delivery and accessibility of healthcare service amenities (Naphtali 2006) and conflicting transportation needs (DeSena 2012) are major issues in the Greenpoint and Williamsburg area. Northwest Brooklyn neighborhoods are also experiencing super-gentrification, a condition where the even the so-called middle class is displaced by the ultra-rich (Osman 2011; Lees 2003; Halasz 2018; Curran and Hamilton 2012; Johnson et al. 2021; Freeman 2015). Gentrification, rising housing costs, and racial segregation accompanied by various types of green amenities or rejuvenation of the naturalistic part of the landscape is also prevalent across the borough.

METHODS

To understand green gentrification within the resilience paradigm, this project examines the spatial coincidence of urban greening practices and gentrification risk throughout the borough, and the planning practices, such as public-private partnerships, that have contributed to it. GSI assets managed by the NYC Green Infrastructure Program (GIP) were chosen as a proxy representation for urban greening. This program has stakes at federal, state, community-board, neighborhood, block, and household levels, which speak to linkages in investigating green gentrification in Brooklyn at various scales. A comparative analysis of socioeconomic indexes will be used to employ this framework of evaluating sites of commission vs. sites of omission for linking social conditions to infrastructure installation at three scales in Brooklyn (Figure 2). This will contextualize the uneven distribution of resilience infrastructure in a larger literature of uneven development.

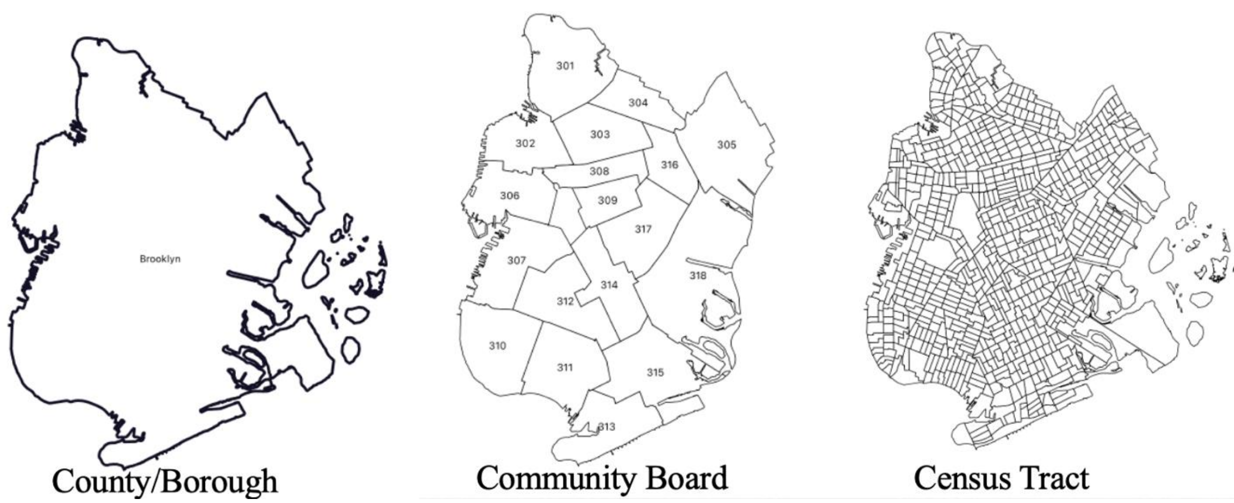

Figure 2. Three Scales of Evaluation.

Methodological Inspirations

A framework comparing sites of commission (areas where GSI was installed) versus sites of omission (areas where GSI was not installed) for stormwater management infrastructure "demonstrate[d] that green resilience interventions from 2000 to 2016 are tightly enmeshed with processes that generate Sites of Commission through the correlation with gentrification," (Shokry, Connolly, and Anguelovski 2020, 10). Areas the real estate finance sector has predicted (and effectively decided) will gentrify or where ongoing gentrification will accelerate spatially coincide with sites of GSI commission. On the other side of the coin, the sites of GSI *omission* are "forgotten places…that have experienced the abandonment characteristic of contemporary capitalist" transformations (Gilmore 2008, 31). For example, a spatial analysis of green gentrification in Brooklyn using community gardens as an urban greening proxy ultimately found that while community gardens are spaces of intimate community building that transform vacant and derelict land into useful green amenities, the linkages of new green space to property value appreciation lead to gentrification that threatened the very people who fostered that green space (Maantay and Maroko 2018; 2015; Maantay 2002a).

Environmental Modeling and Spatial Analysis with Proxy Representations

Two types of proxy representations were used to evaluate green gentrification for this project: 1) indexes which create time-series-inclusive gentrification scores for polygons/areas in the study extent as a stand-in for the intangible phenomenon, and 2) assets from the NYC GIP as a proxy for government-supported urban greening.

The GIP asset shapefile does three things as a proxy. It has continuity with the spatial data NYC uses for municipal management[10], it gives us actual location data to place elements on a map, and it encapsulates elements of urban greening that this study wishes to interrogate: the resilience paradigm, city planning and development actions, funding differentials, and real estate relationships to urban greening[11]. Additionally, for the purposes of a cross-sectional analysis, the suite of GIP assets remains a static factor and the gentrification indexes will represent a change in condition over time in the space around the static factor.

The choice to use the GIP as a proxy for urban greening and CSOs as a proxy for existing grey infrastructure is not a neutral one, even though they are intimately connected (it is almost a dialectical "no-brainer" that you have to discuss one when discussing the other) and the convenience and breadth of data availability are factors in choosing them. There are other options, such as change in vegetation over time gathered from satellite data, or growth and loss of parks and open spaces. However, this would not encompass all of the spatial politics at play, especially since so many of the green infrastructure projects are tied to funding and structure. Some data are dynamic and ever-changing, like satellite imagery of vegetation. Dynamic data like this might be more useful in evaluations of afforestation success. For this cross-sectional experiment, it is more appropriate to have static data points from the Green Infrastructure Program and indexes that represent a change in time around them.

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[10] The GIP data is readily, reliably, and publicly available, which is deemed necessary for accuracy and success in principles of GISc research methods (Montello and Sutton 2006; Bowen et al. 2020; National Centers for Environmental Information n.d.; Clarke, Parks, and Crane 2002). The GIP dataset also offers continuity with the spatial data the City of New York uses for municipal management. Sociological critique of representations, or proxies, emphasize that the author's choice(s) in representation reveal "conditions for environmental action, communication, politics, democracy, management, and governance" (Boström and Uggla 2016, 356).
[11] Other options, such as satellite data on the change in vegetation over the time period, parkland presence, or community gardens, would not encompass the particular mechanisms we wish to interrogate in this project.

