Tracking Neighborhood Change in Geographies of Opportunity for Post-Disaster Legacy Cities: A Case Study of San Juan, Puerto Rico

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Abstract

While legacy cities have had a long struggle with deindustrialization, population loss, fiscal constraints and economic decay, many will likely need to address compounding stressors stemming from climate change, specifically the devastating effects of natural disasters. Using the San Juan Metropolitan (SJMA) as a case study, we provide key insights on how a post-disaster context affects underlying tendencies, specifically in housing markets, through regression analyses that identify pre- and post-disaster neighborhood change across geographies of opportunity. Our findings show that disaster impacts have strong associations with segregation, housing affordability, gentrification, and neighborhood decline. These findings suggest that post-disaster reconstruction should explicitly focus on improving the spatial distribution of opportunities. These baseline results that will help improve scenario planning exercises in Puerto Rico by incorporating the disruptive potential of natural disasters in housing markets.

Keywords: Post-disaster reconstruction; Housing; Climate Change; Legacy Cities; Neighborhood Change; Puerto Rico

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Tracking Neighborhood Change in Geographies of Opportunity for Post-Disaster Legacy Cities: A Case Study of San Juan, Puerto Rico

Introduction and Background

Legacy cities continue to seek viable approaches to address deindustrialization, population loss, fiscal constraints and economic decay. In order to address these issues effectively, city governments and non-government actors need baseline data to develop new tools for scenario planning that allow them to identify trends and forecast possible futures. An additional factor that cities need to consider in the years and decades to come are the effects of climate change and how they could increase the likelihood for disasters. As such, research that can assist cities in determining how disasters change the models and parameters used for scenario planning is sorely needed. One area where understanding long-term dynamics of disasters becomes salient for planners is in housing markets and how these pertain to neighborhood change.

As prior research has shown, exploratory scenarios in urban planning must focus on incorporating stakeholder values and not only rely solely on expert judgment and analysis since planning is a political process characterized by unequal power relations between decision-makers and those that receive the benefits and burdens of such decisions (Avin and Goodspeed 2020; Goodspeed 2020). Nonetheless, planners engaged in scenario projects must still rely on baseline data and research to define project scope, desired outcomes, and scenario construction and evaluation tools (Chakraborty and McMillan 2015). Therefore, when contemplating something as complex as post-disaster neighborhood change in scenario planning, it is important to understand both the technical and political dynamics at play.

Previous studies on disasters and long-term housing reconstruction in the United States show that recovery is highly unequal among neighborhoods. In their study of post-disaster housing recovery after Hurricane Andrew in Miami and Hurricane Ike in Galveston, Peacock et al. (2014) show that income, race and ethnicity were critical determinants of higher losses and slower recovery rates in Miami, while income was the critical factor in Galveston. Moreover, in their study of post-disaster recovery in Miami after Hurricane Andrew, Zhang and Peacock (2009) find that “major natural disasters are likely to be followed by housing market volatility, high rates of property abandonment, and uneven housing recovery.”

New Orleans’ experience after Hurricane Katrina also provides significant insights., Kamel’s (2012) analysis of post disaster housing recovery programs found that areas that experienced the lowest repopulation rates were the ones that suffered high levels of damage and received disproportionately low housing assistance. A detailed examination of New Orleans’ Road Home Program by Green and Olshansky (2012) showed that New Orleans homeowners living in low-value housing communities received inadequate funding for repairs and rebuilding due to flaws in the design of the program. Studies carried out more than a decade after the disaster, have found that recent gentrification waves in New Orleans are associated to housing damages stemming from Hurricane Katrina (Holm and Wyczalkowski 2018; Aune, Gesch, and Smith 2020).

Considering that disasters can affect housing markets and lead to neighborhood change, it is important to identify the underlying factors that determine the likelihood of these phenomena. Neighborhood change can be driven by the spatial distribution of opportunities at the regional level—namely, access to jobs, education, health, and safety—as these are considered key determinants of social mobility (Galster and Mikelsons 1995; Lens 2017). Unequal access to opportunities or public goods can drive increased levels of segregation (Trounstein 2015; Lens 2017), as well as affect housing affordability and the likelihood of gentrification (Ellen and Oregan 2011; Owens 2012; and Preis et al. 2020). Thus, mapping the distribution of opportunities across geographies can inform policy to address underlying inequities (Brain and Prieto 2018; Knapp 2017).

