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"They Didn't See It Coming": Green Resilience Planning and Vulnerability to Future Climate Gentrification

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ABSTRACT

As cities strive to protect vulnerable residents from climate risks and impacts, recent studies have identified a challenging link between these measures and gentrification processes that reconfigure, but do not necessarily eliminate, climate insecurities. Green resilient infrastructure (GRI) may especially increase the vulnerability of lower income communities of color to gentrification, an issue that remains underexplored. Drawing on the forerunner green city of Philadelphia, Pennsylvania, as our case study, this article adopts a novel intersectional approach to assess overlapping and interdependent factors in generating vulnerability and resilience using spatial quantitative data and qualitative interviews with community-based organizers, nonprofits, and municipal stakeholders. More specifically, this article develops a new methodology to assess vulnerability to future climate gentrification and contributes to debates on the role of urban development, housing, and sustainability practices in climate justice dynamics. It also informs strategies that can reduce social and racial inequities in the context of climate adaptation planning.

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As cities strive to adapt to the increasing intensity and frequency of climate risks and impacts, from flooding to extreme heat and worsening air pollution, decision makers are beginning to recognize that the most vulnerable urban residents often go unprotected. Among key measures to build resilience, cities are especially turning to green resilient infrastructure (GRI) such as rain gardens, green roofs, bioswales, and climate-proof parks. But in an increasing number of cases, socially vulnerable residents are concerned about green gentrification. In other words, those with fewer resources to manage risks at the individual and neighborhood level fear that they will be excluded from the long-term benefits of new green investments. This points to a green resilience paradox in that green resilience measures that are meant to reduce vulnerability to climate risks and impacts may do so for some even while exacerbating vulnerability to gentrification and displacement to areas at greater risk for other, socially vulnerable residents (Anguelovski et al., 2019; Gould & Lewis, 2018; Shokry, Connolly, & Anguelovski, 2020). The "green space paradox" identified elsewhere (Pearsall & Eller, 2020; Wolch, Byrne, & Newell, 2014) therefore extends into climate resilience initiatives (Gould & Lewis, 2018).

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The green resilience paradox is an essential consideration for urban policy given the wide support that green infrastructure and investment for climate resilience has received from federal and international agencies. In the United States, the Environmental Protection Agency (EPA) incentivizes green resilience in cities through implementation of the federal Clean Water Act (CWA), as a part of efforts to regulate storm and wastewater discharges from combined sewer systems (CSS) and prevent it from entering the same streams from which drinking water is sourced (Heckert & Rosan, 2016). Under pressure to find affordable solutions to EPA mandates, which included hefty fines for breaching discharge limits, some frontrunner municipalities—including Philadelphia, Pennsylvania; Washington, DC; Portland, Oregon; and Seattle, Washington—began in the 2000s to promote green stormwater infrastructure as a cost-effective means for increasing ground permeability to reduce runoff. Convinced by these early efforts, the EPA increased support to municipalities through technical guidance, the sharing of best practices, and funding opportunities such as its Superfund Redevelopment and Nonpoint Source Pollution programs (Johns, 2019; U.S. EPA, 2015).

The incentives to create more GRI in cities extend beyond the EPA. Federal programs such as the U.S. Department of Housing and Urban Development (HUD)'s Sustainable Communities Initiative[1] also finance GRI through grants that support climate resilience and promote community revitalization. HUD's Community Development Block Grants and the Department of Transportation's Congestion Mitigation and Air Quality funding can also be directed toward GRI components of other public works initiatives (U.S. EPA, 2015). Further fueling this process of integrating GRI in urban regeneration projects are state initiatives such as Pennsylvania's Department of Conservation and Natural Resource Keystone Grants and Arizona's Department of Environmental Quality, the latter of which funded a project in Tucson to convert vacant lots into pocket parks with green stormwater features (GCC, 2016). Lastly, cities themselves draw on local funds to finance GRI implementation through permit fees and income and property taxes, including tax increment financing of development projects that depend on future increases in property values (GCC, 2016).

There is a growing understanding that socioecologically vulnerable neighborhoods receiving green climate interventions are often simultaneously those being targeted for urban regeneration projects (Tubridy, 2020), which may spur new inequities (Arbaci & Tapada-Berteli, 2012; Dillon, 2014; Weber, 2010). Several studies have examined the link between urban regeneration and gentrification through new green spaces, transit, and other amenities (Anguelovski, Connolly, Masip, & Pearsall, 2018; Cucchiara, 2008; Dawkins & Moeckel, 2016; Derakhti & Baeten, 2020; McGovern, 2013; Safransky, 2014; Shaw, 2005), but the role of climate interventions remains understudied (Shokry et al., 2020). There is a need to better understand the extent to which concurrent climate resilience projects, urban revitalization, and changes in housing markets may intensify inequities and vulnerability to gentrification or, in contrast, whether social support services and antidisplacement policies and practices are in place to build adaptive capacity.

Using spatial quantitative data on GRI and qualitative interviews, we examine the nexus between green resilience infrastructure and a process increasingly known as *climate gentrification* in Philadelphia, an emblematic case of urban green adaptation practice and of recent gentrification. We therefore offer new understandings of the equivocal role of green resilience interventions for climate justice and injustice dynamics. Moreover, we contribute to critical housing studies by unpacking how neighborhood (re)development and social support resources participate in either advancing sensitivity to gentrification and displacement or, conversely, strengthening adaptive capacity in the face of changing housing markets.

Overall, our study enriches understandings of drivers for social and green resilience—or lack thereof—in cities (Kaika, 2017). It also offers some novel methodological aspects by using a clustering approach to weight vulnerability to gentrification factors—that is, to theorize a community's level of sensitivity and adaptive capacity toward gentrification in terms of overlapping and intersecting concentrations resulting from differential exposure and access to systemic harms and structural resources. The results demonstrate that along with equity and inclusion, adaptation must account for the uneven and historically produced urban conditions in which it is

embedded. Otherwise, vulnerable residents face a perpetual double insecurity and displacement risk—one from climate risks and impacts and the other from green (climate) resilience gentrification.

Next, we turn to the main theoretical underpinnings of the article—social and racial inequities in urban greening and climate adaptation practice—before presenting the research design and data for our analysis of Philadelphia's green adaptation practice. We then present a comprehensive overview of our findings before discussing their meaning in the broader critical resilience literature and in the more normative context of engendering urban green climate justice.

Complex Entanglement of Urban Climate Adaptation and Green Inequities

Urban Greening for (Unequal) Adaptation and Resilience

Today, urban climate adaptation planning in the Global North increasingly translates into investments in green infrastructure (Meerow & Newell, 2017), such as green stormwater management tools (Liu & Jensen, 2018), to achieve greater climate resilience. Traditionally, the manifold cobenefits generated by exposure to green spaces are described as those for health and well-being (Douglas, Lennon, & Scott, 2017; Kondo et al., 2020; Triguero-Mas et al., 2015), greater citizen inclusiveness and social cohesion through collaborative and community-based actions (Connolly, Svendsen, Fisher, & Campbell, 2013; Mandarano & Meenar, 2017).

But as mounting evidence from environmental justice scholars and activists indicates, the historical distribution of and access to green goods—and therefore their benefits—are uneven (Checker, 2011; Dooling, 2009; Gould & Lewis, 2017). Recent research points to land availability but also political and financial factors as complicating planners' ability to green the most disinvested neighborhoods (Boulton, Dedekorkut-Howes, & Byrne, 2018; Pearsall & Eller, 2020). Even when low-income residents of color live in urban areas with green spaces or thick tree canopies, these environmental amenities are often of low quality or overgrown, a result of enduring municipal disinvestment and neglect (Brownlow, 2006; Heynen, Perkins, & Roy, 2006). Some green initiatives such as tree plantings are the object of much skepticism on the part of residents because of perceptions that planting and maintenance is both time- and cost-intensive and that trees may cause costly structural damage to sidewalks and homes (Baptiste, Foley, & Smardon, 2015; Carmichael & McDonough, 2019; Newburn & Alberini, 2016).

Residents of color have also been shown to be less likely to frequent parks and gardens—many of which are being remodeled into GRI—in more integrated or Whiter neighborhoods because of experiences of rejection, violence, racist microaggressions, formal and informal surveillance, and fears of being reported to the police (Brownlow, 2006; Byrne & Wolch, 2009; Finney, 2014). This legacy of disciplining and Othering of Black and Brown bodies (Byrne, 2012; Pellow, 2016) may result in residents refusing outside efforts to improve or build new green amenities, knowing that urban greening often attracts White residents to their neighborhoods. A growing thread within the green gentrification literature (Anguelovski et al., 2020; Checker, 2011; Gould & Lewis, 2017) highlights cultural and political emplaced displacement (Hyra, 2015; Wynne & Rogers, 2020)—how the exclusionary practices of newcomers empty a neighborhood of its soul and prevent more life- and dignity-affirming approaches to its regeneration (Brand & Miller, 2020; McKittrick & Woods, 2007).

Thus, new green or environmentally cleaned up amenities can lead to the exclusion and displacement of the most vulnerable residents (Dooling, 2009; Essoka, 2010; Pearsall, 2010) while creating enclaves of pleasure and privilege for wealthier ones (Anguelovski, Connolly, & Brand, 2018; Park & Pellow, 2011). Tied to this green space paradox (Connolly, 2019; Pearsall & Eller, 2020; Wolch et al., 2014) are demonstrated rises in real estate values around greened spaces (Heckert & Mennis, 2012; Immergluck & Balan, 2018), rendering neighborhoods less affordable, increasing evictions, and generating residential displacement. Here, many green gentrification scholars agree that green projects are also a means for exploiting a "green gap" (Anguelovski et al., 2018) between underserved neighborhoods and those that have already been greened and gentrified (Gould &

Lewis, 2017; Immergluck, 2009), usually located near to each other (Pearsall & Eller, 2020). Yet these findings are mostly associated with larger scale interventions. Less is known about the exclusionary and gentrification patterns and potentials of accumulated smaller scale acupunctural interventions for climate resilience.

In relation to increasingly dedicated planning and funding efforts to climate adaptation (Aylett, 2015; Carmin, Anguelovski, & Roberts, 2012; Hughes, 2015; Woodruff & Stults, 2016), cities' greening strategies to reduce climate vulnerability—even those with a social equity objective—are nonetheless built on existing legacies of racialized and class-based housing and environmental policies and uneven development (Anguelovski et al., 2020; Gould & Lewis, 2018). Cities tend to lean on existing planning and financing frameworks (Anguelovski et al., 2016; Bigger & Millington, 2019; Bulkeley & Castán Broto, 2013) to fund and market measures, and adaptation is seldom transformational of unsustainable development pathways (Zografos, Klause, Connolly, & Anguelovski, 2020). Yet the racialized and racist foundations of these frameworks are often unacknowledged, let alone addressed, in discourse or implementation.

Green Growth, Capital Accumulation, and Dispossession

From a broader political economy perspective, cities' green adaptation practices have been linked to a neoliberal governance agenda through urban regeneration arrangements (Tubridy, 2020), including privatization, entrepreneurialism (Whitehead, 2013), and financializing nature (Bigger & Millington, 2019), which commodify and marketize urban resilience interventions (Leitner, Sheppard, Webber, & Colven, 2018). As cities go green, they also develop a green city branding and nature-based solutions discourse as a key instrument of neoliberal governance strategies for attracting local and global capital and wealth (Garcia-Lamarca et al., 2019; Kotsila et al., 2020) to centrally disinvested neighborhoods, eventually stimulating economic growth (Dooling, 2009; Quastel, Moos, & Lynch, 2012).

Furthermore, by variously employing the discourses of sustainability, resilience, and the smart city, municipalities justify new green infrastructure (Connolly, 2019), as a win–win or no-regrets solution for climate adaptation, and evade questions of equity and inclusion (Kaika, 2017) by framing benefits as inherently good for all (Anguelovski et al., 2018; Brown, 2014; Ziervogel et al., 2017). This depoliticized promotion of green and resilient solutions—presented as a kind of "sustainability fix" (Long, 2016; While, Jonas, & Gibbs, 2004)—may especially overlook historical and ongoing racialized inequalities, justifying its approach by capitalizing on collective anxiety about a climate-changed future (Harper, 2020) rather than reinvesting in longtime residents' protection. Injustices therefore may be reproduced and aggravated by what Hardy and colleagues (2017) call "colorblind adaptation planning" when interventions do not take account of social vulnerability (Connolly, 2018) or make social justice an explicit goal (Agyeman, 2013).