Indexing Socioeconomic Risk

An index represents "multifactorial phenomena like gentrification or deprivation" with a discrete score (Johnson et al. 2021). Many indexes have been developed at various scales to measure gentrification or other hazards in NYC or areas that include NYC. Among these are rate-based gentrification indexes like NOAA's Gentrification Pressure index for coastal communities, The NYC Heat Vulnerability Index (HVI) developed by the Department of Health, the Housing Risk Chart from the Association for Neighborhood & Housing Development (ANHD), and the Small Area Index of Gentrification (SAIG) from researchers at the City University of New York. There are also graduated typology-based indexes, such as the Typologies of Gentrification and Displacement from the Urban Displacement Project (UDP) (Table 2). For this study, we used five different indexes as proxies of gentrification risk.

Each index tallies a unique set of varying economic, demographic, and/or ecological factors to grade levels or typologies of gentrification at a certain scale in an area. Among themes in the index data are traditionally accepted factors in evaluating gentrification[12]. While most of the indexes use governmental data[13], each of the permutations of gentrification is likely to result in marking hot spots of gentrification risk. Each has its own purposes and its own limitations. The findings of each index also emphasize a particular factor as highly definitive.

To compare gentrification hot spots, each index was applied to a map of Brooklyn using QGIS geographic information systems software Version 3.10, using a shapefile of Kings County from NYC Open Data—a data portal created and provided by the municipal government. Each index was symbolized into approximately five categories using the same color ramp for ease of comparative visual analysis, while also remaining loyal to the index author's categorization. Comparative visual analysis can be useful between maps with different data sets for the same physical area. Instead, indexing multiple data factors to create single symbols for regions offers a unified picture, although they are still visually subjective.

The "Count Points in Polygon" vector analysis tool was used to count the number of GSI points inside the index polygons (which are shaped by clusters of census tracts). This algorithm counts the number of attributes in a points layer that fall within the boundaries of polygons in a vector layer on the same map and generates a new layer containing all the data from both original layers and a new attribute table field with the count corresponding to each polygon ("QGIS" 2021) (Figure 3). The count results from the automated vector process tool yielded results for individual polygons. The attribute tables were exported to spreadsheet files. Then the data were sorted by the gentrification score result and the number of assets was tallied for each gentrification score for each index.

[12] Age group distribution, level of college education, and housing cost burdens, where new residents related to gentrification patterns tend to be some combination of young (aged 18 to 35), non-Hispanic white, wealthy, able-bodied (not receiving disability or social security benefits) and educated in 4-year institutions of higher learning.
[13] United State Census, American Community Survey (ACS), and American Housing Survey (AHS) data

Table 2. Index Factors.

Index	Creator	Data Year(s)	Scale	Score Style	Score Factors
Gentrification Pressure Index	NOAA NMFS (federal)	2010, 2018	County	Risk Level Scale	Retiree Migration ▪ -% Households w/ Residents aged 65+ ▪ % Population receiving SSI ▪ % Population receiving retirement income ▪ %$^{-1}$ Population in labor force Urban Sprawl ▪ Population density ▪ Distance-1 to urban cluster ▪ Cost of living ▪ Median home value Housing Disruption ▪ % Change in mortgages ▪ % Change in home value ▪ Housing costs compared to income (35%)
NYC Heat Vulnerability Index	NYC DOHMH (municipal)	2018	Community Board	Risk Level Scale	Environmental ▪ Daytime summer surface temperature ▪ Green space Social ▪ % Households with air conditioning ▪ Poverty (% People using public assistance) ▪ Race (% non-Latino Black population)
Small Area Index of Gentrification	Johnson, et al. (Scholarly)	2010-2016	Census Tracts	Risk Level Gradient	Changes in: ▪ Median Rent ▪ % non-Hispanic white population ▪ % 20–34-year-olds ▪ % Adults with 4-year college degree
Typologies of Gentrification and Displacement	Urban Displacement Project (Activist)	2000, 2016	Census Tracts	Typologies	▪ 2000 Population ▪ 2016 Income level ▪ Market type (‘hot’, ‘at risk’, etc.) ▪ Past gentrification trends ▪ Loss/gain of low-income housing (absolute) ▪ Low-income migration rate
Housing Risk Chart	Association for Neighborhood and Housing Development (Non-profit)	2020	Community Board	Ranking	▪ COVID Case Rate (per 1000) ▪ COVID Death Rate (per 1000) ▪ Mortality from underlying conditions (per 1000) ▪ % Uninsured (2018) ▪ % Service workers (2018) ▪ % With severe crowding (2018) ▪ % People of color (2018) ▪ % With rent burden ▪ % Of area median income ▪ Rate of evictions (per 1000) ▪ Number of housing litigations (2019) ▪ Number of foreclosure filings (2019) ▪ Number of SCRIE/DRIE recipients (2019) ▪ % Change in avg price per ft^2 of residential sales ▪ Number of rent stabilized apartments ▪ Number of NYCHA units (2020) ▪ Serious housing code violations in 6+ Unit buildings (per 1000 units) ▪ LIHTC Units Eligible to Expire 2021-2025) ▪ Share of 1-4-unit non-bank home purchase loans, 2018