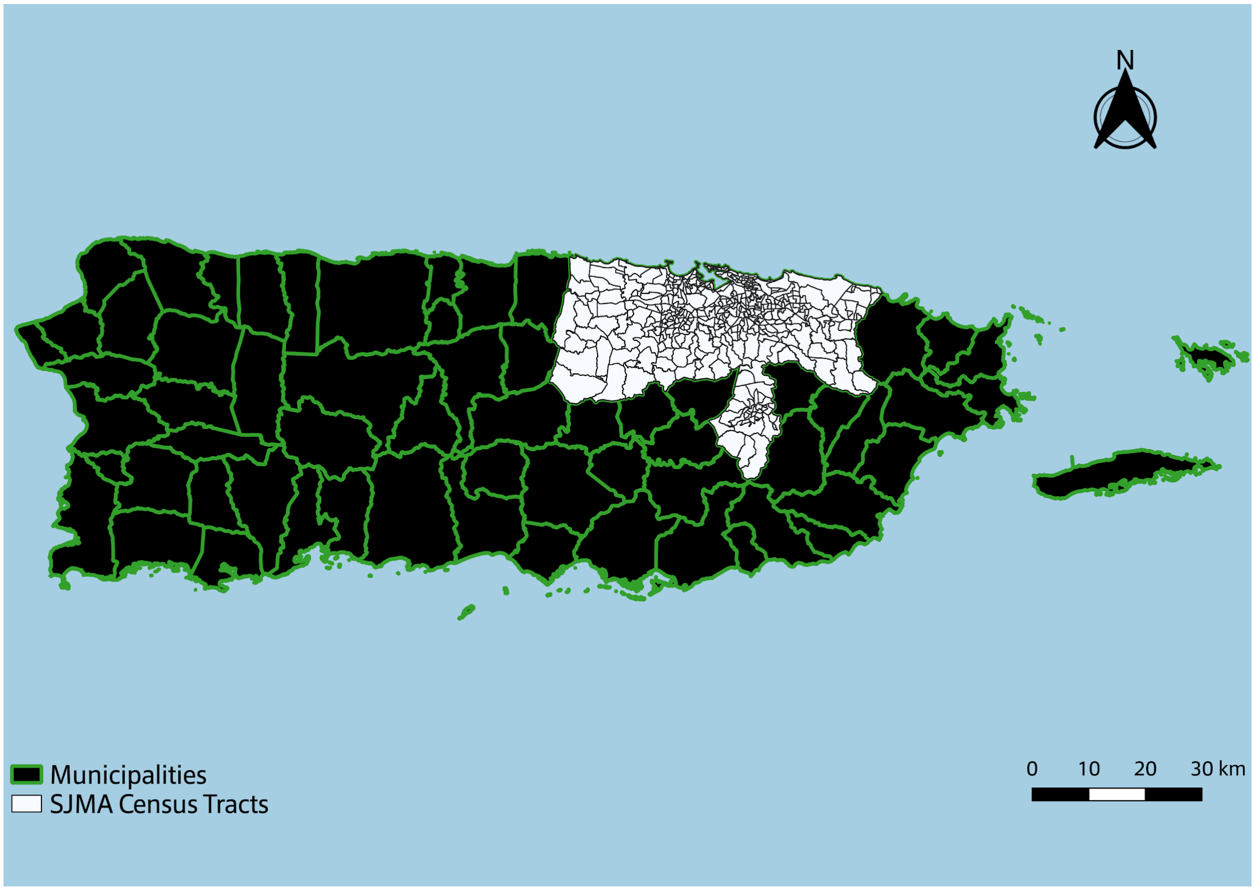
Our research provides important insights on how to consider long-term neighborhood change in post disaster contexts. Using the San Juan Metropolitan Area (SJMA) as a case study, we measured how different indicators for neighborhood change are associated with storm impacts, specifically those stemming from Hurricane María, and the geographical distribution of opportunities. These analyses provide key insights to assess how storm events can potentially affect neighborhood change in the long run. Moreover, they will allow us to make policy recommendations regarding post-disaster reconstruction efforts particularly with regards to how public spending can be funneled to specific communities given their differing levels of opportunities.

Data and Methods

Case Study: San Juan, Puerto Rico

Our study is focused on the SJMA, a functional region defined by the Puerto Rico Planning Board in its island-wide land use plan. The SJMA is composed of 15 municipalities (Figure 1) that are home to over 40 percent of the island's population. Nonetheless the region has been experiencing population loss for more than a decade. Figures from the Puerto Rico Community Survey (PRCS) show that population in the SJMA has declined from 1.4 million in 2016, to 1.33 million in 2019.

Figure 1: San Juan Metro Area (SJMA) location and census tracts



As Puerto Rico's largest metropolitan region, the SJMA is the island's primary location for employment and economic opportunities (Puerto Rico Planning Board 2015). It has, however, been facing a steep decline in manufacturing and other industrial activities, as has the rest of the island, resulting in shifts towards retail, tourism, and other service-oriented activities. These industrial shifts have also led to significant reductions in wages.

At the same time, the SJMA experienced an aggressive drive towards suburbanization throughout the 1990s and early 2000s. But suburbs and urban centers have begun to hollow out, leading to a rise in vacant properties, as deindustrialization and economic decay has taken its toll on the island. Somewhat paradoxically, there is an ongoing housing affordability crisis. According to the 2018 PRCS, over half of renters in SJMA spend more than a third of their income on rent, while 43 percent of households that have mortgages are housing burdened. In addition, the SJMA has also been facing extensive fiscal constraints. This is due to the acute economic crisis that has been evidenced in Puerto Rico since 2005, and the application of austerity measures that have also severely limited state capacity.

To make matters worse, Puerto Rico was battered by Hurricane María in September of 2017. The storm caused severe damages to infrastructure and housing units, and recovery efforts have been painfully slow. More than a third of the island's housing units suffered heavy damage, and a mortgage foreclosure crisis ensued. At present, reconstruction efforts are still in the planning stages, but most of these will seek to address housing needs.

In addition to the damages caused by the hurricane, the post-disaster SJMA has also seen an influx of US mainland investors that have been buying properties in San Juan, thanks to a series of tax incentives provided by the government of Puerto Rico, as well as an increase in short-term rentals throughout the main urban areas of the metro region. Moreover, the government of Puerto Rico has been aggressively proposing additional tax exemptions to potential investors as part of the federal government's Opportunity Zones program, created as part of the Tax Cuts and Jobs Act of 2017. All of these dynamics have raised concerns regarding gentrification and displacement among vulnerable populations in the region.

The aftermath of the hurricane is showing is that there are increased opportunities for real estate investments in many of the urban centers that are also some of the most important geographies of opportunity for households. Meanwhile, there are parts of the SJMA where communities are still waiting for reconstruction funds in order to repair, rehabilitate, and rebuild damaged housing units. This situation will likely reproduce pre-existing patterns of socioeconomic segregation, urban decay and hollowing, housing affordability issues, gentrification, and residential displacement in ways that were perhaps unforeseen in a non-post-disaster context.

Since Hurricane María made landfall, Puerto Rico has been allocated $20 billion in Community Development Block Grant–Disaster Recovery (CDBG-DR) funds and almost $30 billion in Federal Emergency Management Agency (FEMA) funds for Public Assistance and Hazard Mitigation Grants. These funds include programs for housing repair and reconstruction, affordable housing construction, infrastructure upgrading, hazard mitigation, workforce development, and local business aid programs.

Despite the substantial funding allocated for post-disaster reconstruction in Puerto Rico, these programs tend to target individual, low-income and vulnerable households, or focus on discrete projects, which inevitably leads to coordination and sequencing problems. In addition, program designs do not address the long-term neighborhood changes that may arise as a result of the damages generated by Hurricane María. Our research provides valuable insights on this particular issue and provides a point of departure for discussions on how to improve spatial equity throughout the reconstruction process.