Critical urban scholars have examined the role of urban transformation (i.e., regeneration, revitalization, renewal, and redevelopment) in capital accumulation and dispossession of the urban poor and more recently identified a process of "accumulation by *green* dispossession" (Safransky, 2014; emphasis ours). Resembling the location of toxic industries (Mohai & Saha, 2015) in working-class, Black and Brown neighborhoods (using the promise of jobs), in this case, it is green infrastructure that is pushed and sited despite its relationship with gentrification and displacement. By hinging greening and resilience efforts on business-as-usual growth-driven agendas, they perpetuate settler colonial practices together with racialized displacement and dispossession (Safransky, 2017).

Therefore, the greening of cities paired with climate adaptation actions may actually undermine the long-term security and livelihoods of the most vulnerable residents (Ranganathan & Bratman, 2019; Shokry et al., 2020). GRI, like other amenities associated with urban regeneration and capital accumulation, is an ingredient in climate gentrification, potentially putting vulnerable residents at risk of displacement (Gould & Lewis, 2018) while possibly creating private intraurban competitive

regimes of resilience (Teicher, 2018). Recent research in Philadelphia uniquely shows that GRI has tended to be sited in already gentrifying neighborhoods, followed by more gentrification, and that Black and Latinx residents are moving to hotter, more impervious areas with little to no climate protection (Shokry et al., 2020).

Understanding Vulnerability to Future Climate Gentrification: A New Framework for Urban Climate Justice

In sum, whereas some scholars and practitioners view resilience as a necessary step to a deeper, more structural and systemic transformation of social-ecological relations (Pelling, 2011), green resilience measures as practiced may, paradoxically, be aligning adaptation with private real estate interests and urban renewal strategies that hazardously reinscribe and reconfigure existing risks and inequalities across the city (Anguelovski et al., 2016; Bigger & Millington, 2019; Shokry et al., 2020). In such circumstances, resilience scholars have recently argued, resilience should be reduced rather than enhanced because an "abrupt transformation" is desired (Elmqvist et al., 2019; Langemeyer & Connolly, 2020). Rather than responding to the intersectional vulnerabilities, traumas, and precarity of working-class and minoritized residents, as would be the case with an approach like "abolitionist climate justice" (Ranganathan & Bratman, 2019), green adaptation that disregards its normative implications (Fainstein, 2015; Wilkinson, 2012) and muddles toward a vague resilience goal might create greater injustice and residential vulnerability over space and time.

Our article builds on these critical insights to shed light on the role played by GRI in generating vulnerability to future gentrification, and thus to greater climate injustice. We address two critical research questions: (a) What are the characteristics, in terms of vulnerability to gentrification, of areas that are planned to receive GRI in the future? and (b) In what ways does GRI exacerbate vulnerability to gentrification for socially vulnerable residents? We thereby theorize and mobilize vulnerability to future climate gentrification as a critical analytical lens for examining (a) how cities' planned climate adaptation and protection efforts relate to preexisting vulnerabilities, and (b) how the social justice implications of urban adaptation practice can be measured. We operationalize measures that indicate preexisting vulnerability to gentrification to assess the potential future impact for the most vulnerable residents in neighborhoods exposed to recent and future green resilience interventions. We also account for neighborhood resources that might prevent displacement and thus might need to be bolstered.

This is, to the best of our knowledge, the first study to assess vulnerability to *future* climate gentrification and to evaluate the implications of planned GRI for *future* patterns of racial equity and urban climate justice. Processes of racialization that are foundational to explaining inequities and injustices in access to resources and protection are particularly underexplored in the urban resilience and climate adaptation planning literature (Bigger & Millington, 2019; Hardy, Milligan, & Heynen, 2017) even as climate resilience measures increasingly harness green urbanization and green growth strategies that have been linked with gentrification and the displacement of communities of color (Gould & Lewis, 2018). In this vein, our article also uniquely employs a large range of diverse social and structural factors underlying vulnerability that are not typically considered in climate adaptation research or planning. In addition, whereas vulnerability indicators typically focus on the status quo, this article offers new insights into climate justice and injustice dynamics by examining how resilience strategies (re)shape urban vulnerability and insecurity over time and space.

Transformation and Greening in Philadelphia

Our analysis is based in Philadelphia, a postindustrial, redeveloping, and recently gentrifying city that has been dedicating substantial resources to urban greening over the last two decades. Despite several major population shifts throughout its history, Philadelphia remains a highly segregated city, with an uneven urban development trajectory that can be analyzed for spatial variations in social

and structural vulnerability. Both its demographic and development landscape today are much influenced by postindustrial decline, a slow ongoing recovery, and corresponding strategic policy decisions related to neighborhood investment and development (Hunter, 2013). We were able to construct the study thanks especially to a strong availability of data on both recently implemented and planned GRI, as well as an abundance of data on factors that our analysis reveals to be relevant to vulnerability.

Urban Transformation and Gentrification of a Recovering Philadelphia

Amidst a mid-20th century transition to a postindustrial economy, Philadelphia's Center City area became a key target for reinvestment, which focused largely on office building construction and residences to reattract middle- and upper class residents (Beauregard, 1990) who had fled to the suburbs as Black residents moved downtown (Adams, 1991; Cooke, 2003). The demolition and resale of deteriorating housing stock to new homeowners was achieved through the application of eminent domain and the use of federal historic tax credits with the condition that investors rehabilitate the homes to reflect the city's colonial past. In each instance, neighborhood parks were created and, if applicable, waterfronts were rehabilitated. Using this model, the Society Hill neighborhood became particularly emblematic of the success of renewal for urban transformation and gentrification (Beauregard, 1990; Smith, 1979).

However, other Philadelphia neighborhoods followed different paths, mostly gentrifying at slower paces. By the 1980s, success from reinvestment seemed worth the gamble, such that private developers and individual investors began taking more of a lead in speculating on the value of some surrounding Center City neighborhoods, with various media helping to transform neighborhood images. In the Spring Garden neighborhood, this spelled disaster for the majority Latinx (principally Puerto Rican) community. Despite active resistance that resulted in a few small victories, having little political clout in City Hall and being mostly renters, the Latinx presence was eventually erased block by block as reinvestment focused on attracting homeowners (Beauregard, 1990).

At the turn of the 21st century, Philadelphia was still a city in recovery from deindustrialization and suburbanization with 40,000 vacant lots, an ailing economy (Heckert & Mennis, 2012) and rising crime in some neighborhoods (Brownlow, 2006); meanwhile, others had started to gentrify (Hwang, 2016). In keeping with a broader housing boom, the pace and spread of gentrification increased rapidly from 2000, until the Great Recession of 2008, and then restarted again in the ensuing recovery period (Ding, Hwang, & Divringi, 2016). As real estate prices soared in many central neighborhoods, socially vulnerable residents displaced from those intensely gentrifying areas were moving to areas with worse housing and infrastructural conditions, especially postrecession (Ding et al., 2016). These residents tended to have lower credit scores and were therefore rendered ineligible for new mortgage loans or even rental opportunities where landlords conducted credit checks.

According to the National Community Reinvestment Coalition (NCRC), Philadelphia was the fifth most gentrifying city in the United States from 2000 to 2013, with the top seven cities accounting for nearly half of all gentrification nationwide (Richardson, Mitchell, & Franco, 2019). Shokry et al.'s (2020) study of gentrifying Philadelphia identified 45 neighborhoods experiencing especially high rates of change from 2000 to 2016. During that same period, downtown gentrifying census tracts experienced losses of Black residents by up to 64 percentage points and Latinx residents by up to 16 percentage points, whereas the percentages of White, college-educated, and higher income residents increased. The NCRC study concurrently found that more than 12,000 Black residents moved out of gentrifying neighborhoods and that Philadelphia was among the top 12 cities with the highest rates of displacement for Latinx residents. The resulting widening racial wealth gap in Philadelphia is illustrated by Latinx residents having the highest poverty rate at 37.9% (PEW Charitable Trusts, 2016) and Black residents having a median income two thirds that of White residents, with twice the rate of unemployment (Anderson et al., 2018).

Philadelphia's Green Resilience Turn: Greening Programs for Climate Protection and Adaptation

Starting in the early 2000s, the Philadelphia Water Department (PWD) embarked on a mission to tackle flooding, stormwater runoff, drinking-water pollution, and wastewater overflow with green interventions that, by the early 2010s, became a major milestone in watershed planning in the United States (Fitzgerald & Laufer, 2017; Liu & Jensen, 2018; Uittenbroek, Janssen-Jansen, & Runhaar, 2016). The program used a variety of data collection methods, green stormwater practices, and citywide public–private partnerships to reduce the contamination in combined sewer areas by 85% (PWD, 2009) and to mitigate urban heat island effects and air pollution. Efforts by the PWD to incorporate green stormwater interventions into vacant lots, schools, and local universities followed on decades of deindustrialization, suburbanization, population decline, and widespread land pollution and abandonment. PWD especially highlighted the economic and esthetic cobenefits as well as the cost-effectiveness and multifunctionality of green infrastructure.

PWD selected the most visible neighborhoods with the lowest implementation risks for demonstration projects to gain political backing (Bulkeley & Castán Broto, 2013; Madden, 2010) in the cash-strapped city. In 2009, this work was incorporated in the Greenworks sustainability plan, conceived to boost the city's revival by making Philadelphia the greenest city in the United States and increasing its economic competitiveness while delivering "equitable access to healthy neighborhoods" (Philadelphia OOS, 2009, p. 6). In 2011, the adoption of the Green City, Clear Waters (GCCW) plan (PWD, 2009)[2] set in motion a 25-year land and water strategy for improved urban permeability through green stormwater management with commitments to improve public access to water corridors.

In Philadelphia, these resilience-enhancing interventions increasingly greened and protected central gentrifying areas, especially after the passage of the GCCW plan. Vulnerability—with regard to infrastructure and populations—came into focus in 2016 with the adoption of the climate adaptation framework—Growing Stronger: Toward a Climate-Ready Philadelphia—which identified climate risks and resilience strategies for various government sectors, with green stormwater infrastructure a key tool for reducing climate vulnerability. That year, the Office of Sustainability also updated Greenworks and introduced the idea of a Greenworks Equity Index as evidence of its commitment to equity but has yet to publish it. As part of these endeavors the city plans to partner with lower income communities and communities of color in the hottest neighborhoods—through Beat the Heat initiatives—to expand tree planting and green stormwater infrastructure. In December 2019, the Philadelphia Department of Parks & Recreation also launched its Future of the Urban Forest planning process for a 10-year equitable tree planting strategy.

In sum, Philadelphia has become a model for wide-scale urban green stormwater infrastructure (Liu & Jensen, 2018) and appears to be successfully overlaying a new green and resilient brand atop a deeply racially and economically segregated past. Yet a recent study (Shokry et al., 2020) has shown that percentages of Black and Latinx residents have significantly risen in some of the most impervious and least climate protected areas of Philadelphia, whereas numbers of Whiter and wealthier residents have increased in cooler, more permeable areas. These findings point to a process characterized by the displacement of communities of color through gentrification to more at-risk areas and the shifting—rather than the elimination—of climate risks and insecurities. So, knowing the widespread deployment of GRI throughout the city and, concurrently, increased social inequities, we ask: Are these protective measures indeed protecting all residents or actually making some more vulnerable to future climate gentrification?

Research Design

Overall Strategy

We designed this study as a mixed spatial quantitative and qualitative analysis of the relationship between the multiple overlapping and interdependent factors that generate vulnerability to gentrification and climate adaptive interventions, operationalized here as GRI.

Building on a previous study that explored associations between prior GRI siting, climate risks, and past gentrification in Philadelphia (Shokry et al., 2020), we turn here toward understanding the extent to which neighborhoods that have been planned to benefit from protective climate infrastructure recently or in the near future are also those that will likely gentrify.