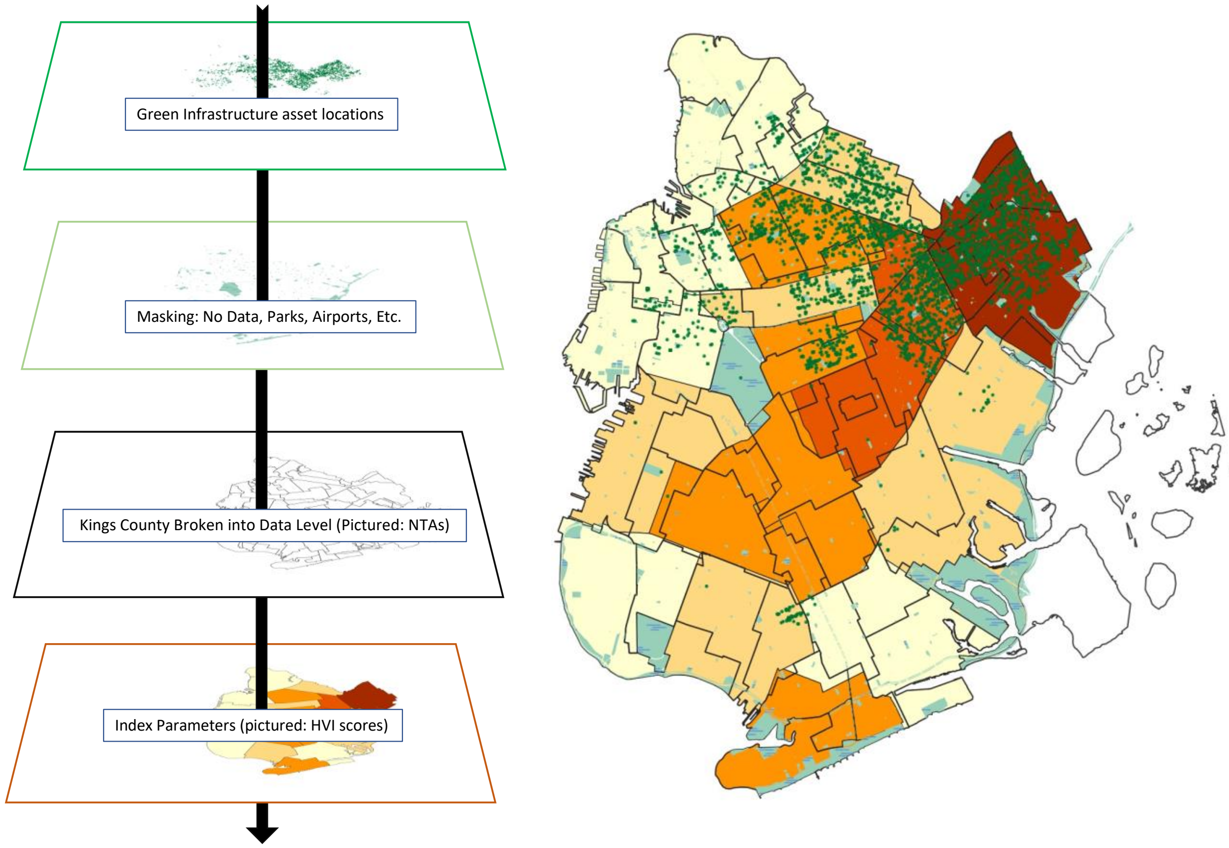

Figure 3. Map Layers.

RESULTS

Table 3. GSI assets per gentrification score per index.

Index	Income Group	Category (Raw Score, if applicable)	Polygon Count	# GI Units[14]	
1. Social Vulnerability Index		Gentrification Pressure	1	4035	Borough
2. Heat Vulnerability Index		1	1	0	Community District
		2	4	118	Community District
		3	3	128	Community District
		4	6	946	Community District
		5	4	2857	Community District
3. Housing Risk Chart 2020		1 (1-4)	5	292	Community District
		2 (4-8)	5	705	Community District
		3 (8-13)	5	754	Community District
		4 (13-20)	1	681	Community District
		5 (20-23)	2	1617	Community District
4. Small Area Index of Gentrification[15]		1 (–1.68 - –0.58)	149	89	Census Tract
		2 (–0.58 - –0.21)	149	276	Census Tract
		3 (–0.21 – 0.40)	148	917	Census Tract
		4 (0.4-1.83)	150	1513	Census Tract
		5 (1.83-4.5)	149	1212	Census Tract
5. Typologies of Gentrification and Displacement[16]	Low Income	Not Losing Low-Income Housing	208	1259	Census Tract
	Low Income	At Risk of Gentrification	53	836	Census Tract
	Low Income	Ongoing Displacement of Low-Income Housing	100	424	Census Tract
	Low Income	Ongoing Gentrification	80	1094	Census Tract
	Moderate to High Income	Advanced Gentrification	44	73	Census Tract
	Moderate to High Income	Stable Exclusion	187	206	Census Tract
	Moderate to High Income	Ongoing Exclusion	67	108	Census Tract
	Very High Income	Super Gentrification or Exclusion	4	4	Census Tract

[14] Count of GSI units within residential areas. Units on borders of polygons may be counted twice if they pose equal representation for both units, and impact street flooding and storm flow for both areas.

[15] 44 GSI units fell outside of the active study area for this index (I.e., in parks rather than residential areas, areas with insufficient census/ACS data)

[16] 44 GSI units fell outside of the active study area for this index because of missing data and non-residential placement

Social Vulnerability Indicators of Gentrification Pressure

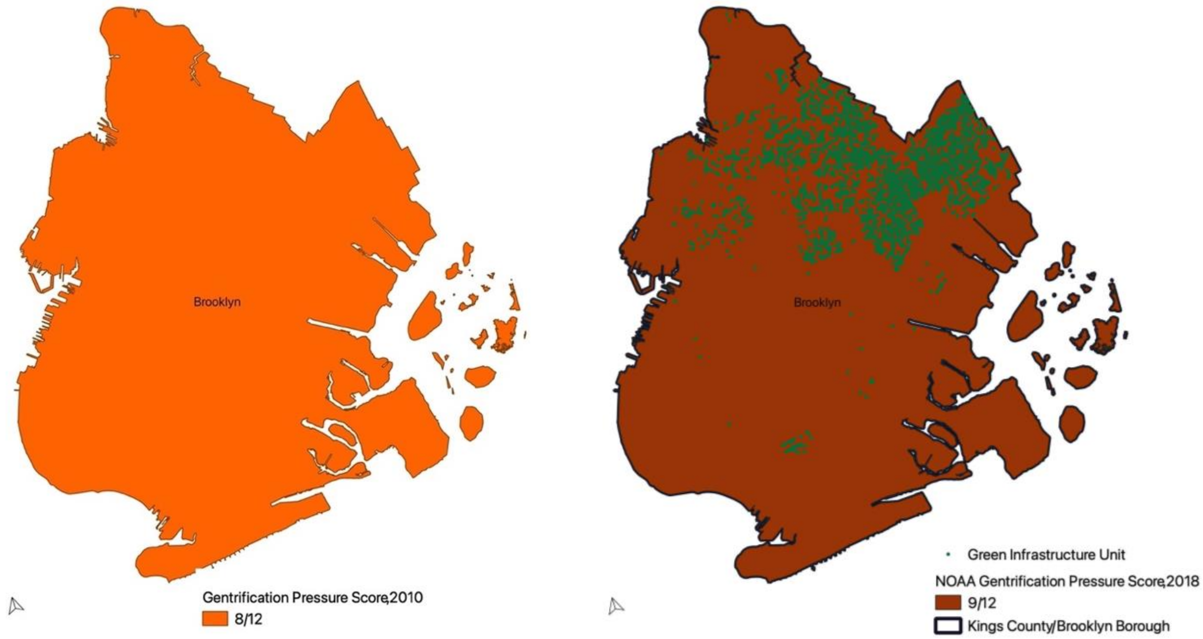

Figure 4. Application of NOAA's Social Vulnerability Indicators of Gentrification Pressure to Kings County in 2010, and in 2018 with an overlay of GSI units.