Data Collection

To carry out the analysis, we created a pooled data set that includes numerous variables for each census tract in Puerto Rico from 2016 to 2019. The data used to construct the panel comes from six main sources: (1) socioeconomic and demographic variables were obtained from the PRCS conducted by the US Census Bureau; (2) real estate point data was purchased from Luis Abreu and Associates; (3) damage estimates for Hurricane Maria stem from FEMA's Individual Assistance Housing Registrants- Large Disasters (IAHRLD) dataset; (4) GIS data on municipalities, infrastructure and other geographic factors were obtained from the Puerto Rico Planning Board and the Puerto Rico Office of Management and Budget; (5) firm-level jobs and school point data were provided Estudios Técnicos, Inc.; and (6) type 1 felony data was provided by Puerto Rico Police Department.

The process by which we created the panel dataset used in this analysis can be divided into three main stages: importing and cleaning, geocoding and aggregating, and generating variables for analysis. Census data was collected using the Census API. We used 5-year estimates by census tracts in accordance with prior studies on this topic. This scale maintains a reasonable data resolution while balancing estimation errors in the census data.

Although FEMA publishes other datasets which serve to measure damages, we chose FEMA's Individual Assistance Housing Registrants Large Disasters (IAHRLD) dataset because it contains individual level data that is georeferenced. To create damage estimates for each census tract we filtered the data to reflect applicants in Puerto Rico claiming damages from Hurricane Maria, then aggregated FEMA verified losses, counts of damaged housing units, and assistance awards, to the census tract level.

To obtain counts of real estate transactions, jobs, schools, and crime in each tract we projected a layer of points representing all data points onto a map of census tracts in Puerto Rico. Using the QGIS software, we joined these layers by location and generated a count of points in each tract. Once joined, we aggregated the data by census tract.

The real estate data presented several geocoding challenges. The data was geocoded using point coordinates and merging those observations without coordinates to the municipal revenue collection center's cadastral map, which is geocoded. This allowed us to project our data onto the map of census tracts and aggregate sales volume, price per square foot, and property values.

Regression Analysis

For this stage of the project, we set up a series of regression models to identify associations between multiple measures of neighborhood change and storm impacts, access to opportunities, and demographic characteristics. We used a pooled ordinary least squares (POLS) model with clustered standard errors at the census tract level, as well as municipal fixed effects, for all regressions.

The measures for neighborhood change include: (1) socioeconomic segregation; (2) housing affordability and gentrification; and (3) neighborhood decline. Table 1 shows the summary statistics for the variables used for each measure of neighborhood change. We discuss each one of these variables in the latter subsections.

Table 1: Summary statistics for measures and variables of neighborhood change

Measure	Variable	Obs	Mean	Std. Dev.	Min	Max
Segregation	High-income concentration	1,566	0.26%	0.40%	0.00%	3.06%
	Poverty concentration	1,566	0.26%	0.16%	0.00%	0.96%
	Dissimilarity	1,566	0.000	0.004	-0.029	0.010
Affordability and gentrification	Housing sales volume	1,460	0.62%	0.45%	0.04%	3.15%
	Median housing unit price (USD/ft^2)	1,457	$95.23	$36.79	$25.29	$369.23
	Median rent	1,499	$582.03	$220.25	$99.00	$1,722.00
Decline	Vacancy rate	1,566	11.59%	5.58%	0.00%	68.29%
	Percent change population	1,174	-2.19%	6.69%	-51.09%	34.31%

To assess the impacts stemming from Hurricane María, we used two measures using FEMA's data: (1) average pending need and (2) percent of damaged homes. Average pending need refers to the mean of remaining damages per census tract, and it was estimated by averaging the difference between estimated damages and awarded aid by FEMA for each applicant household in FEMA's IAHRLD dataset. Percent of damaged homes shows the share of total housing units that were identified by FEMA to have suffered damage. We also included a temporal binary variable for those observations that took place before and after Hurricane María struck Puerto Rico. This variable also allows us to control for temporal fixed effects.

With regards to measures of access to opportunities, we used the total number of jobs and schools per tract and divided it by the surface land area for each one. For disamenities in the form of type 1felonies, we used the yearly average crime incidents for each tract and divided it by the surface land area for each one.

Lastly, we used additional controls for demographic characteristics, including poverty rate, household median age, race, and migrant status. Table 2 shows the summary statistics for all non-binary independent variables.

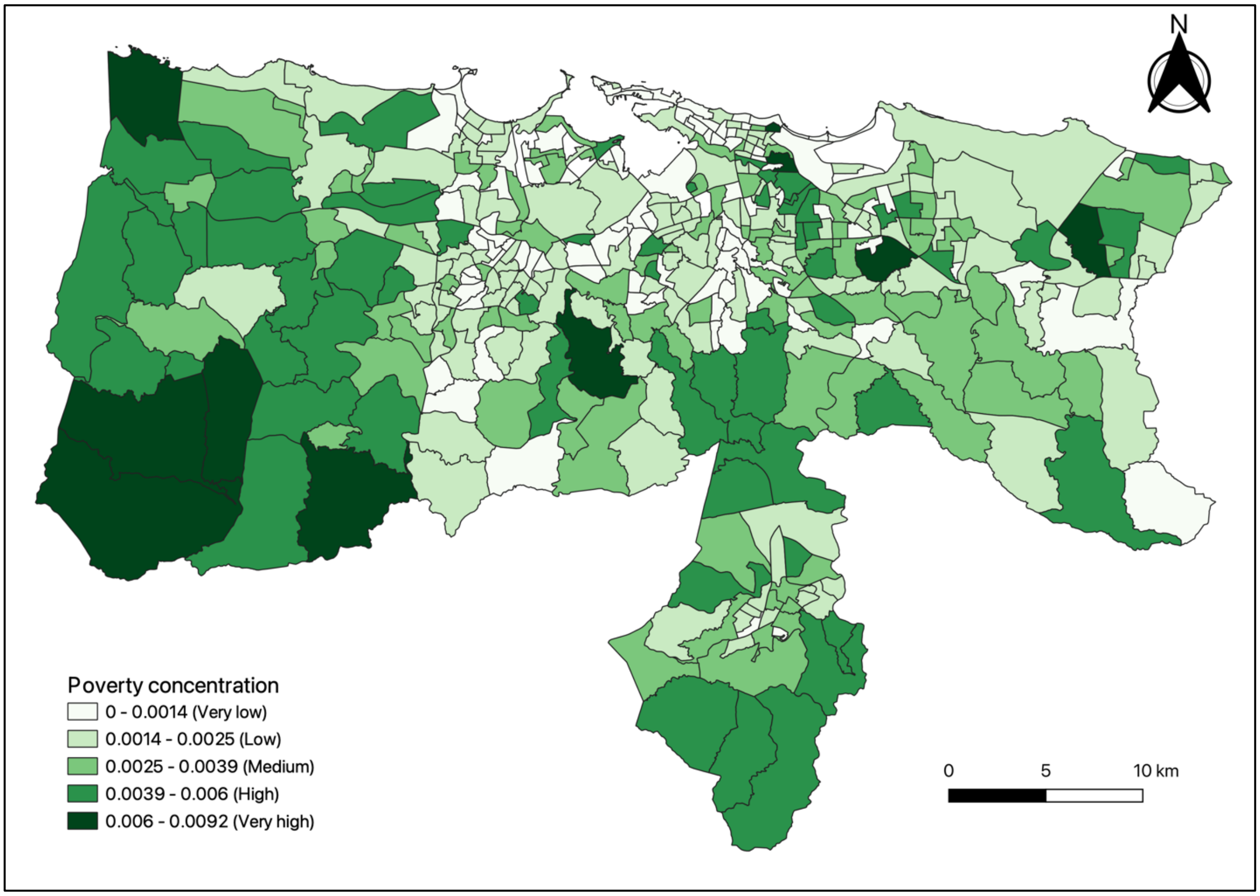
Table 2: Summary statistics for measures and variables of storm impacts, access to opportunities, and demographic characteristics