Identifying Vulnerability to Climate Gentrification by Green Resilience

To identify the relationship between vulnerability to gentrification and recent and planned GRI, we (a) developed multivariate indices of neighborhood vulnerability to gentrification, which we organized into typologies using cluster analysis; (b) compared vulnerability typologies, as well as social vulnerability characteristics, with the amount of green (climate) resilient infrastructure, using bivariate correlations at the census tract level; and (c) ground-truthed and contextualized our results in relation to qualitative data on local perceptions of vulnerability to climate gentrification gathered through semistructured interviews. A visualization of the conceptual framework for variable identification, operationalization, and analysis is presented in Figure 1.

A Novel Vulnerability Framework in Climate Adaptation Studies

In this article, we build a custom vulnerability index by adapting a common assessment framework from the global environmental change literature, which has three dimensions: exposure, sensitivity, and adaptive capacity (Gallopín, 2006; O'Brien et al., 2004; Turner et al., 2003). Exposure refers to how much a social-environmental system, such as a population and its neighborhood, is exposed to a particular risk or stressor (e.g., flooding or heat-island effect) that contributes to an outcome of concern (e.g., gentrification, displacement, new racial inequities). The system's sensitivity corresponds to factors that downregulate its response to the risk and/or intensify its impact (i.e., factors that might augment a neighborhood's likelihood of gentrifying), whereas adaptive capacity reflects factors that improve the system's ability to respond to and/or recover from risks to its well-being (i.e., factors that might mitigate gentrification and/or moderate the likelihood of the displacement of socially vulnerable residents; Adger, 2006; Pearsall, 2010). Following Pearsall (2010), we apply this vulnerability framework to better understand the impacts and risks associated with the siting of GRI for residents vulnerable to gentrification and extreme climate impacts.

The novel aspect of our approach emphasizes the intersecting and compounding *neighborhood* and *structural* characteristics of sensitivity (e.g., urban renewal zoning, waterfront redevelopment, lower crime rates), whereas vulnerability research tends to define sensitivity as the *demographic* and *socioeconomic* characteristics of population groups (e.g., race, income, education). Following the conceptual framework proposed by feminist theorists Mackenzie, Rogers, and Dodds (2013, p. 7), we understand vulnerability to have "distinct but overlapping" ontological and context-specific qualities and to be delineated by different sources (inherent, situational, and pathogenic) and states (dispositional and occurrent). Therefore, we evaluate the demographic and socioeconomic characteristics linked with the individual- or household-level sensitivity of socially vulnerable residents, separately, to understand who benefits from and who is burdened by neighborhood contextual factors. We consider contextual factors especially relevant because of their embeddedness in urban policies, politics, and institutional practices and because of their broader implications for social and racial equity and relations.

We therefore developed a list of potential neighborhood sensitivity and adaptive capacity factors, as well as individual and household social vulnerability factors, based on a review of the literature pertaining to neighborhood gentrification drivers, antidisplacement resources, and the characteristics of residents at risk of displacement. Our selection of neighborhood factors was limited by the availability of open-source data for Philadelphia.

Second, we identified the spatial clusters of each variable that we theorized to contribute to neighborhood adaptive capacity and sensitivity to climate gentrification. We then identified the amount and type of overlap between clusters of each factor by census tract (see Cutter, Mitchell, & Scott, 2000 for a map overlay approach to identifying vulnerable areas) to build an index. Next,

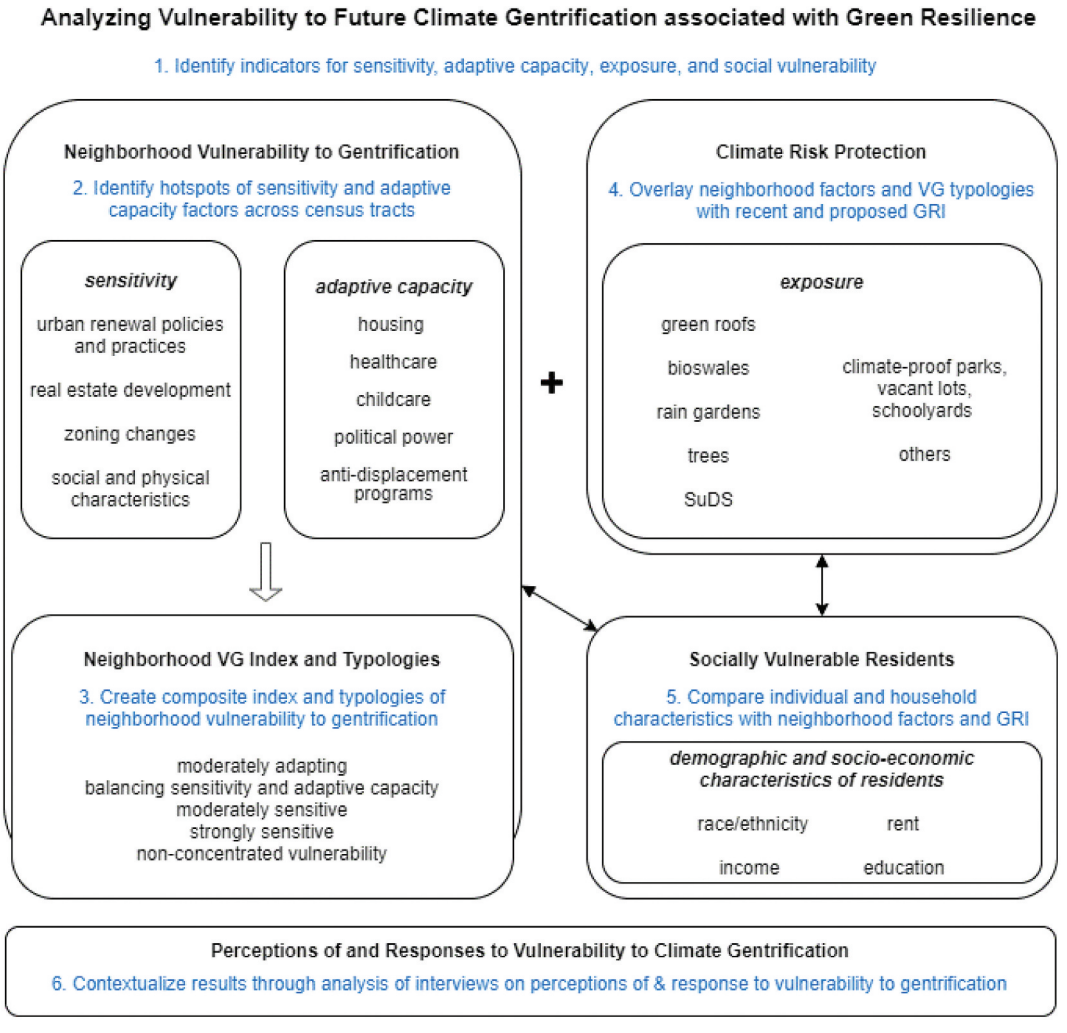

Figure 1. Conceptual framework for variable identification, operationalization, and analysis. VG = vulnerability to gentrificaton; GRI = green resilient infrastructure.

we examined the spatial overlap by tract between (a) degree of exposure to recent and planned GRI (as a percentage of tract area) and (b) degree of concentrated neighborhood sensitivity and/or adaptive capacity. The results indicate the neighborhood characteristics of areas with the greatest and least concentrations of contextual drivers of vulnerability to climate gentrification. We further investigate the correlation between those neighborhood characteristics and the spatial concentration of characteristics of residents more likely sensitive to displacement by gentrification and climate risks and impacts (rather than benefiting from the climate protective value of GRI).

Exposure

In this study, we operationalized GRI as our exposure variable, hypothesizing that, based on established green gentrification literature (see Anguelovski, Connolly, Garcia-Lamarca, Cole, & Pearsall, 2018) and emerging scholarly work on climate gentrification (Anguelovski et al., 2016;

Gould & Lewis, 2018; Keenan, Hill, & Gumber, 2018; Shokry et al., 2020), green resilient projects may be linked with future climate gentrification in vulnerable tracts. This strategy allows us to assess the degree to which neighborhoods and residents exposed to GRI (compounded with other contextual neighborhood factors) are vulnerable and/or likely to experience climate gentrification.

Neighborhood Sensitivity to Gentrification

Sensitivity refers in our study to structural and systemic factors and risks that cumulatively contribute to augmenting a neighborhood's likelihood of gentrifying and displacing lower income residents and people of color. We include these factors based on existing scholarship showing how they participate in unequal redevelopment and in the exclusion and erasure of vulnerable residents. It is important to note that no factor alone is sufficient to connote an overall sensitivity to gentrification, and there are exceptions in all cases, but taken together these factors by and large demonstrate an underlying condition that makes an area a target for gentrification. The neighborhood sensitivity factors that could be mobilized in Philadelphia, based on existing data, include the following.

Urban Renewal and Redevelopment Zones

Studies in real estate economics, urban geography, planning, and cultural anthropology have found evidence that urban renewal efforts are a core contributor to gentrification and displacement (e.g., Smith, 1979). Large-scale state-sponsored urban renewal and redevelopment helps translate this gap into gentrification (Smith, 2005) through enabling reinvestment in housing markets after devalorization of capital in the inner city (Lees, Slater, & Wyly, 2010; Smith, Williams, & Williams, 2013; Zukin, 1987). In the United States, empowerment zones (EZ) and opportunity zones are federal policy instruments created to stimulate revitalization, new development, and neighborhood revaluation. Yet studies have shown that benefits accrue mostly to higher income populations who have been attracted to EZs or go to EZs that were already relatively better off (Childers Roberts, 2012; Reynolds & Rohlin, 2014). Potentially worse social impacts are expected for lower income residents of newly designated opportunity zones (Richardson, Mitchell, & Edlebi, 2020). Linked to these new capital flows is the arrival of gentrifier classes (Beauregard, 1990; Hackworth & Smith, 2001), who, in the absence of mitigating policies and local capacities, displace socially vulnerable residents (Newman & Wyly, 2006).

Historic Properties and Districts

Gentrifiers tend to show a strong appreciation for the material, architectural, and esthetic qualities of historic buildings (Zukin, 1987), and neighborhoods with historical landmarks, especially historic downtowns, attract developers (Beauregard, 1990; Shaw, 2005). Although historic designation may also be a protective tool for low-income homeowners by preventing the demolition of historic properties and their replacement by taller, denser buildings for newcomers with higher purchasing power, eventually this protection often generates rising property values, and fuels gentrification and displacement (Zukin, 1987). Therefore, city governments—like Philadelphia's—have seen in historic preservation an efficient tool for urban renewal and the gentrification of disinvested urban centers, which they assist by formally certifying them for redevelopment (Beauregard, 1990; Brown-Saracino, 2013).

Proximity to Waterfronts

Waterfront areas, especially those associated with current or future clean-up, sustainability, and greening programs and policies, are hot spots of attractiveness and private investor attention, increasingly envisioned as new recreational, commercial, and residential spaces in the city (Harvey, 1989; McGovern, 2013). Encompassing substantial swaths of underutilized and often publicly owned land, especially in the postindustrial city, waterfronts tend to be sold to private developers as part of large-scale urban revitalization and intensification schemes (Bunce, 2009). In addition, even small-scale popups along disconnected and/or derelict waterfronts, as seen in Spruce Street Harbor Park

and Penn's Landing along Philadelphia's Delaware River, may participate in the eventual privatization of these public spaces (Schaller & Guinand, 2018).

High Proportion of Cleaned and Greened Vacant Lots

The cleaning and greening of vacant lands may be a channel for working-class and migrant residents, and residents of color, to reclaim an historically disinvested neighborhood—through, for example, community gardening—especially because vacant and derelict land has been associated with negative mental health outcomes, social stigma, and fears of crime and insecurity (Branas et al., 2018; Maantay, 2013). However, vacant lands may also be redeveloped for new housing, commerce, green spaces, and other urban amenities (Maantay & Maroko, 2018). Heckert and Mennis (2012) have demonstrated in Philadelphia the role that greened vacant land has in raising property values, especially in moderately distressed neighborhoods.[3] This vacant land transformation has been shown to be part of a new settler colonial process (Safransky, 2014).