The Gentrification Pressure Index from NOAA's SVI is a county-level score, so all 4,052 units of GSI fall within the polygon, but it is notable that aspects related to housing disruption passed the threshold into "high" level housing disruption in 2011[17]: the same year that the forthcoming landscape of GSI was announced. Housing disruption has been the largest contribution to rising gentrification pressure in Brooklyn (Table 4; Figure 5). This comparison of GI assets and gentrification risk in 2010 vs. 2020 illustrates that there was a major change at the countywide level using ordinates from federal criteria that are actively used determine which areas to deploy resources to.

[17] based on 5-year ACS averages

Table 4. Social Indicator Scores for Gentrification Pressure in Brooklyn, 2009-2018. Data Source: NOAA Social Indicators Tool (National Marine Fisheries Service 2019).

Social Indicators of Gentrification—Kings County, New York

Raw Score

Indicator	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Housing Disruption	0.945	0.896	1.105	1.233	1.3	1.603	1.621	1.851	1.839	2.179
Retiree Migration	-0.449	-0.528	-0.546	-0.575	-0.628	-0.674	-0.72	-0.738	-0.72	-0.741
Urban Sprawl	3.707	1.597	3.827	3.846	1.812	4.086	1.174	4.08	4.104	4.13

Categorical Ranking: 1-Low, 2-Medium, 3-Med-High, 4-High

Indicator	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Housing Disruption	3	3	4	4	4	4	4	4	4	4
Retiree Migration	1	1	1	1	1	1	1	1	1	1
Urban Sprawl	4	4	4	4	4	4	4	4	4	4
Score (out of 12)	8	8	9	9	9	9	9	9	9	9

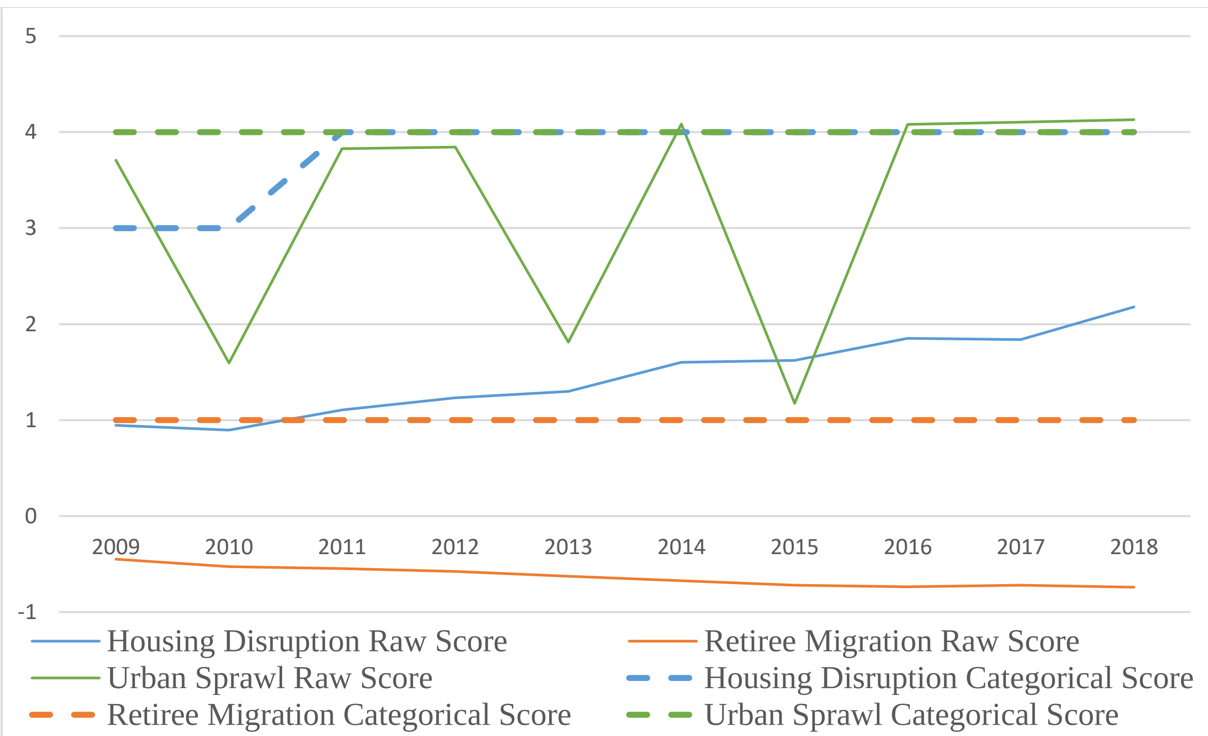

Figure 5. SVI Gentrification Pressure Raw and Categorical Scores 2009-2018. Categorical scores are based on 5-Year averages. Data Source: NOAA Social Indicators Tool.

The New York City Heat Vulnerability Index (HVI)

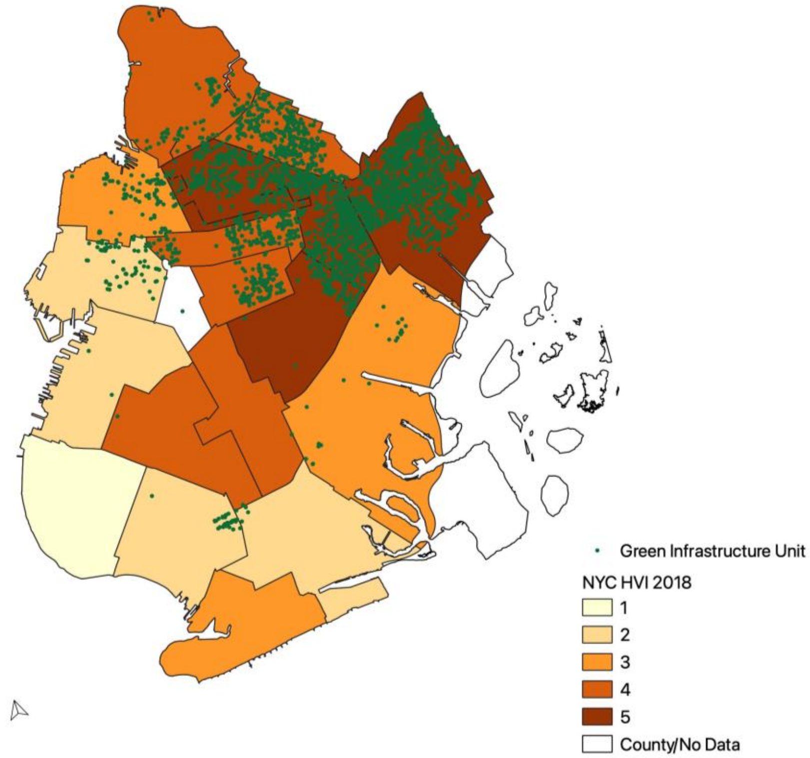

Figure 6. Application of the 2018 Heat Vulnerability Index to Community districts in Brooklyn, with GSI units.