Measure	Variable	Obs	Mean	Std. Dev.	Min	Max
Storm impacts	Average pending need	1,566	$831.12	$1,198.22	$0.00	$11,575.13
	Percent damaged homes	1,566	12.18%	19.64%	0.00%	100.00%
Access to opportunities	Job density	1,566	2026.33	5190.63	0.14	40565.74
	School density	1,566	1.31	1.89	0.00	16.49
	Crime density	1,566	42.61	55.86	0.56	369.56
Demographic characteristics	Poverty rate	1,566	38.99%	17.93%	0.00%	100.00%
	Household median age	1,564	41.55	6.59	17.90	61.80
	Percent immigrant population	1,566	7.04%	9.06%	0.00%	58.18%
	Percent non-white population	1,566	33.51%	16.43%	0.00%	95.03%

Socioeconomic Segregation

We used three variables that provide different measures of socioeconomic segregation. The first one, poverty concentration, is a measure of residential segregation and was estimated by dividing the census tract population living under the federal poverty line by the total population living under poverty in the SJMA. Figure 2 shows the distribution of poverty concentration throughout tracts in SJMA. It is highest in the outskirts of the region, especially in the southwestern rural areas, although there are notable "pockets" of high poverty concentration in the most densely populated neighborhoods in San Juan. The categories displayed in the map were designated using Jenks natural breaks optimization.

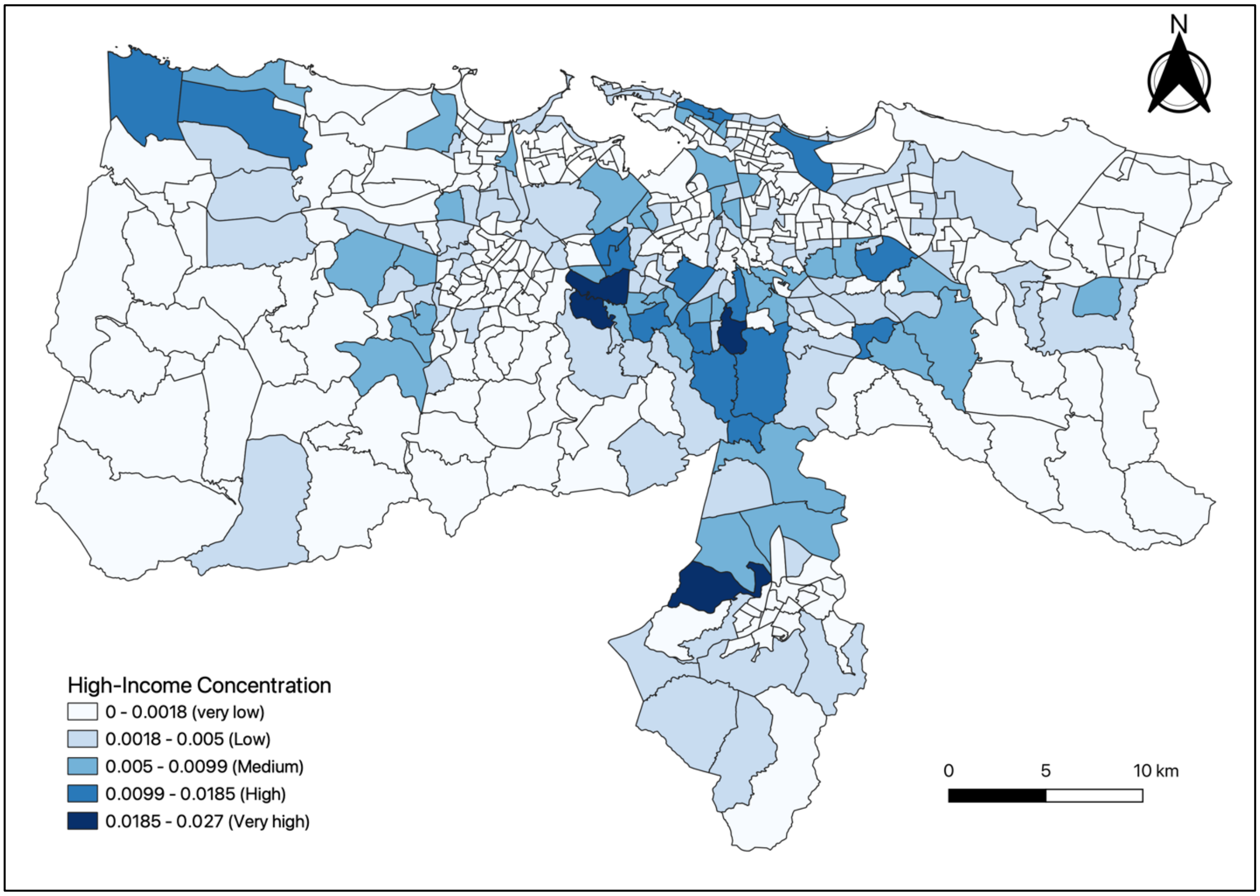
Figure 2: Average concentration of poverty in the SJMA, 2016–2019



Source: PRCS

High-income concentration is another measure of socioeconomic segregation and follows a similar approach to poverty concentration, but it refers to the share of households above the largest census income bracket for each tract, from the total number high-income households in the SJMA. Figure 3 shows that high-income households are mostly concentrated in central San Juan, Guaynabo, and Caguas. The categories displayed in the map were designated using Jenks natural breaks optimization.