Improving or Higher Performing Schools

Some cities, including Philadelphia, have rebranded and marketed public schools to gentrifier families as urban amenities in efforts to restructure and regenerate central-city districts (Cucchiara, 2008). Gentrifier parents tend to rely on school test scores and performance data as well as their personal networks or online forums to evaluate potential properties (Boger & Orfield, 2005; Godwin & Kemerer, 2010; Weininger, 2014). The competitive market for quality schools means that public and charter school performance is strongly linked with the property values of surrounding real estate (Black, 1999; Figlio & Lucas, 2004)[4] as well as increasing race and class inequalities (Candipan, 2020; Kimelberg & Billingham, 2013). Therefore, through increased property taxes and the social capital of early gentrifiers, neighborhoods with improving schools see an improved financial base and become ripe for more gentrification (Childers Roberts, 2012).

Decreasing Crime per Capita

In neighborhoods where measures are in place to reduce crime, desirable amenities and appreciating house values may attract investors and gentrifiers (Taub, Taylor, & Dunham, 1984). Some studies indicate that the arrival of wealthier residents actually contributes to new petty (Covington & Taylor, 2016) and property crime (McDonald, 1986; Papachristos, Smith, Scherer, & Fugiero, 2011). These sources, and a study in Philadelphia (Ferrick & Hall, 2017), further suggest that early gentrification is correlated with declining homicides and other personal crime. Localized crime rates also tend to mirror changes in adjacent neighborhoods, for better or for worse (Kirk & Papachristos, 2011).

Neighborhood Adaptive Capacity

Adaptive capacity, in our study, refers to the types of hard and soft urban infrastructure that play a social support role for socially vulnerable residents (especially those historically marginalized from and by development opportunities or other neighborhood infrastructure because of income or race, for example). Their impact may be material, for example by reducing cost burdens, or political through actions that underscore, expand, and preserve those infrastructures. They also participate in mitigating gentrification and/or moderating the likelihood of the displacement of socially vulnerable residents.

Adaptative infrastructure or resources may include affordable childcare (Banuelos et al., 2013; Bezanson, 2006; Ruhm, 2011), community health centers (Al-Kodmany, 2005; Jarvis, 2005; Pearson & Elson, 2015), housing counseling agencies (Levy, Comey, & Padilla, 2006; Pollack & Lynch, 2009; Quercia & Cowan, 2008), public-subsidized housing (Bates, 2013; Levy et al., 2006; Newman & Wyly, 2006; Pattillo, 2013; Pearsall, 2012), and community-based organizations (CBOs; Graham, Debucquoy, & Anguelovski, 2016; Pearsall & Anguelovski, 2016). The latter can play numerous roles that help stabilize low-income neighborhoods. These include services such as food banks providing critical

support for lower income and working-class residents in everyday and disaster scenarios (Mathbor, 2007; Whittle et al., 2015), and advocacy, ensuring that community benefits (e.g., affordable housing, health care and childcare) are included in planning, zoning, and (re)development efforts (Graham et al., 2016; Stokes, Mandarano, & Dilworth, 2014). Housing counseling agencies can also assist families to locate and remain in housing they can afford, whether for rent or for homeownership (Anderson et al., 2018; Levy et al., 2006). Different forms of affordable and publicly assisted housing are available to low-, lower- and moderate-income residents, which together support those residents to remain in gentrifying neighborhoods (Pearsall, 2012).

Socially Vulnerable Residents

In our study, socially vulnerable residents are operationalized by those individual and household level factors (social characteristics, stratifications, and sensitivities) associated with a higher displacement risk for underprivileged groups. Communities of color in Philadelphia continue to grapple with legacies of segregation, redlining, unequal development opportunities, and municipal abandonment (Beauregard, 1990; Brownlow, 2006) as well as influxes of Whiter and wealthier residents. They also face entrenched institutional barriers to accessing adaptive capacity resources and climate protection (Connolly, 2018). Indeed, studies have also shown that residents of color tend to live in aging housing stock and in areas that are especially vulnerable to climate impacts (Pearsall, 2017). They are also more likely to be displaced by gentrification to areas at risk of flooding and extreme heat (Shokry et al., 2020) or excluded from adaptation planning processes in gentrifying neighborhoods (Heckert & Rosan, 2018; Mandarano & Meenar, 2017; Van Zandt et al., 2012). For these reasons, and because of persistent discrimination in the housing and job markets and in business ownership, displacement is especially onerous for these communities (Bates, 2013). Therefore, we give particular attention to the racialized dimension of social vulnerability to climate gentrification.

Data Collection for Spatial Quantitative Analysis

In this section, we briefly describe the data sources we used to construct each factor included in the index of vulnerability to climate gentrification.

GRI, our green spatial indicator and exposure variable, refers to "all surface-level, vegetated interventions, installed to mitigate environmental risk or impact, and improve adaptive capacity in the context of climate change, while enhancing neighborhood attractiveness" (Shokry et al., 2020). Adapting Shokry et al.'s (2020) approach to our study of future climate gentrification, we therefore selected recent and proposed polygon features meeting these green criteria from the PWD Stormwater Management Practice (SMP) database. These included rain gardens, wetlands, green roofs, and tree trenches, among others (see Figure 2).[5] We excluded nonvegetated or belowground infrastructure such as underground cisterns and permeable pavements. We then applied the dimensions of each green polygon to calculate the surface area per tract of "greened acres" (PWD, 2009). Because GRI may be implemented in vacant lands, parks, and schoolyards, we joined those corresponding shapefiles with the SMP file to identify and integrate parcels with green stormwater features. Where GRI surpassed 10% of the surface area, we considered the entire green space to be GRI. The result was a combined shapefile of all active GRI from January 2016 to April 2020 and all GRI proposed for after April 2020. Out of 1,597 GRI data points included in the study, only one park/playground and 76 vacant lots met the conditions for including the entire space in the GRI data set.

Details are shown in Table 1 for each variable selected as a neighborhood sensitivity, neighborhood adaptive capacity, or social vulnerability factor, its source, and how it was operationalized. The neighborhood-level factors (examined from 2010 to 2016[6]) were summed up in an index that we analyzed as the main indicator of the cumulative effect on neighborhoods receiving GRI. Each neighborhood-type factor was then examined independently in relation to individual- and

Figure 2. Examples of green resilient infrastructure in Philadelphia. Images © Philadelphia Water Department.

household-type social vulnerability (in the year 2016) and GRI (from 2016 onward). In the next section, we provide a detailed overview of our analytical strategy.

Analytical Strategy

GRI and Neighborhood Vulnerability to Climate Gentrification

We begin by describing our spatial quantitative analysis. To address the first research question—What are the characteristics, in terms of vulnerability to gentrification, of areas that are expected to receive GRI from 2016 onward?—we identified the spatial clusters of each variable that we theorized to contribute to neighborhood adaptive capacity and sensitivity to gentrification. Next, we examined the relationship between adaptive capacity clusters, sensitivity clusters, and discrete values for our exposure variable.

Identifying Areas With Hot Spots of Neighborhood Sensitivity and Adaptive Capacity Factors Across Tracts. A Local Moran's I spatial clustering method, which is commonly used for urban and urban environmental applications (Mitchell, 2009; Pearsall, 2017), was employed to identify hot spots of sensitivity and adaptive capacity factors in Philadelphia (see Figure 3 for one example). We theorized that a greater degree of neighborhood sensitivity or adaptive capacity derives from a spatial concentration of the factors that define it. In using a clustering approach, first we understand that an area's characteristics are influenced by its position and proximity relative to another area's characteristics (Grubesic, Wei, & Murray, 2014; Ransome et al., 2017). Second, cluster analyses help overcome the problem of fixed administrative boundaries (Maantay, 2007)—such as census tracts—which tend to be static and arbitrary, in relation to the more dynamic distribution of social and physical phenomena that occur across them (Rainham, McDowell, Krewski, & Sawada, 2010). Third, clustering allows analysts to overcome the issue of trying to similarly weight very different variables (Eakin & Bojórquez-Tapia, 2008) when it is their compounding effect that is of interest.[7] Hence, a clustering approach may better approximate the unevenness and relationality of the distribution of different urban

Table 1. Descriptions of vulnerability to climate gentrification indicators.

Feature name	Description	Definition	Cluster-outlier type	Score	Data source[1]
Exposure					
GRI	Green stormwater infrastructure implemented discretely or as a part of vacant land, parks, and schoolyards from 2016 onward	% of tract area that is GRI surface area	n/a	n/a	Philadelphia Water Department, Philadelphia Department of Parks & Recreation
Neighborhood sensitivity to gentrification					
Active construction permits	Active permits for new construction, major alteration, and zoning changes between 2011 and 2018	No. of active new construction, major alteration, and zoning change permits	HH, HL, LH	1	Philadelphia Department of Licenses and Inspections
Certified redevelopment areas	Areas deemed blighted and eligible for urban renewal, new or updated certificates since 2010	% of tract in a redevelopment area	HH, HL, LH	1	Philadelphia Department of Planning and Development
Empowerment zones	Federal program to stimulate jobs and businesses in distressed communities through infrastructure, tax credits for businesses, and grants	1 = tract in an empowerment zone	HH, HL, LH	1	Philadelphia Department of Planning and Development
Opportunity zones	Federal program to incentivize investment in low-income communities by allowing investors to defer capital gains tax	1 = tract in an opportunity zone	HH, HL, LH	1	U.S. Department of Treasury
Low to moderate gentrification	Composite score for 2010–2016. Maximum score of 6 is based on the number of criteria, measured as rates of change, fulfilled in relation to the citywide median: increasing median income, % non-Hispanic White and college educated residents and median rents; decreasing % non-Hispanic Black and Hispanic residents.	Modified composite gentrification score: low and moderately gentrifying tracts = greater sensitivity to future gentrification	HH, HL	1	2006–2010 5-year estimate: Geolytics database; 2012–2016 5-year estimate: American Community Survey
Historic properties	Historic properties including districts, sites, and interiors	% of buildable area that is designated as historic	HH, HL, LH	1	Philadelphia Department of Planning and Development
Waterfront proximity	Waterfronts along Delaware and Schuylkill Rivers and Wissahickon and Tacony Creek	1 = tracts that intersect 400 m buffer	n/a	1	Philadelphia Water Department
Cleaned vacant land	Vacant lots cleaned and greened as part of the LandCare program from 2010 to 2017	% of vacant land cleaned	HH, HL	1	Philadelphia Office of Housing and Community Development
Improved school performance	Public and charter school performance from 2012 to 2017 as measured by School Progress Reports	No. of schools with improving report card scores inside tract or within 400 m	HH, HL, LH	1	School District of Philadelphia
Decreasing crime per capita	Part 1 (homicide/robbery/theft) and Part 2 (arson/drugs/assault) crime incidents from 2011 to 2017	% change in crimes per capita per tract. Decreases = greater sensitivity to gentrification	LL, LH	1	Philadelphia Police Department

(*Continued*)

Table 1. (Continued).