NYC HVI is evaluated at the community district (CD) level. Of 18 CDs in Brooklyn, 10 fell into the two highest categories of heat vulnerability, and have 3803 units of GSI within them. Within the 4 CDs that scored the highest alone (CD-3, CD-5, CD-16, and CD-17), 2857 units of GSI are sited—70% of all GIP assets in Brooklyn. In contrast, there are 118 units in the 4 community districts that scored at level 2, and zero units of GIP assets were installed in the CD with the lowest heat vulnerability category.

The HVI includes a confluence of economic and demographic factors to score its areas of interest common in most gentrification studies, but also has socio-ecological condition factors. These include racial disparities in deaths related to heat stress, percentage of households with air conditioning, poverty rates, surface temperature, and green space (in the form of tree, grass, or shrub cover). With reduction of UHIE being one of the multiple benefits used to justify urban greening projects and the emergent EH crisis, the HVI is an invaluable measure of socioeconomic risk to compare against green infrastructure installation.

The Housing Risk Chart

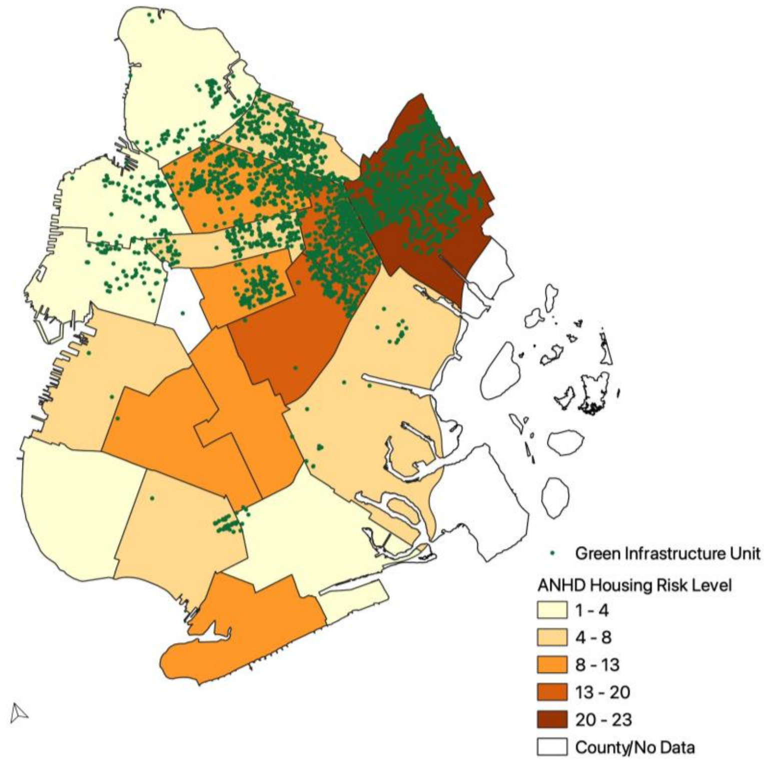

Figure 7. Application of the 2020 Housing Risk Chart to Community districts in Brooklyn, with GSI units.

In the 2020 Housing Risk Chart, entitled *How is Affordable Housing Threatened in Your Neighborhood?*, variables are summed and the resultant scores are applied at the community district level. Out of 18 Brooklyn CDs, three (CD-5, CD-16, and CD-17) fell into the two highest categories of housing risk and house 2298 units of GIP assets. About 40% of the GIP assets (n = 1463) are sited in the highest category of housing risk alone. In contrast, 292 units were sited within the lowest housing risk categories, accounting for less than 1% of assets.

ANHD's purpose of conducting this analysis[18] is to help community-based groups, government officials, and other stakeholders "determine where to direct resources to promote community stability and vitality," (Block 2020). In 2020, the index was updated to account for the hit on the economy caused in-part by extreme drop in population related to the COVID-19 pandemic from out-migration and, unfortunately, premature deaths.

[18] Original research and analysis by the Association for Neighborhood & Housing Development (ANHD)

The Small Area Index of Gentrification (SAIG)

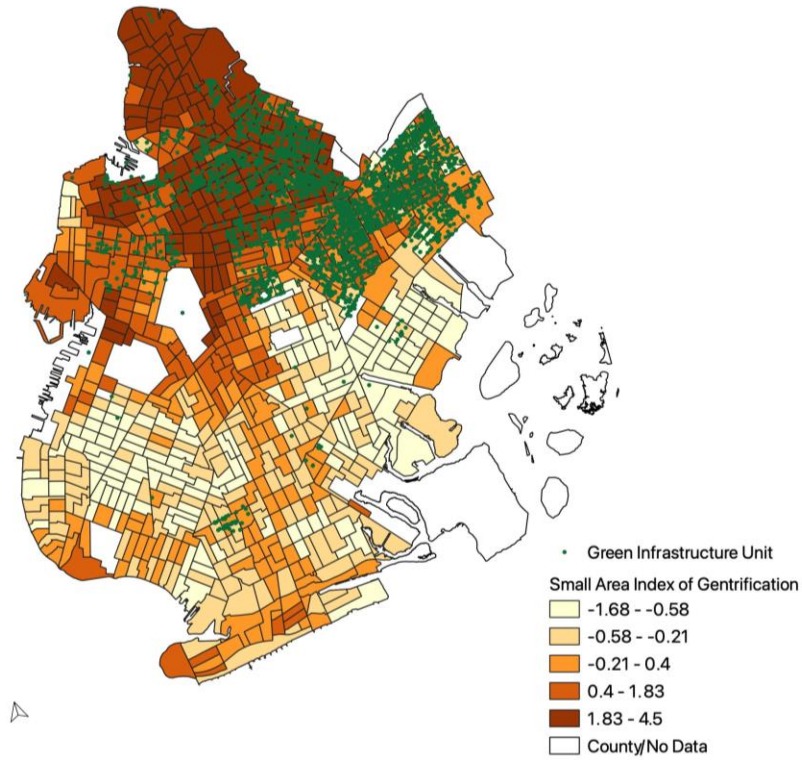

Figure 8. Application of the SAIG to census tracts in Brooklyn, with GSI units.