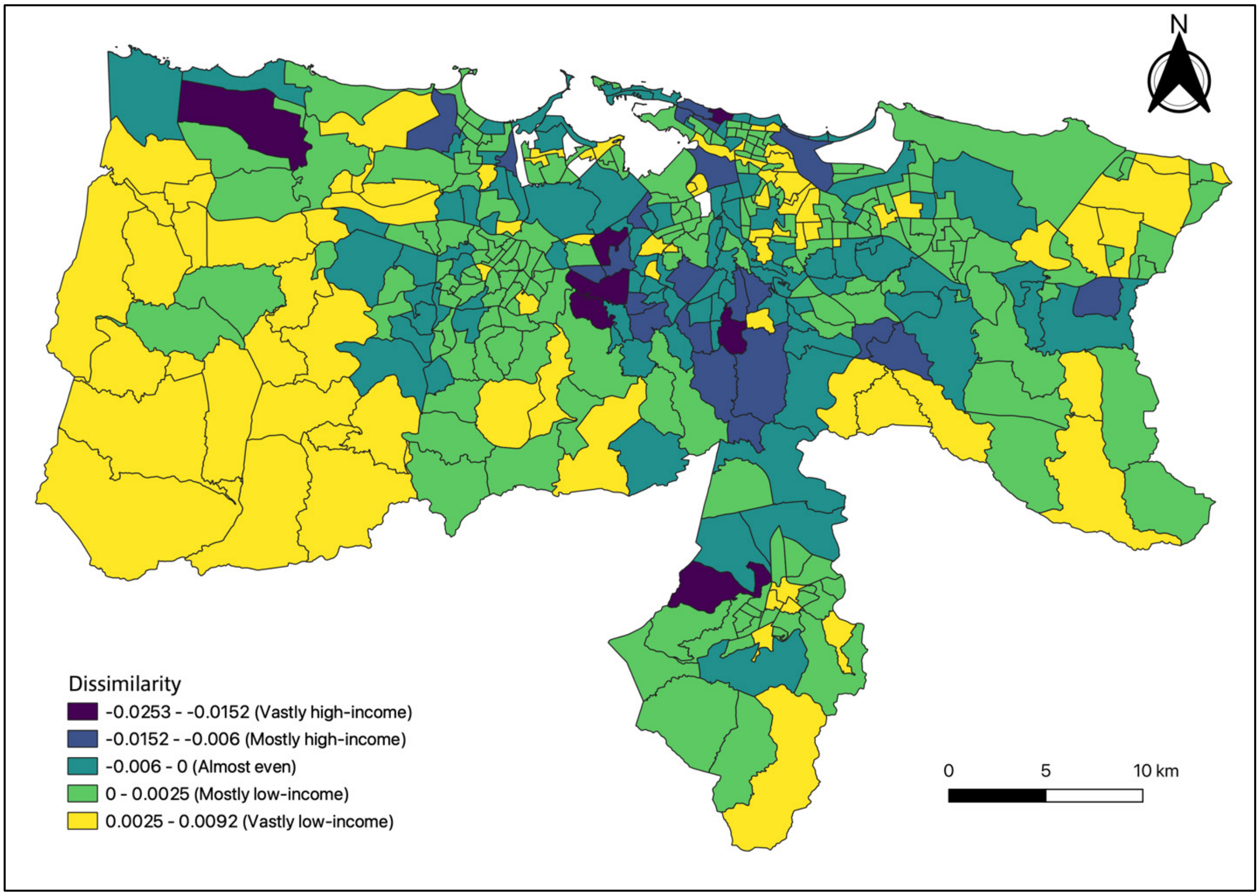
Figure 3: Average concentration of high-income individuals in the SJMA, 2016–2019



Source: PRCS

The final measure of socioeconomic segregation, dissimilarity, is estimated as the difference between poverty concentration and high-income concentration. It is a measure of segregation as evenness, where a negative value indicates a larger presence of high-income households in a given tract, whereas a positive value reflects a larger share of households under the poverty line. Figure 4 shows the spatial distribution of dissimilarity throughout the tracts of the SJMA. The categories displayed in the map were designated using Jenks natural breaks optimization.