Feature name	Description	Definition	Cluster-outlier type	Score	Data source[1]
Neighborhood adaptive capacity					
Community health centers	Current low-cost or free healthcare centers include Federally Qualified Health Centers and City Health Centers operated by Philadelphia Department of Health	No. of health centers inside tract or within 400 m	HH	− 1	Philadelphia Department of Public Health
Affordable childcare	Centers providing affordable childcare programs: federally sponsored Headstart and Early Headstart, state and local Pre-K counts and PHLpreK	No. of childcare centers inside tract or within 400 m	HH	− 1	Pennsylvania COMPASS
Public housing	Existing developments and scattered sites owned and managed by Philadelphia Housing Authority	No. of public housing units inside tract or within 400 m	HH	− 1	Philadelphia Housing Authority
Affordable housing	Rental or for-sale housing built from 2000 to 2016	No. of affordable housing units inside tract or within 400 m	HH	− 1	Philadelphia Division of Housing and Community Development
Housing counseling agencies	Agencies approved by the U.S. Department of Housing and Urban Development to support low–moderate-income families navigate housing-related financial issues	No. of agencies inside tract or within 400 m	HH	− 1	Philadelphia Office of Housing and Community Development
Philly Rising	Mayor's Fund Initiative to assist 19 Philadelphia neighborhoods with chronic crime and quality of life issues, 2010–2016	% of tract that is Philly Rising	HH	− 1	Philadelphia Managing Director's Office
Community services organizations	Emergency food and shelter services; legal, medical, dental	No. of services inside tract or within 400 m	HH	− 1	Code for Philly
Higher capacity registered community organizations	Registered community organizations (RCOs) serve a fixed geographic area with a mission to conduct public meetings on projects that will affect the physical development of their community	Average of combined income and assets of RCOs with service areas that intersect a tract	HH	− 1	Philadelphia Department of Planning and Development; Charity Navigator
Socially vulnerable residents					
Individual and household characteristics	2016: Non-Hispanic Black, Hispanic/Latino, Non-Hispanic White, Limited-English speakers, college educational attainment, median household income, median household rent	% of tract population for each indicator except for income and rent, which are given as dollars per tract	n/a	n/a	2012–2016 5-year estimate: American Community Survey

Note. GRI = green reslilent infrastructure; HH = high-high cluster; HL = high-low cluster; LH = low-high outlier. n/a = not applicable.
Data were joined to 2010 normalized census tract boundaries created by Geolytics. We excluded 13 of 384 tracts that had no or low population and/or housing.
Where the normalization process appeared to have created large discrepancies across years in a tract's population, we reapportioned the tracts to allocate population counts more evenly.
All non-census data was retrieved from OpenDataPhilly. (2018). https://www.opendataphilly.org/; 2006-2010 American Community Survey 5-year estimates were purchased in 2016 from Geolytics; and 2012-2016 American Community Survey 5-year estimates were retrieved from https://www.census.gov/data.html.

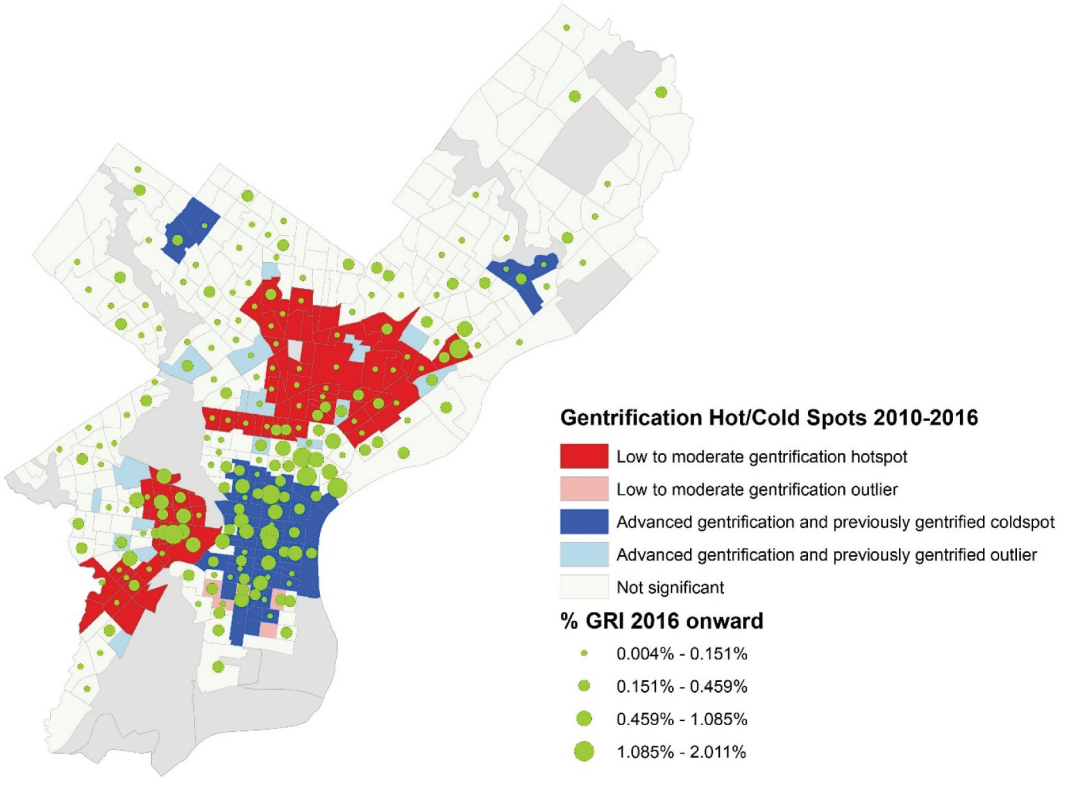

Figure 3. Hot and cold spots of gentrification from 2010 to 2016, and GRI from 2016 onward.

populations, urban infrastructure, and climate risks, and thereby the differential but nonrandom distribution of social vulnerability.

Creating the Neighborhood Vulnerability to Gentrification Index. To visualize and evaluate the compounding effect of different neighborhood sensitivity and adaptive capacity factors across census tracts, in relation to GRI, we developed an index based on a simple additive score:

$$\textit{Neighborhood Vulnerability to Gentrification} = \textit{Sensitivity to Gentrification} + \textit{Adaptive Capacity}$$

For each factor (e.g., empowerment zones), we used the results of its cluster analysis to assign a score of + 1, 0, or − 1 to each of its four cluster/outlier (CO) types (see Table 1). In all cases,[8] tracts with high-high (HH) CO types—which signify a high value tract surrounded primarily by other high value tracts—were scored + 1 for sensitivity to gentrification, given that factor's role in increasing a tract's vulnerability, and − 1 for adaptive capacity, based on that factor's role in reducing it. Depending on how we theorized the role of the variable in vulnerability to gentrification, we may also have given a + 1 score to high-low (HL) and low-high (LH) outliers, which tend to be tracts situated adjacent to clusters. In those cases, we assumed that having a high value in relation to neighboring low-value tracts (HL), or having a low value with neighboring high-value tracts (LH), indicated the possibility of a future hot spot or spillover effect from a neighboring hot spot. Because our study is not interested in comparing concentrations of lower values with higher values of the same variable, low-low (LL) clusters were scored 0, as were tracts signifying a lack of nonrandom significant clustering.

We then used a simple additive method (Cutter et al., 2000) to generate a composite index score for overall degree of neighborhood vulnerability to gentrification (VG) for each tract. A minimum of −8 was possible, and a maximum of +10, but the range of scores actually obtained from the Philadelphia tracts was −3 to +7. From these results we developed five VG typologies, by combining several ranges of scores. The resulting tract typologies were the following: moderately adapting to gentrification (score −1 to −3), balancing sensitivity and adaptivity to gentrification (score: 0), moderately sensitive to gentrification (scores 1–3), and strongly sensitive to gentrification (scores 4–7). A fifth typology—nonconcentrated vulnerability to gentrification—indicates tracts that were not a part of any cluster and/or coincided with LL clusters. This process yielded a map of citywide trends representing each of the five typologies of neighborhood vulnerability (see Figure 4).

Identifying Spatial Incidence of Neighborhood VG Factors With Recent and Proposed GRI. Next, we identified the spatial incidence of VG factors with recent and proposed GRI. We overlaid the neighborhood VG index map with our GRI layer (see Figure 4). We then summarized our VG typologies according to mean values of recent and planned percentage GRI per tract and conducted a one-way analysis of variance (ANOVA) to identify any significant differences between the means of GRI attributed to each typology. Finally, we conducted Pearson correlation analyses of percentage GRI per tract, tract values of each VG factor, and tract percentages of socially vulnerable residents.

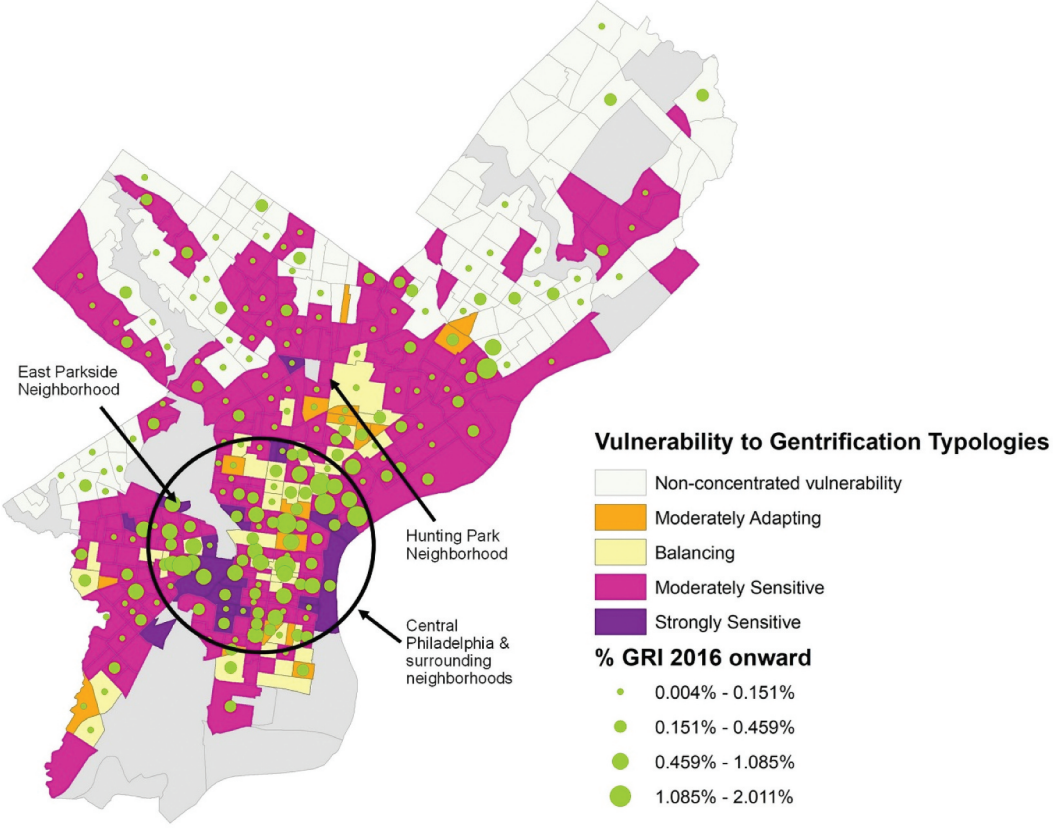

Figure 4. Map of index of neighborhood vulnerability to climate gentrification by green resilience infrastructure (GRI).

GRI, Neighborhood VG Factors, and Socially Vulnerable Residents

In a second step, we addressed our second research question: In what ways do green resilient interventions exacerbate VG for socially vulnerable residents? For this step, we focused on racial and ethnic characteristics as a key indicator of socially vulnerable residents in Philadelphia, mapped tract percentages of those characteristics and overlaid this with the GRI layer (see Figure 5). We last conducted a Pearson correlation analysis between tract percentages of residents of color, and other demographic and socioeconomic characteristics, and tract values of each of the 18 VG factors (see Table 3).

Qualitative Research Design

To ground truth and expand the interpretation of our findings in the quantitative study and to further address our research questions, we drew on a sample of semistructured interviews conducted in Philadelphia with community representatives, activists, developers, environmental nonprofits, planners, and policymakers from August through October 2019.[9] After transcription and coding, we selected 16 interviews that best helped us to understand how GRI was being procured and incorporated in vulnerable neighborhoods, factors perceived as gentrification pressures and contributing to vulnerability to gentrification, and perceptions of green gentrification and antidisplacement tools.[10] These interviews were complemented by an additional review of all available and relevant policy, planning, and nonprofit documents related to green infrastructure, gentrification, and vulnerability in the city. For our qualitative analysis, respondents included representatives from a variety of key Philadelphia city and nonprofit greening programs, GRI advocacy groups, citywide antidisplacement activists, and CBOs. We analyzed interviews using a mix of predefined thematic and grounded theory approaches.