SAIG scores are applied to census tracts and measure change from 2010 to 2016. The distribution of risk is different than other indexes—there are an equal number[19] of tracts distributed with each of five scores in resultant "quintiles," per the authors' methods. This shows scores in relation to each other in ranking, rather than categorizing by graduated scores. Here, 4004 units[20] of GSI coincide with areas measured by the SAIG. However, 2725 units (~67% of the GSI assets) lie in the two highest quintiles (1513 units in level 4 and 1212 units in level 5). Only 365 units, less than 1% of the included GSI assets, lie in the census tracts that fall in quintiles one and two.

Using this methodology for gentrification does two things. First, it deemphasizes the arbitrary, but "official" polygons like census tracts or official neighborhood tabulation areas (NTA) made from census tract clusters that are used to define regions because neighborhood boundaries may be better described as gradients or networks with a functional identity, lacking complete "economic or social self-containment" (Jacobs 1992, 117). People walk freely and interact across these boundaries or limit their actual time within them. However, base polygons from census tract data or other empirical datasets are perhaps the only way to effectively geolocate the qualitative attribute data that is available. The Bayesian model emphasizes both of these conflicting aspects of defining an area.

[19] 149±1

[20] This number excludes GSI units in areas with missing data and GSI units that fall outside of census tracts

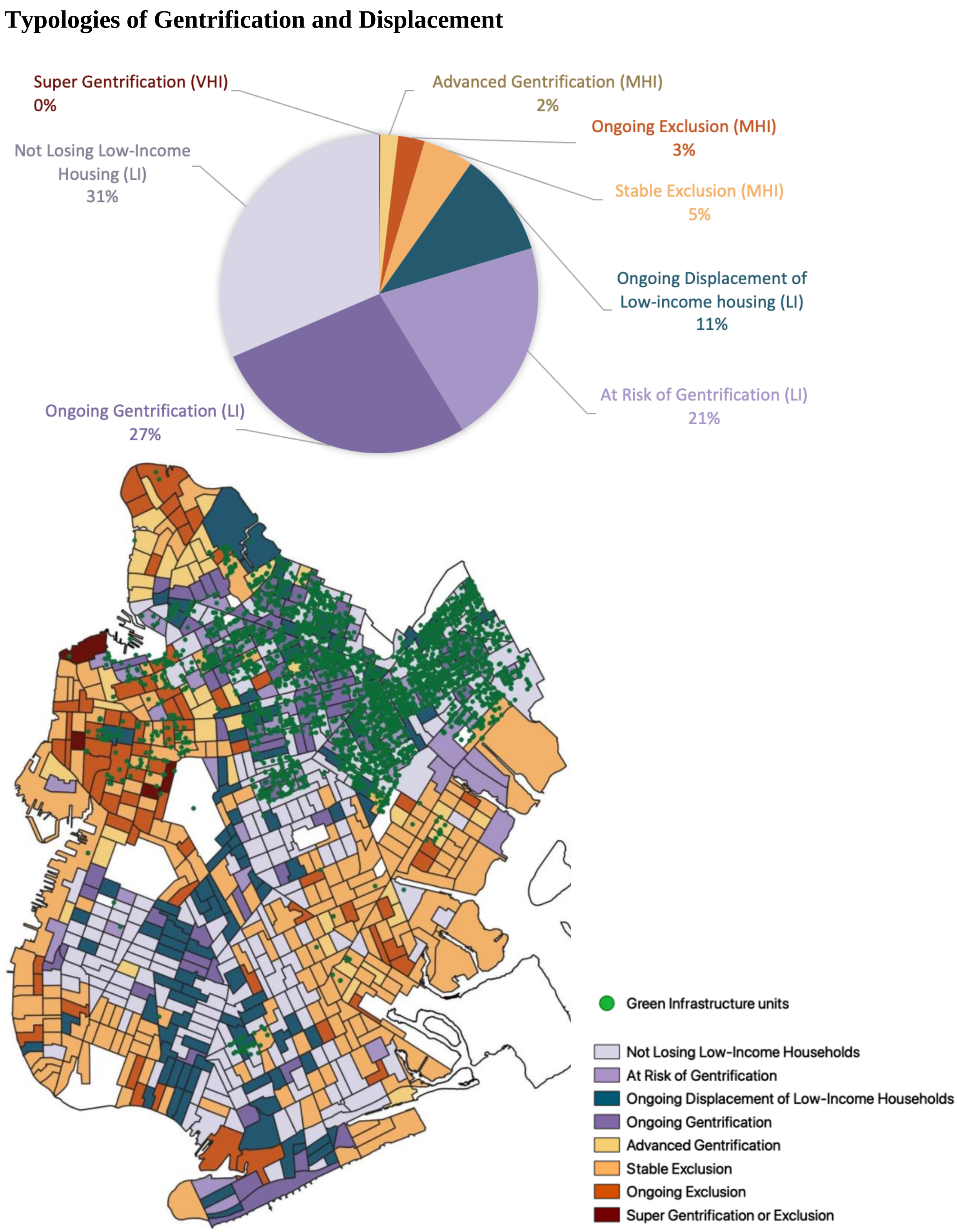

Figure 9. Percent of GSI unit locations within each gentrification type and map of GSI overlaid on UDP Gentrification Typologies.

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UDP's gentrification and displacement index offers a typology-based, rather than hierarchical, representation of gentrification permutations, comparing 1990-2000 to 2010-2016. The index indicates eight types of gentrification, grouped by three income levels: "Very high income" (VHI), "moderate to high income" (MHI) and "low income" (LI).

There are 4004 units[21] of GSI in census tracts measured by the UDP. Four units (less than 0.01%) of the GSI were installed in VHI census tracts marked as in a completed phase of "super gentrification." These super-gentrified census tracts lie west of Prospect Park, from Park Slope to Brooklyn Heights. About 9% of the units fall within the MHI bracket, which include types of late-stage gentrification (stable or advanced exclusion phases). Finally, 3613 units amounting to over 90% of GSI are located in areas in the "low income" category. There are four types of gentrification statuses under LI. Three are earlier-stage gentrification and the fourth is "not losing low-income housing." About 59% of GSI units that land in areas covered by this index fall within the three earlier-stage gentrification types: "ongoing displacement of low-income housing," "at risk of gentrification," and "ongoing gentrification."