Figure 4: Average measure of dissimilarity, 2016–2019

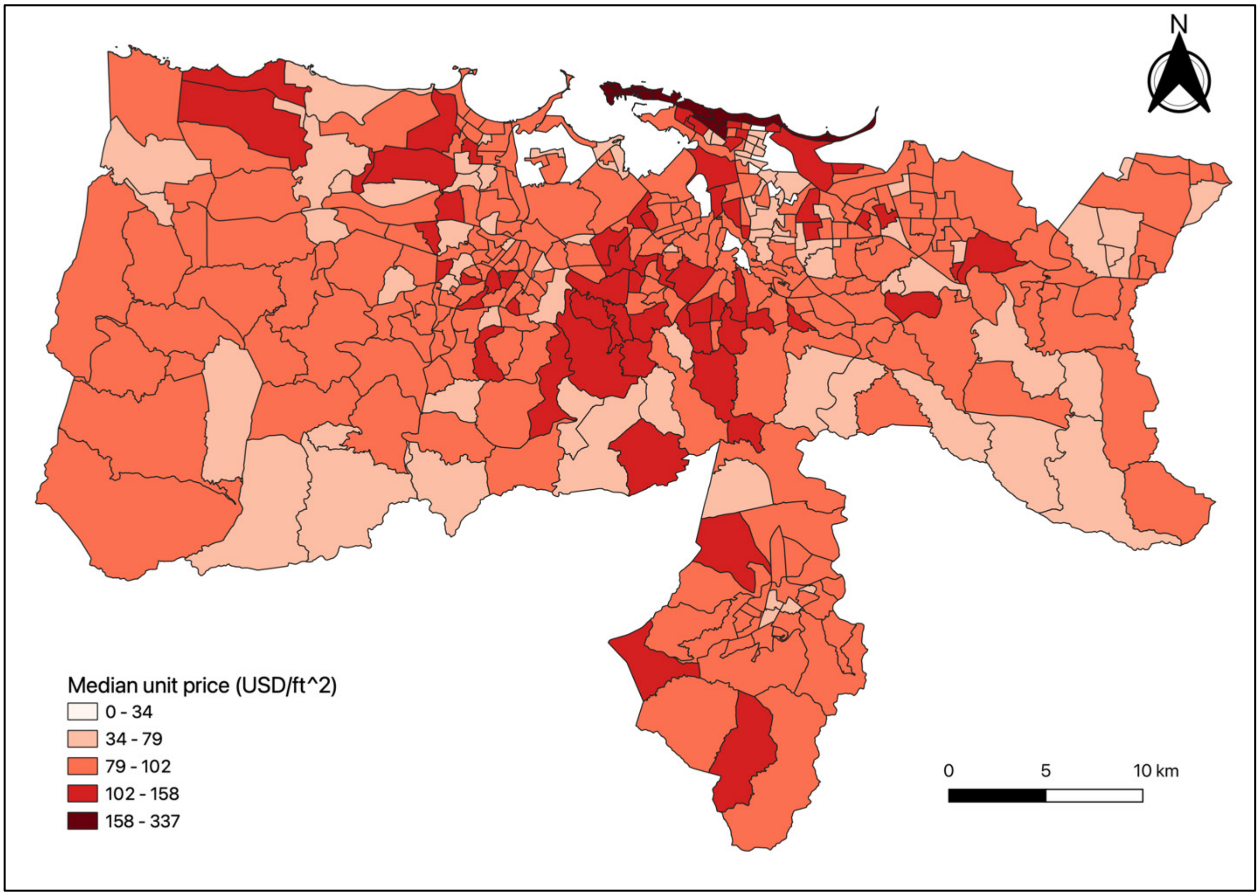


Source: PRCS

<u>Affordability and Gentrification</u>

To measure changes in housing affordability and gentrification, we used three variables: (1) median home unit price; (2) home sales volume; and (3) median rent. Median home unit price refers to the median price in dollars per square feet derived from housing sales in each tract. The priciest neighborhoods are located along the northern coast of San Juan and Carolina, while the lowest priced neighborhoods tend to be located along the rural southern border of the SJMA (Figure 5).

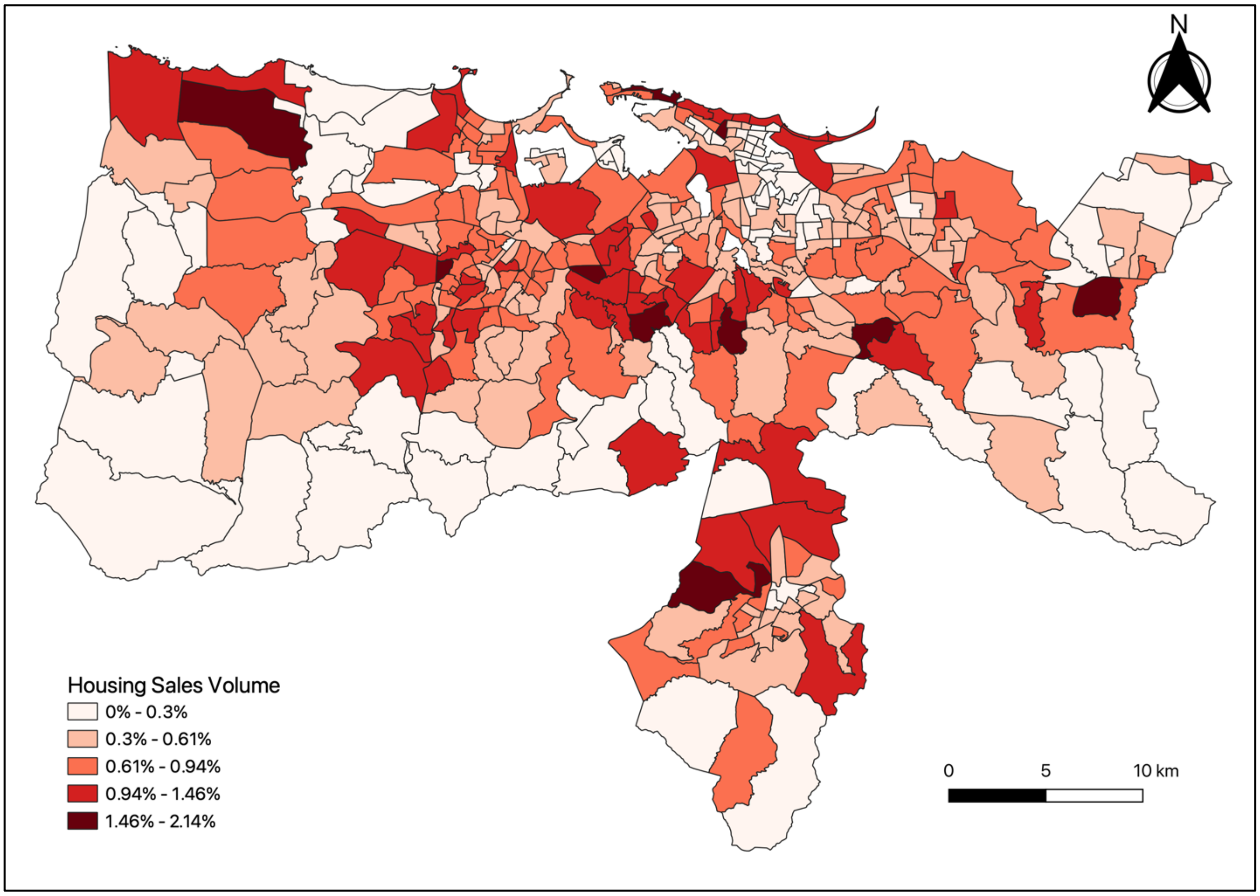
Figure 5: Average median unit price for the SJMA, 2016–2019



Source: Luis Abreu and Associates.