Results for the Spatial Quantitative Analysis

Results for the Gentrification Cluster Analysis

Our gentrification cluster analysis for 2010–2016 reveals that much of North, West, and Southwest Philadelphia includes hot spots of low to moderate gentrification (indicated by dark red census tracts in Figure 3), signaling higher risk of future climate gentrification and displacement. These tend to be in close proximity to advanced gentrification and previously gentrified cold spots (indicated by dark blue tracts). We observe that most of the recent and proposed GRI is planned for the already most gentrifying or gentrified areas (dark blue) and the part of West Philadelphia known as University City, which logically follows the recent study of greening and climate gentrification in Philadelphia (Shokry et al., 2020). Low to moderately gentrifying areas in North Philadelphia are also planned to receive GRI but in lower concentrations.

Results for the Neighborhood Vulnerability to Climate Gentrification Index and Map

In this subsection and the next, the results address the first research question: What are the characteristics, in terms of VG, of areas that are expected to receive GRI from 2016 onward? Results are shown in Table 2 and Figure 4.

Results from our neighborhood VG index indicate that census tracts that are moderately sensitive to gentrification (1–3 factors; indicated in dark pink) represent approximately half of all census tracts (184) and correspond to 62% of total GRI area or an average area of 0.18% GRI per tract area. In combination with the 20 tracts that are strongly sensitive to gentrification (4–7 factors; indicated in purple) which have an average area of 0.16% GRI per tract area, 55% of all census tracts are moderately or strongly sensitive to gentrification and account for 71% of all GRI area. Tracts that are moderately adapting to gentrification (1–3 factors; indicated in orange) constitute 4.6% of all

census tracts and correspond with 3.5% of total GRI area and an average area of 0.12% GRI per tract area—the lowest number of tracts and the least GRI of the four main VG typologies. There are no strongly adapting census tracts (4–7 factors) in Philadelphia. Tracts balancing sensitivity and adaptivity to gentrification (indicated in yellow) constitute 10.8% of all census tracts and correspond to 13% of the total GRI and an average area of 0.24% GRI per tract area. They have the most GRI as a percentage of tract area. There were 110 census tracts (29.6%) with no VG factors—nonconcentrated VG tracts—meaning that they did not coincide with any neighborhood sensitivity or adaptive capacity hot spots. They align with 13% of the total GRI area and an average area of 0.04% GRI per tract area. The difference in means (for average % GRI per tract) between the main four tract typologies was not significant for $p < .05$, although the difference in means between them and nonconcentrated VG tracts was significant (ANOVA and post hoc test results not shown).

Tracts that are balancing neighborhood sensitivity and adaptive capacity factors may be destabilized by the addition of new GRI, which may then lead to the displacement of socially vulnerable residents, whereas tracts that are moderately or strongly sensitive to gentrification may have already lost socially vulnerable residents by the time future planned GRI is implemented.

Table 2. GRI concentrations by vulnerability to gentrification typology.

VG typology	VG scores	No. of tracts	% of total GRI area per tract type	Average % GRI per tract area
Moderately adapting	−3 to −1	17	3.46	0.12
Balancing sensitivity and adaptivity	0	40	12.76	0.24
Moderately sensitive	1 to 3	184	62.24	0.18
Strongly sensitive	4 to 7	20	8.50	0.16
Nonconcentrated VG	0	110	13.04	0.04
Totals		371	100.00	

Note. GRI = green resilient infrastructure; VG = vulnerability to gentrification.

Results for correlation tests between vulnerability factors and typologies and GRI

Neighborhood sensitivity to gentrification factors: As shown in Table 3, percent recently executed or planned GRI is positively correlated ($p < .01$) with sensitivity to gentrification factors most representative of real estate activities and zoning changes. In other words, GRI is linked with neighborhood investment and redevelopment. Therefore, tracts with greater GRI coverage had more active construction permits (0.283), redevelopment certificates (0.227) and historic properties (0.158) and were more likely designated empowerment zones (0.211) or future opportunity zones (0.142). GRI were however weakly correlated with other amenities and enhanced social conditions such as lower crime per capita, cleaned vacant land, waterfronts, or improved school performance.

Neighborhood adaptive capacity factors: Percent GRI per tract is positively correlated ($p < .01$) with neighborhood adaptive capacity factors most related to the social and antidisplacement support work of nonprofits and NGOs, such as providing essential aid for the lowest income residents and protection from the negative impacts of private real estate development. Tracts with greater GRI coverage had more affordable housing (0.177), housing counseling agencies (0.242), community service organizations (0.273), registered community organizations (0.154), and community health centers (0.194). GRI were, however, weakly correlated with other off-the-market public programs and broader municipal neighborhood stabilization efforts such as affordable childcare, public housing or the Philly Rising program.

Social vulnerability factors: Percent GRI per tract is positively correlated with tracts that had higher proportions of Latinx (0.111, $p < .05$), and negatively correlated with tracts that had lower proportions of non-Hispanic Black residents (0.123, $p < .01$). Tracts with higher rents (0.103, $p < .05$) and

college-educated residents (0.137, $p < .01$)— two indicators of gentrification—are linked with more GRI. The link was weak with percent non-Hispanic White residents and income.

Neighborhood vulnerability to climate gentrification index: Percent GRI per tract is weakly correlated with the composite neighborhood vulnerability to gentrification index score. A greater percentage of GRI per tract is significantly correlated ($p < .01$) with having both more neighborhood sensitivity factors per tract (0.329) as well as with having more neighborhood adaptive capacity factors (0.286).

However, in Philadelphia only a very few tracts were adapting (17); therefore, even though tracts with factors contributing to adaptive capacity are receiving GRI, so are a far greater number of sensitive tracts (204).

Results for socially vulnerable residents, and correlations with GRI and neighborhood VG factors

Next, we examine the neighborhood vulnerability factors most correlated ($p < .05$ or $p < .01$) with percent of socially vulnerable residents, that is racialized residents in the case of Philadelphia, per tract and compare correlation results (Table 3) with observations from the maps in Figure 5 to address our second research question: In what ways do green resilient interventions exacerbate vulnerability to gentrification for socially vulnerable residents?

Latinx residents in 2016

Our correlation analysis suggests that greater tract percentages of Latinx residents in 2016 are positively correlated with more GRI coverage per tract (0.111, $p < .05$). However, when we observe the map of tract percentages of Latinx residents and GRI in Philadelphia, shown in Figure 5a, we find that still many neighborhoods of North Philadelphia, with higher concentrations of Latinx residents (from 20% to 89% Latinx), do not have GRI. Rather, many more tracts with a lower to moderate concentration of Latinx residents (up to 20%), in or near the center and the Temple University campus, appear to have a higher concentration of GRI. These may be areas which have lost Latinx residents in recent years. There is a negative correlation with tract percentages of White residents (0.231, $p < .01$), but a positive correlation with tract percentages of college-educated residents (0.137, $p < .01$).

Higher tract percentages of Latinx residents are also positively correlated with the neighborhood adaptive capacity index (0.227, $p < .01$), and negatively correlated with the neighborhood vulnerability to gentrification index (0.251, $p < .01$). Comparing across the neighborhood VG index map and the map of percent Latinx residents in 2016, we observe that many tracts with higher percentages of Latinx residents tend to overlap with tracts that are either balancing gentrification risks or moderately adapting to them. This is further evidenced by the positive correlations ($p < .01$) with community health centers (0.177), affordable childcare (0.381), the Philly Rising program (0.160) and registered community organizations (0.380). RCOs may especially have the capacity to mitigate the impact of neighborhood sensitivity factors, to help build adaptive capacity and meanwhile procure and balance the effects of more greening. However, as Figure 5a illustrates, there is nonetheless little GRI planned for many areas with the highest concentrations of Latinx residents—especially Upper North Philadelphia—therefore leaving the most heavily minoritized areas underprotected. Furthermore, there is a positive correlation ($p < .01$) with empowerment zones (0.185) and ongoing low to moderate gentrification (0.245), serving as a warning that still more attention is needed to protect residents from the threat of displacement.

Black residents in 2016

Higher tract percentages of Black residents on the other hand were negatively correlated with more GRI tract coverage (0.123, $p < .01$). Figure 5b, strongly illustrates this point. Virtually all the GRI from 2016 onward is concentrated in areas with the lowest percentages of Black residents, except for several tracts in West Philadelphia. We also find that tracts with higher percentages of Black

residents, although not correlating with the neighborhood sensitivity to gentrification index, do appear positively correlated ($p < .01$) with several individual sensitivity factors which are especially indicative of highly unstable neighborhoods. These were: certified redevelopment areas (markers of blight but future possible investment) (0.340), increasing crimes per capita (0.175), future opportunity zones (0.253) and declining school performance (0.375). There is no correlation with affordable health care or organizational support systems, although tracts with greater proportions of Black residents in 2016 were more positively correlated ($p < .01$) with public housing (0.296) and Philly Rising program efforts (0.151) as well as affordable childcare access (0.205). While we find a positive correlation with low to moderate gentrification in Black neighborhoods (0.223, $p < .01$) from 2010 to 2016, the strong correlations ($p < .01$) shown in Table 3 with lower median incomes (0.545), lower rents (0.461) and lower tract percentages of White residents (0.841), suggest that the link may in many instances be explained by decreasing percentages of Black residents from these neighborhoods rather than a current influx of White residents. In other words, in some neighborhoods, like East Parkside and parts of Southwest Philadelphia, Black residents are likely also being pushed out due to the enduring crisis of disinvestment—which has meant investment and gentrification elsewhere or in non-community resources—the abundance of undesirable vacant lots, and the predatory practices of new private investors. These have created severe instability over time.

Table 3. Correlations between GRI, neighborhood and social vulnerability factors, and VG typologies.

Indicators	% GRI per tract	% NH Black	% Latinx
Exposure			
% GRI per tract	1	− .123**	.111*
Neighborhood sensitivity to gentrification			
Sensitivity Index	0.329**	0.022	0.069
Active construction permits	0.283**	−0.070	−0.082
Certified redevelopment areas	0.227**	0.340**	−0.080
Empowerment zones	0.211**	0.022	0.185**
Opportunity zones	0.142**	0.253**	0.032
Low to moderate gentrification	0.003	0.223**	0.245**
Historic properties	0.158**	−0.227**	−0.107*
Waterfront proximity	0.044	−0.184**	−0.014
Cleaned vacant land	0.001	0.480**	−0.014
Improving school performance	−0.031	−0.375**	−0.208**
Decreasing crime per capita	−0.077	0.175**	−0.035
Neighborhood adaptive capacity			
Adaptive Capacity Index	0.286**	−0.083	0.227**
Community health centers	0.194**	0.000	0.177**
Affordable childcare	0.044	0.205**	0.381**
Public housing	0.063	0.296**	−0.113*
Affordable housing	0.177**	0.005	0.019
Housing counseling agencies	0.242**	−0.037	0.094
Philly Rising program	0.010	0.151**	0.160**
Community service organizations	0.273**	−0.081	−0.108*
Higher capacity registered community organizations	0.154**	−0.029	0.380**
Neighborhood Vulnerability to Gentrification Index[a]	0.052	0.108	−0.251**
Other social vulnerability factors			
Median incomes	−0.027	−0.545**	−0.263**
Median rents	0.103*	−0.461**	−0.141**
% White residents	0.052	−0.841**	−0.231**
% College-educated residents	0.137**	−0.023	0.137**

[a]Tracts with no factors were treated as missing; n=261.
* Two-tailed significance at $p < .05$. ** two-tailed significance at $p < .01$.