Trends

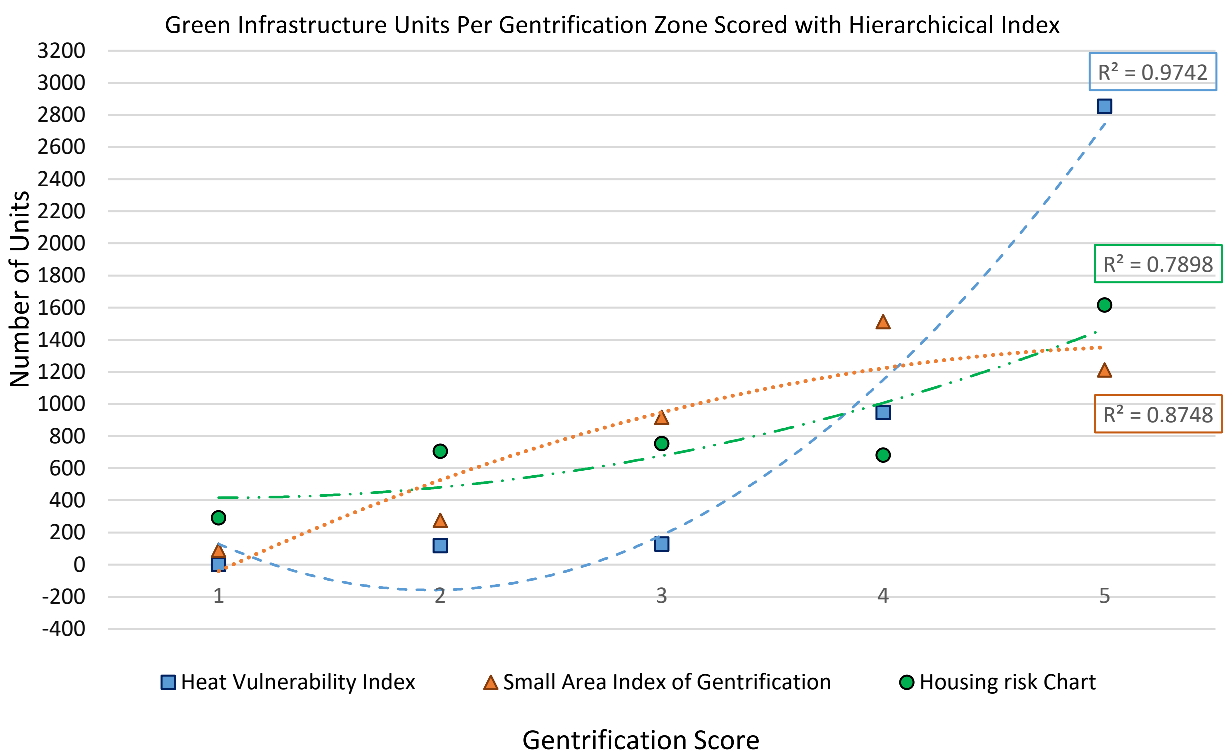

Figure 10. GSI Units Per Gentrification Zone Scored with Hierarchical Index showing trends of high correlation between GSI installation and presence of gentrification.

[21] Excluding census tracts with missing information

In the annual county-wide index, we see that gentrification crossed a threshold into a new category rating for housing disruption in Kings County in 2011—around the same time that GSI was proposed across the city. The ratings are categorical and based on raw scores that are derived from five-year averages of census data.

In the three indexes that provide hierarchical scores—The Housing Risk Chart, SAIG, and HVI—there is a positive spatial relationship between the two highest gentrification score categories out of five and the vast majority of GIP assets. In contrast, less than 7% of GSI falls into areas in the lowest risk categories for both the Housing Risk Chart and SAIG. Zero units fall into the lowest heat vulnerability category (Figure 10). The correlation is highest in the heat vulnerability index (97%). This high correlation is not unexpected owing to the tight links to urban heat island effect remediation co-benefits in GSI.

The SAIG was the only hierarchical index where the very highest score (5 out of 5) did not have the most units of GSI, although it is still largely gathered within the top two categories. Though this was unexpected, the smaller polygon size (census tract vs. community district) leads to much higher variability within each area, and more entropy might be anticipated.

But this variation might be better explained by comparing it to findings in the census-tract based trend analysis for the gentrification and displacement typologies in UDP's index application, where the highest category in the SAIG coincides somewhat with the "super-gentrification" typology. There are several categories of gentrification types (including "not gentrifying" and "super-gentrification," a late-stage gentrification status) in the UDP index. Very few units of GSI fall into late-stage gentrification brackets or high-income gentrifying areas. About 90% of the units fall into low-income categories in this index, which also follows patterns in the HVI. However, 59% of all the infrastructure falls into areas that have both of the following two characteristics: low-income populations and early-stage gentrification. GSI is highly associated with both displacement risk and phases of gentrification that are related to more recent economic changes in the area, such as financialization of urban greening initiatives. High correlation between GSI and gentrification constitutes a green gentrification condition.

Typologies of Gentrification and Displacement were found to be most illuminating index for the purposes of identifying the relationship between GSI and resilience-era gentrification. While all the indexes and all the scales were illuminating (the Housing Risk Chart and HVI both have significant health indicators, for example), the UDP index was most useful for interpreting the results of the other indexes and drawing conclusions. Greening can be understood here as a way to refuel ongoing gentrification processes that had stagnated amongst the climate crisis, and gentrification as a means to fund climate solutions. Urban greening in the form of GSI relies on the *processes* of gentrification for its funding.

Synthesis of Theoretical and Material Research

"Attractiveness" of coastal towns for new residents is produced. In addition to the primary ecological benefits, GSI proposals include beautification as part of a suite of neighborhood attractiveness co-benefits. For example, green resilience developers list these as the benefits of bioswales:

1) Reduced temperatures and energy use
2) Enhanced habitat
3) Increased property values
4) Improved streetscape aesthetics, and
5) Green jobs[22]

GSI co-benefits like heat mitigation are necessary to get projects greenlighted as per mandated design principles (Shokry, Connolly, and Anguelovski 2020). There are concerted efforts to use urban greening as a strategy to actively reduce thermal inequity, for example (Byrne et al. 2016; Klein Rosenthal, Kinney, and Metzger 2014). However, diminished heat stress in one area does not help people who wind up being displaced from these "cooled" areas—and cooled areas are cool. Lowered risk of heat vulnerability and access to natural amenities are linked to neighborhood attractiveness to more affluent populations (Colburn and Jepson 2012). In contrast, areas in cities across the United States communities with people of Asian, Black, and Latin descent, and/or low-income populations are the hottest and have the least tree canopy by 92% (Bock et al. 2021; K. M. Hoffman et al. 2016; J. S. Hoffman, Shandas, and Pendleton 2020; McDonald et al. 2021; Klein Rosenthal, Kinney, and Metzger 2014; Nayak et al. 2018).