Home sales volume is used as a measure of real-estate market activity to determine which tracts have "hot" or "cold" housing markets and was estimated by dividing the yearly number of sales by the total number of housing units. Using this variable, we identified that the "hottest" housing markets are located in the northern coast of San Juan, as well as central Dorado, Bayamón, Guaynabo, Carolina, and Caguas (Figure 6). The "coldest" housing markets were again located along the rural southern border of the SJMA.

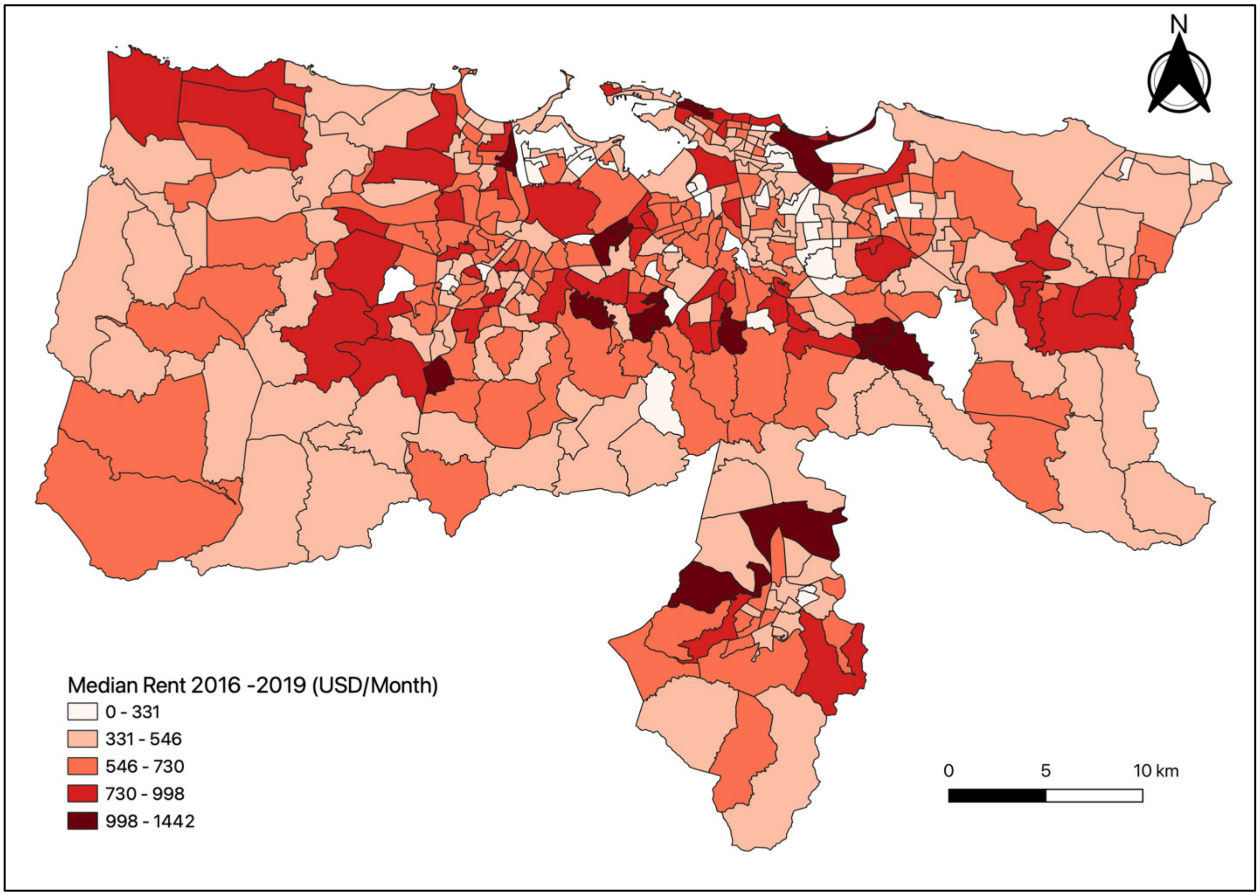
Figure 6: Average housing sales volume in the SJMA, 2016–2019



Source: Luis Abreu and Associates.

Median home rent refers to the US Census measure of this variable. Somewhat unexpectedly, the spatial distribution of median rent seems to coincide more with home sales volume, rather than median unit home prices (Figure 7). The most expensive places to rent are mostly concentrated in central San Juan, Bayamón, Guaynabo, Carolina, and Caguas.