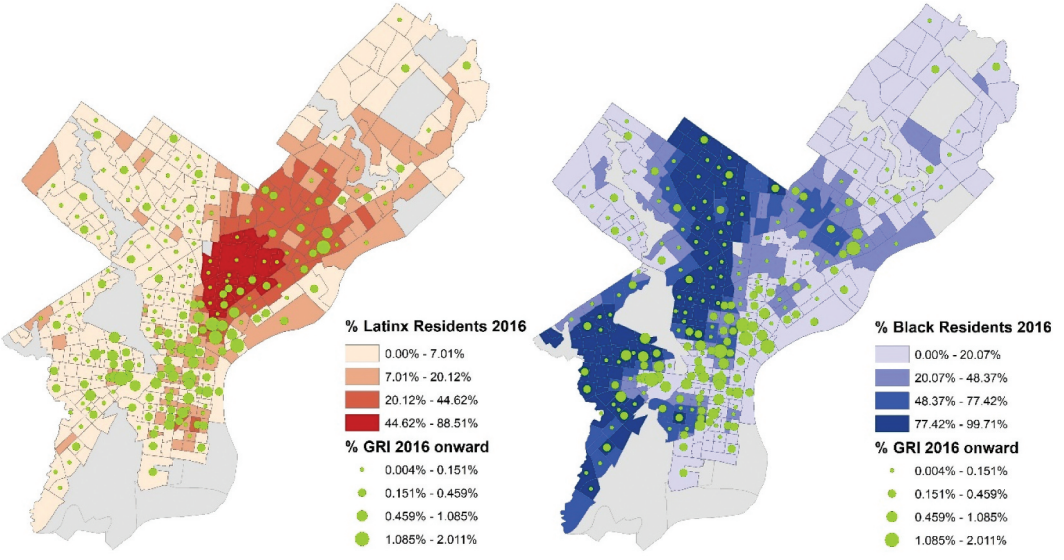

Figure 5. Maps of social vulnerability to climate gentrification by green resilience, depicting percentages of (a) Latinx and (b) non-Hispanic Black residents per total census tract population and percentage of GRI acres per total tract area.

Qualitative Results

In this section, we analyze narratives from our semistructured interviews conducted in Philadelphia to help ground truth and contextualize our spatial quantitative results and expand our findings. Our results build on our full coding work and data analysis. Here, we quote respondents to illustrate selected findings, but do not systematically incorporate quotations because of space limitations.

Our analysis reveals that although environmental public programs and nonprofits have become increasingly aware of residents' green gentrification fears, they continue to struggle with a full commitment to address these broader equity concerns that underlie the eventual exclusion of socially vulnerable residents from the climate protective benefits of greening. Although the question of "resilience for whom" remains elusive in these environmental efforts (Cote & Nightingale, 2012; Vale, 2014; Wilkinson, 2012), public agencies and nonprofits tend to be especially shortsighted about "whose city" is being planned for (Tozer, Hörschelmann, Anguelovski, Bulkeley, & Lazova, 2020; Vale, 2014) and who will actually benefit from resilience strategies—socially, economically, and environmentally—over the long run (Connolly, 2018; Gould & Lewis, 2018). Community-based housing and development groups, on the other hand, are struggling to lead and safeguard community-owned greening while entrenched in antidisplacement efforts and creating and preserving other community assets. The qualitative data affirm quantitative trends about the uneven landscape of GRI provision, compounded neighborhood sensitivity to gentrification, and the unequal organizational capacities and overall preparedness of neighborhoods in the face of displacement pressures. However, it also demonstrates nuances that must be considered in the differing perceptions of environmental and community groups regarding the drivers of vulnerability to green (climate) resilience gentrification and how to mitigate it.

Provisioners or Visionaries? Implementing GRI Equitably Amid Intensifying Green Gentrification Fears

Most of our municipal and nonprofit interviewees—representatives from environmental groups—expressed concern about uneven climate risks and impacts and uneven greening across Philadelphia. They were also increasingly aware of residents' apprehensions about green

gentrification—as voiced at community meetings and greening promotional events. In some cases, these views were heard as a fair interrogation of greening intentions: Who is really intended to benefit when a sudden interest in greening arrives concurrently with intense private investment in socially vulnerable neighborhoods? Addressing these perceptions while improving green equity has thus become a recent interest of municipal and nonprofit environmental programming going forward.

This equity concern has meant a growing response that has consisted of environmental programs partnering with a few CBOs, mostly on a pilot basis, in socially vulnerable and environmental justice neighborhoods and supporting their leadership in greening efforts. This strategy seems to be linked with a prevailing logic—or simply a hope—that if greening is led by community groups, the problem of gentrification is avoided. A city staff member points out that this strategy may not be enough, suggesting that greening nonetheless caters to the tastes of Whiter and wealthier groups, over time participating in attracting more gentrifiers:

> We're trying to come to terms with the fact that no matter what the intention is, no matter what long-time resident community leader plants the tree, the property value goes up and it becomes a more desirable place to live and the people with more money – they're the ones that get the chance to have their desires fulfilled.

In some cases, there is an emerging movement toward more holistic partnering across sectors and aligning with CBOs and leaders who are explicitly antidisplacement, especially those that own land and have a historical responsibility to avoid producing active gentrification in the neighborhoods that host their work. An interviewee from one nationally recognized environmental conservation organization acknowledges the limits of traditional environmental movements' approaches and discourse:

> We need to be well-meaning environmental organizations. We can't just be pushing this one solution of 'environment is good' because we know what that has meant for the last 120 years – environment is good – well for sure for a certain swab of people who have privilege is what that has meant.

However, whereas environmental city- and nonprofit-led programs may provide the vegetation to limit green adaptation costs for residents, already time and resource-strapped community partners might increasingly lead everything including promotional events, translation of materials, outreach to other longtime residents through their networks, site selection, envisioning the desired change, the planting of green resilience interventions, and ensuring their maintenance. This strategy may undermine CBOs' antidisplacement efforts, whose number and capacity—as our spatial analysis has shown—are uneven across Philadelphia neighborhoods.

Furthermore, environmental programs seem to maintain blinders to the more extreme and imminent dangers of intense and speculative private development that would more surely wipe out green resilience benefits for socially vulnerable residents. Indeed, even as awareness grows of residents' green gentrification fears, skepticism remains among some environmental program leaders about the actual role of greening in gentrification, a belief that the evidence is still too thin to act on.

Overall, there is a strong will to continue greening regardless. In this sense, there may be an overemphasis on the apolitical technicalities of inclusion while advancing a program's environmental contributions rather than adequately addressing residents' gentrification fears and ongoing threats to their security—that is, the policies and practices that back the dispossession of neighborhood assets from socially vulnerable residents and thereby undermine local adaptive capacity and resistance to displacement. City and nonprofit environmental groups seem to feel that preventing displacement is simply outside their purview.

Reinforcing Antidisplacement Capacity and Environmental Protection in Black and Latinx Neighborhoods

Thus, in Philadelphia, the work of creating and preserving community assets falls heavily on the shoulders of (nonenvironmental) CBOs, with higher capacity groups better able to organize both for

antidisplacement and environmental protection. We briefly develop this point, focusing on a Latinx and a Black neighborhood with contrasting recent attention and development: Hunting Park and East Parkside.

Hunting Park, one of the warmest neighborhoods in Philadelphia,[11] has a mix of balancing and moderately sensitive tracts. It is a mostly Latinx neighborhood of North Philadelphia bordered by an active opportunity zone. Characterized by activists as facing an incoming gentrification wave, Hunting Park has received the support of the Hunting Park Community Collaborative—a coalition of local stakeholders—to educate the community about the benefits of greening. These groups, led by Esperanza, the area's largest and most established CBO, have been translating materials to Spanish, finding and training volunteers, and partnering with nonprofit and municipal programs to gain access to trees at low or no cost. They aim to achieve a 30% canopy cover by 2050. Although their educational outreach has increasingly made residents more receptive to trees, convincing local cash-strapped businesses with large impermeable surfaces to install green stormwater infrastructure has been more challenging because of the perceived costs of upkeep and land loss.

At the same time, Hunting Park is increasingly beset with displacement challenges. Through tremendous efforts and access to funders, several active and longtime CBOs have managed to create nearly 40 affordable housing units, improve public safety, bring quality programs to the neighborhood park by the same name, and expand social services for health and childcare, even before extensive greening has been implemented. A CBO employee in charge of greening programs discussed the challenge of establishing community land trusts and other community-owned infrastructure:

> People may think that we're too early; we're not. There are a lot of organizations that are now too late. [. . .] If you wanted to do something in certain areas, it's just harder now because you already have development happening and now you cannot purchase property at the rate that you could have purchased property before. Neighbors are selling their homes so they're already being pushed out. Once that's happening, you're a bit too late.

In just the last few years, homeownership in Hunting Park has dropped from 60% to 45%, most renters—most of them Latinx—are cost burdened, and the neighborhood is unbanked. In response, Esperanza is aiming to coalesce nationwide funders to secure more land for community land trusts and help stabilize renters.

In contrast, East Parkside is a 90% African American neighborhood and is strongly sensitive to gentrification. Bordered by the extensive Fairmount Park, home to the new Please Touch Museum, and proximate to the expanding Drexel University campus, its community has benefited little from this major infrastructure in previous years. Until recently, the closest part of the park lacked safe and direct access points for East Parkside residents and the city had even allowed the for-profit museum to replace residents' free community recreation center. However, by forming the new Centennial Parkside Community Development Corporation (CPCDC), residents have managed to transform a city and local conservancy plan to create a nature playground with rain gardens near the museum into more of an accessible everyday community space along Parkside Edge and to employ residents to maintain it.

At the same time, the neighborhood faces complex development challenges: it is physically isolated and lacks basic services and everyday shops. Although some vacant lands have been transformed into beautiful community gardens, many remain blighted properties held hostage by private owners and developers awaiting a more profitable market; furthermore, the Philadelphia Land Bank—which was created to oversee the return of vacant and tax-delinquent properties to productive use—has failed to make publicly held lots available to the community. Under pressure and harassment from *we buy homes* speculators, residents are selling off their homes at a fraction of their value, and many of the neighborhood's historic single-family homes have been converted into multiple profitable rooms for rent to transients. With its population shrinking, attracting businesses and convincing developers to build affordable housing has proven challenging. Yet some respondents report being grateful that East Parkside has not been designated an opportunity zone—

although it is surrounded by them—which they perceive as an acceleration of developer investment without community groups being able to propose alternatives.

Although local organizers report that a lack of community spaces to meet and organize continues to be a key problem, the new CPCDC provides a more cohesive local representation to politicians, developers, and funders. According to one employee, there is an eagerness to address the displacement component of gentrification and be prepared for upcoming changes:

> I think you can prevent or at least mitigate displacement. We can't prove this because we haven't done it yet, but we're trying to, by preparing people for gentrification. Neighborhoods that get wiped out by gentrification are the least organized and the least prepared—they didn't see it coming. But if you see it coming, you can be prepared, you know what the effects of it are.

In this sense, they and other local groups have been active in affordable housing, rezoning to prevent multiunit residential conversions, and educating residents about predatory buyers. They also advocate for residents' input on amenity design to achieve a greater sense of ownership in the process of urban greening and neighborhood redevelopment.

Overall, we note that both neighborhoods are juggling, on the one hand, a risk of displacement by future intensifying gentrification—in which recent and future GRI may participate—and on the other hand the already ongoing displacement of socially vulnerable residents because of the overwhelming pressures of enduring disinvestment, even while local CBOs struggle to build neighborhood adaptive capacity.

Discussion and Interpretation

This study evaluates the role of small-scale green resilience interventions in relation to social and neighborhood vulnerability to climate gentrification and contributes to critical research on housing and sustainability, especially in the context of postindustrial cities undergoing redevelopment and gentrification. It unpacks the potential impacts of GRI for residents most vulnerable to social and climate insecurities and the neighborhood antidisplacement resources that may mitigate undesired change. It therefore brings new critical understandings about the equivocal role of GRI and informs strategies that can reduce social and racial inequities in climate adaptation planning and support climate justice policies. It also has a notable original focus on adaptation impacts for racialized minorities.

Most notably, our spatial quantitative study found that green resilience interventions are concentrated in the wealthier and gentrified neighborhoods of central Philadelphia and increasingly in those adjacent to them that are gentrifying and strongly associated with real estate development, economic reinvestment, and growth-driven policies. These findings suggest that resilience efforts are embedded in both private (Teicher, 2018) and state-sponsored investments (Checker, 2011; Gould & Lewis, 2018) that are known to drive gentrification (Pearsall & Eller, 2020). This is the case even as 50% of the GRI in our study are being implemented on or planned for public land. Therefore, our study points to how green resilience planning is entangled in the uneven and unequal social dynamics of neighborhood revitalization and new housing developments, whereby future construction of both green infrastructure and housing might benefit new, socially privileged residents rather than long-time or vulnerable ones.