GSI's co-benefits decouple it "from the political-economic landscape of cities' historic and ongoing patterns of uneven and unsustainable growth" (Shokry, Connolly, and Anguelovski 2020, 1). However, there is a slippery slope in the discourse of neighborhood attractiveness causing gentrification. That is, certain qualities make areas attractive to *developers*, who then use market research to develop with *the intention of attracting new residents* to a location, and development prospects must appeal to planners who have the say in official development.

GSI is highly concentrated in the north and northeast of Brooklyn. These districts tend to have hundreds of GSI units installed within them, and CD-5 has the most by far, with 1458 units installed. Southern Brooklyn communities have fewer than 40 units each—CD-10 and CD-13 have none. It is understandable that CSO improvements were more urgent in the northern part of Brooklyn that borders Queens. This area has canals and creeks that have slower flushing times—or water stratification turnover rates— because their underwater contours lead to challenges with removing pollutants naturally. In southern Brooklyn, the larger, more open bodies of water in the New York Bight[23] have faster flushing time and thus better natural capacity to cycle out pollutants (Monsen et al. 2002; Boyd 2015).

But uneven GSI development is owed to state-sanctioned uneven funding as much as it is owed to uneven underlying geological formations, fragmenting the borough into a northwestern green "modernized" Brooklyn and a forgotten southeastern Brooklyn. When "green" is the contemporary mode of modernization, this leaves southeastern Brooklyn behind as the northern area modernizes.

A landscape is a site of two types of transformation. In one, the terrain itself is landscaped by actions and actors, including financialization, ecological events, and law. In the other, materials enter the landscape and become transformed—for example, people live and work

[22] Gowanus Canal Conservancy and Trees of New York 2018, p. 32
[23] The Narrows, Gravesend Bay, Sheepshead Bay, Jamaica Bay, the Lower New York Bay, and the Atlantic Ocean

within a landscape and their health is impacted (for better or worse) by it, or a sum of money that is invested in that landscape will yield either losses or returns, and grow or shrink, depending on the market.

In Brooklyn, two factors are creating an uneven landscape of GSI. First, the different types of underlying geological formations necessitate a high diversity of GSI types to accommodate all areas, and not all areas are meeting site suitability requirements for desirable GSI types. Then, a privatized model for funding leads to uneven support because of the private enterprise's own enigmatic site investment analyses. Green resilience strategy, in turn and by design, leads to increases in property values which draws in cultural investments in the area like new luxury residential buildings and stores.

With a health-promoting amenity like GSI, there is clear distinction between sites of commission and sites of omission. In sites of GSI commission, people in the landscape reap health benefits and monetary investments appreciate in the processes of gentrification. However, green gentrification results in the environmental benefits greening being shifted to the incoming affluent populations, and causing more vulnerable existing populations to be additionally burdened through displacement from the newly improved neighborhood, potentially into worse environments.

The sites of GSI omission—the forgotten places—are left out of the progressive land transformations, and likely experience dilapidated environments. Expulsive greening practices do not just remove poverty and other environmental "negatives" from the greened area—they remove people experiencing poverty. These landscapes are not healing for the people who live there now or the people who have already gone.

When siting for green infrastructure is dependent on both where investors want to invest and site suitability is determined in a way that prioritizes the topology and funding opportunities rather than community health, the development across the county is seemingly uneven. Uneven funding equals uneven governance. Uneven investment in the terrain is equivalent to uneven investment in its people. Resilience is not sustainable.

IMPLICATIONS FOR POLICY AND PRACTICE

The primary objective of the environmental justice imperative is to protect the health, safety, and well-being of the poor, minority and immigrant communities, and other vulnerable populations, who currently are disproportionately burdened by adverse environmental conditions. "The goal should be for the regeneration of neighborhoods through revitalization, rehabilitation, and/or replacement of aspects of the physical environment that are not working well, including housing stock and environmental amenities, but without the replacement of the people who live there," (Maantay and Maroko 2018, 13).

If we acknowledge that urban greening can increase the risk of gentrification, the questions then become: Is it possible to improve a community's environment without instigating gentrification and the concomitant displacement of its existing population and culture? Is green gentrification an inevitable result of urban greening? Can environmental justice and improvements in environmental quality be promoted in communities of color and amongst poor and other vulnerable populations without the subsequent rise in gentrification and displacement? And if some amount of gentrification is unavoidable, can we mitigate or limit its adverse impacts?

Advocates of the “just green enough” approach propose greening projects that tend not to lead to gentrification. This approach should include making “room for continued industrial use and blue-collar work, where cleanup does not automatically or exclusively lead to the ‘parks, cafes, and a river walk’ model of a green city,” (Curran and Hamilton 2012, 1028). Communities can also actively resist gentrification or prevent its acceleration by supporting projects that increase environmental quality in a neighborhood without causing socio-economic and cultural disruption, but they seem to always get squashed by government and corporate forces.

The major remedies for rapid gentrification can only meaningfully be affected through promulgation of public policies and regulations and, of course, allocating adequate funding to support the new policies and programs. Cities must reassess their priorities vis-à-vis development and growth, with social equity goals assuming a much larger role in the planning process than they do at this time (Pearsall and Anguelovski 2016). Conscientious policies can help to stabilize communities, so it is less easy and less profitable for private developers to steamroll grassroots community projects.

Residents and businesses in endangered communities can be strengthened through a combination of the following: rental affordability protections (e.g., “anti-gentrification” rental controls); zoning regulations that prohibit development that is out of context with the existing built environment; financial incentive programs that encourage rehabilitation and renovation of existing buildings rather than rewarding “tear-down” schemes that destroy still-serviceable buildings; smaller new developments at scattered sites rather than mega projects that overwhelm the existing community; designs for new or renovated housing that account for the household sizes in the existing community, rather than, for instance, providing mainly studios or one-bedroom apartments; “limited equity” cooperative apartments, which encourage long-term tenure and prevention of property speculation and “flipping;” mixed-use zoning, and human-scaled buildings. Most importantly, making sure that the inclusion of “nature,” and the “sustainable” and “resilient” aspects of all projects are integrated in such a way that they are not just after-thoughts or profit-making features. All of this entails reversing the privatization of our cities, and returning power to the people who live here and make it work.

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