Our spatial quantitative study also reveals the exclusion of more heavily minoritized neighborhoods from GRI planning and implementation, foretelling future climate insecurities. The highest percentage Latinx neighborhoods are some of the least climate protected. Furthermore, higher percentage Black neighborhoods also tended to be more strongly associated with historical and ongoing disinvestment or a mismatch between needs and infrastructure. They are also especially linked with open land that has been labeled vacant or blighted—a legacy of many iterations of crisis, government abandonment, and dispossession—and today those properties are held privately or sold for private development by the city council, thereby embedded into new dynamics of

gentrification. With this, a clear line becomes visible between long-standing racist housing policies and practices, and environmental racism and injustice that created these social and climate insecurities in the first place (Pulido, 2017). Today, although some lands have been cleaned or gardened, for instance, through the love and labor of longtime residents, these slow gains and healthful green amenities may be lost for Black or Latinx residents when gentrification takes hold (McClintock, 2018; Rosan & Pearsall, 2017).

The fact that GRI are also concentrated in tracts where higher capacity community-based nonprofits are doing social support and antidisplacement work, but that these areas are *also* sites of intense, overlapping private development and neighborhood change, is another key finding that underscores the power asymmetries between capital accumulation strategies and community support and resistance in a progrowth and neoliberal context (McClintock, 2018; Pearsall & Anguelovski, 2016; Pulido, Kohl, & Cotton, 2016). This balancing act between what we have identified as neighborhood sensitivity and adaptive capacity is especially observed for Latinx neighborhoods closer to the city center, reflecting previous findings that suggest that Latinx residents have been increasingly displaced from those same areas (Shokry et al., 2020). Such dynamics highlight that Black and Brown communities vulnerable to social and climate insecurities are already overwhelmed by tremendous displacement pressures and that nonprofits—particularly environmental ones—are not always able to protect them or their work might come too late.

Echoing activist Tracie Washington's now famous demand—"Stop calling me resilient"—scholars have theorized that the growing urban resilience orthodoxy may simply perpetuate the neoliberal paradigm of self-sufficiency while continuing to do harm (Kaika, 2017; Ranganathan & Bratman, 2019; Vale, 2016). In the post-Katrina context, Vale (2016, p. 17) wrote that "the language of resilience provides a seemingly empowering label for a process of double dispossession" through both disaster victimization and postdisaster investment. In this study, it is the predisaster planning itself that may place vulnerable communities at risk for future dispossession and displacement by green (climate) resilience gentrification—despite the leadership of communities of color—when affordable housing and other social infrastructure and protections are too weak or overcome (Graham et al., 2016). Rather than assuming that resilience leads to justice, it is imperative in both research and policy design that action toward justice be an explicit and central aspect of resilience thinking and strategies.

Therefore, this study reveals a new climate gentrification pathway by green resilience, wherein socially vulnerable neighborhoods—despite the antidisplacement efforts of CBOs—persistently face social and climate insecurities because of the overwhelming impact of private market-led investment that is unfettered (and even assisted) by more powerful institutions. Our qualitative findings also demonstrate that the narrow greening focus and current commitment of environmental nonprofits may come at the expense of affordable housing advocacy and funding, thereby spurring environmental gentrification (see Rigolon & Németh, 2018). Our interviewees indeed shared fears of green gentrification and historically rooted distrust in local government and environmental NGOs.

Thus, our study also advances understanding of the *multifaceted* vulnerability to gentrification of neighborhoods in which multisectoral CBOs already work. It shows how the power and privilege of environmental organizations to push a greening agenda may actually exacerbate and subordinate antidisplacement efforts. Whereas bridging CBOs also play a critical role in procuring new climate protective resources for vulnerable neighborhoods (Connolly, 2018), environmental groups tend to prioritize techno-managerial solutions—such as GRI—and consensual politics (Checker, 2011; Finewood, Matsler, & Zivkovich, 2019; Heckert & Rosan, 2018; Kaika, 2017; Pulido et al., 2016) and may thereby stymie efforts to prepare for climate gentrification. A key procedural justice issue in climate justice concerns, it may also be a limiting factor to achieving "emancipatory and antisubordination greening" aims and therefore not only to preventing discrimination and loss (preventative justice), but also to guaranteeing permanent and secure rights to healing, liberating green spaces, and other benefits (restorative justice) for marginalized communities (Anguelovski et al., 2020). Urban resilience and housing policies and planning must work to build trust and dialog with

vulnerable populations who do not have a permanent political and economic voice in these decision-making processes (Fitzgibbons & Mitchell, 2021) and—in a more material sense—guarantee their rights to affordable housing, collective ownership, and community control in establishing healthy, safe environments (Shi, 2020).

In sum, our framework of vulnerability to climate gentrification considers exposure, sensitivity to gentrification, and adaptive capacity in a novel way, as the overlapping and intersecting structural and systemic deterrents, but also the supportive infrastructures of communities in responding to displacement threats. We theorize and operationalize a clustering methodology to measure and accentuate the role of these factors as compounded concentrations of harms and resources. This study highlights that, on the one hand, there is a need for gentrification research to better evaluate the processes that help and hinder adaptive capacity efforts to better predict and understand gentrification effects. On the other hand, to offer a fuller picture of the local processes of climate resilience at stake, vulnerability research would need to better integrate neighborhood sensitivity to gentrification factors that are often prior exposures that have become entangled in the deeper root causes of ongoing inequity, insecurity, and injustice. Lastly, this research done in Philadelphia can be implemented in many cities and at transnational scales (Blok, 2020) to examine similarities and differences across climates, diverse urban development and growth trajectories (i.e., in cities with long-established economic growth) in the Global North and South, and various urban resilience and housing policy landscapes.

Concluding Remarks and Policy Reflections

Even if the roots of injustice, exclusion, and inequality are well known, the work of undoing them to build a more socially and environmentally just city must overcome growth-oriented and elite interests that prevent urban greening from benefiting vulnerable groups through accumulation, dispossession, and racialized displacement (McClintock, 2018; Safransky, 2017). Some cities, such as Philadelphia, are starting to place equity at the center of new planning interventions, yet their efforts do not always achieve expected or hoped-for outcomes. According to recent research by PEW Charitable Trusts (2020), housing affordability is a persistent problem in this high-poverty city, especially so for renters, 54% of whom are cost burdened. Making matters worse, a 10-year full tax abatement for new construction and major renovation projects has been driving a construction boom that largely benefits wealthy developers and higher income homeowners, while accelerating displacement and depriving underserved neighborhoods of revenue for schools. Organizers have recently helped reduce the tax abatement, and in 2020 the City Council passed Philadelphia's first residential development impact tax—a 1% tax on new residential construction to fund affordable housing.[12] These and other tools for preventing displacement and supporting equitable greening, such as Philadelphia's Longtime Owner Occupants Program (LOOP), a property tax freeze program for eligible households, and a good-cause eviction bill that became law in 2019 are significant small victories, but often they are also watered-down versions of community groups' claims for protection of socially vulnerable residents.

Most notably, the bill to create the Philadelphia Land Bank, for which the Garden Justice Legal Initiative and other community partners long advocated as a means to levy some of Philadelphia's 40,000 vacant properties to productive community use, was finally approved by City Council in 2013. Management of the land bank, however, has fallen short of expectations[13] for community-controlled processes and transparency in land transfers, as well as permanent affordability through land trusts to prevent speculation and resale for private profit (BCNUEJ, 2021). If reformed, the land bank has the potential to help strike a balance between creating affordable housing while preserving open space, like parks and community gardens, for community uses, and thereby supporting both social and climate resilience.

Our study also highlights the need for a variety of social infrastructure, in addition to affordable housing, to provide material and organizational support for lower income residents and residents of

color and to mitigate harmful development, by reducing other cost burdens and providing social, child, and health services and community space for education, exchange, and building political power. At the time of writing, millions are marching in the United States and around the world in the name of racial justice to support the Movement for Black Lives. In parallel, many millions of low-income and underinsured workers, forced to work during the COVID-19 pandemic, risk their lives while facing deeply uncertain and precarious futures. The executive director of the Philadelphia Area Cooperative Alliance—a support group for developing Black and Latinx workers' cooperatives—writes: "Since 2016, the Philadelphia police department budget has gone up $120 million. Imagine if even $1 million of that money went toward co-op development that would support Black people and communities of color through this economic crisis and well beyond. (J. Medley, e-mail communication, June 17, 2020)" The latter is one of many life-affirming and redignifying strategies that other local movements like Soil Generation and the Alliance for a Just Philadelphia have also imagined and outlined, building on broader calls for addressing the multiple sensitivities of historically marginalized groups in the city and supporting place resilience. These efforts toward community organizing, education, and advocacy could translate into not only channeling more support for affordable housing, community-controlled land uses, and other adaptive capacity resources, but also directly taking back money, power, and resources from actors, programs, and policies that commodify land and housing and consent to speculative growth, thus making of greening and resilience a polarizing urban land-use practice.

In Philadelphia, city offices and environmental nonprofit organizations are increasingly recognizing green gentrification concerns, but their support for the kinds of initiatives outlined above remains marginal and often discursive at best. Housing programs remain disconnected from greening initiatives, each taking a siloed approach and complicating the ability to comprehensively plan green neighborhoods without residentially displacing people. Greening, housing, and other community advocates must therefore work together to guarantee that when greening is negotiated into new developments, that affordable housing—whether through land value capture, inclusionary zoning, or other measures—as well as support for the kinds of social infrastructure discussed in this article—is a key part of the plan. As climate resilience measures are taken, planners must also back and integrate antidisplacement tools from the very early planning stages of resilience projects so that benefits can be enjoyed by socially vulnerable residents for as long as possible and without perpetuating unjust and inequitable outcomes of the past.

Notes

1. See https://www.hud.gov/sites/documents/GREENINFRASTRUCTSCI.PDF (accessed April 1, 2021).
2. Also known as the Combined Sewer Overflow Long-Term Control Plan Update.
3. Highly distressed neighborhoods may still be too disinvested to be affected in the short term by green improvements.
4. Although Philadelphia charter schools and public schools (because of school choice policy) may draw students from the entire city, residential proximity to the school was still valued by parents.
5. Full descriptions of the various GI tools can be found in Philadelphia Water Department, "Green Stormwater Infrastructure Design Requirements and Guidelines Packet," Philly Watersheds, May 15, 2015, http://phillywatersheds.org/doc/GSI/GSI_Design_Requirements_&_Guidelines_Packet_5-15-2015.pdf (accessed on July 26, 2019).
6. Depending on availability, data collection may have started a year or two later or extended to 2018.
7. A cluster analysis compares the internal value of a tract (using a combination of its local Moran's I value, *z* score and pseudo *p* value) with that of its nearest neighboring tracts to identify hot/cold spots (usually consisting of several census tracts) of correspondingly similar high and low concentrations of values. Local Moran's I also identifies spatial outliers, which signify tracts with values dissimilar to neighboring tracts. Each cluster or outlier identified is statistically significant at a 95% confidence level.
8. We decided to treat waterfront census tracts as spatially discrete because of the linear nature of this data point.
9. The interviews were part of a larger multicity study on green inequalities and green gentrification that covered 30 cities in 10 countries: theUnited States, Canada, the United Kingdom, Ireland, the Netherlands, Austria, Spain, Denmark, Italy, and France. Each interview conducted for this particular substudy lasted between 45 and 90 minutes and followed a similar protocol, focused on neighborhood social and health issues addressed by greening, urban partnerships, perceptions of green gentrification, and equity and antidisplacement tools;

however, our interview guide was designed to allow for flexibility in adjustment to differences in cities' programs and urban gentrification processes as well as individual researcher interests. We identified key respondents in advance and used snowball sampling to reach a broad set of interviewees.

10. The codes pertained to climate resilience planning, climate gentrification through green infrastructure, protection of vulnerable neighborhoods through green infrastructure, and antigentrification/displacement responses.
11. Surface temperatures are 22°F above the average in Philadelphia (Office of Sustainability, 2018).
12. See https://www.natlawreview.com/article/philadelphia-city-council-approves-changes-to-tax-abatement-programs-and-imposes (accessed on April 1, 2021).
13. See https://whyy.org/articles/philadelphia-land-bank-is-finally-selling-its-vacant-lots-now-the-question-is-who-will-benefit (accessed on April 1, 2021).

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