Figure 7: Average median rent in the SJMA, 2016–2019

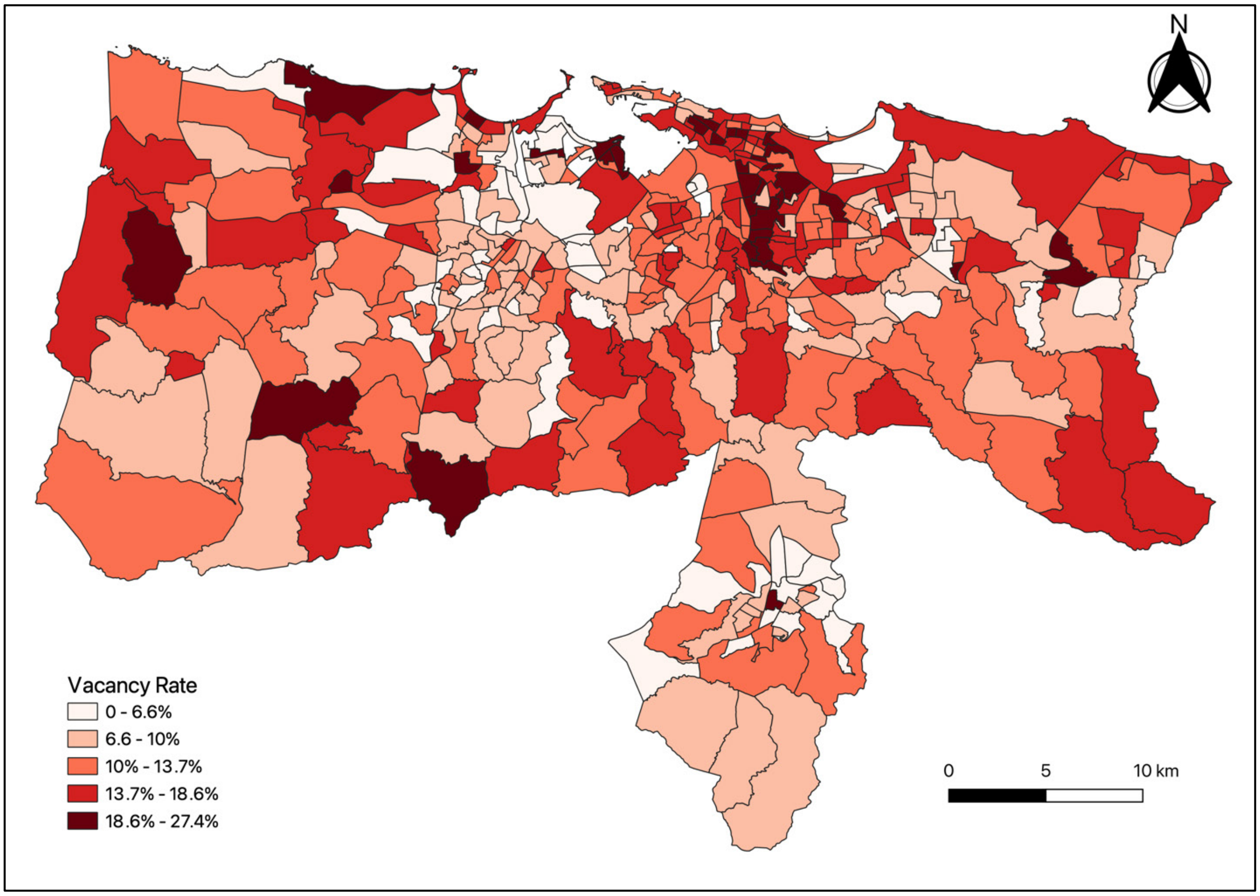


Source: PRCS

<u>Neighborhood Decline</u>

Neighborhood decline is measured using two key variables: vacancy rate and percent of population change. Vacancy rate is estimated as the share of total housing units that were determined to be classified as "other" vacancies by the PRCS. These are housing units that are not currently occupied and are not being actively offered in either the housing or rental markets. Figure 8 shows that the tracts with the highest level of vacancies are located in many of the most densely populated areas of San Juan.

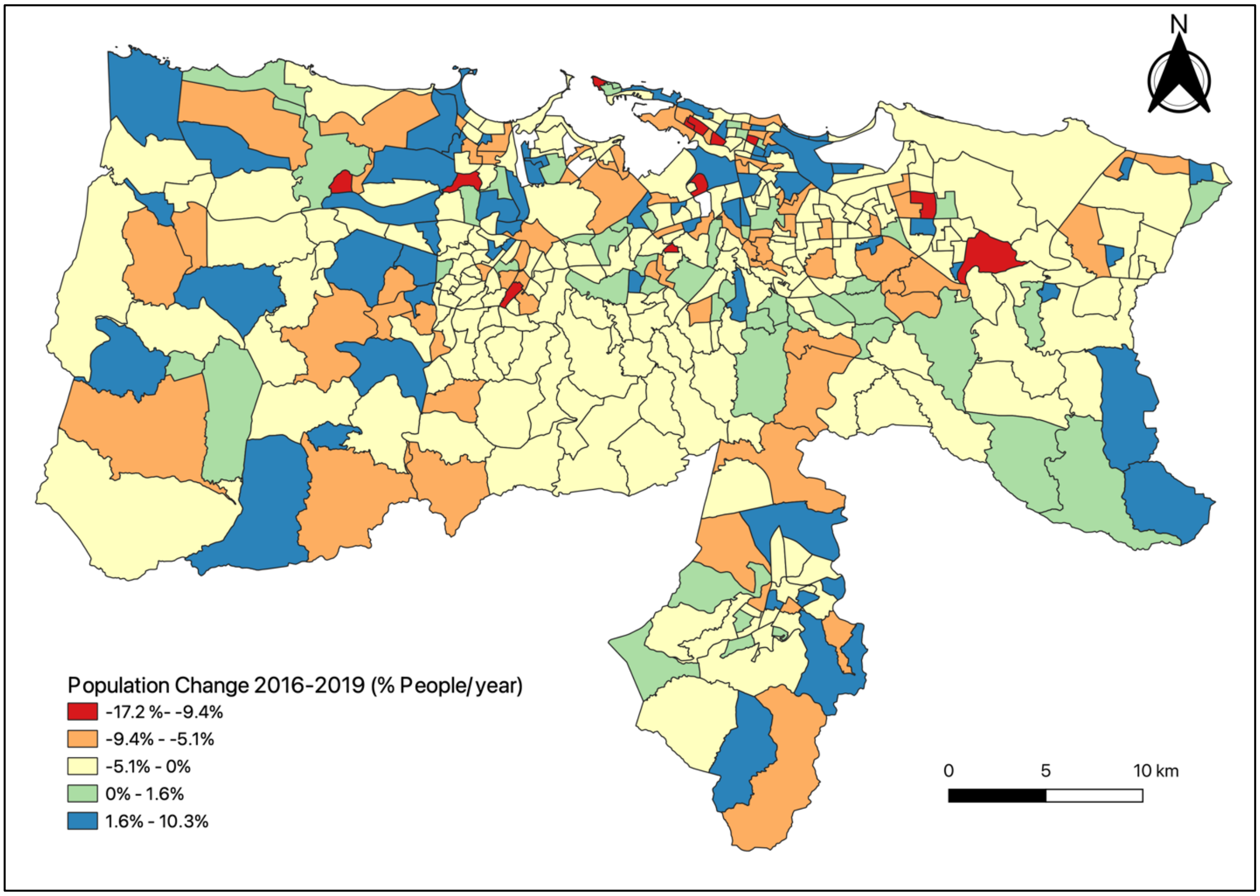
Figure 8: Average vacancy rate in the SJMA, 2016–2019



Source: PRCS

In spite of the fact that the SJMA has been experiencing population loss, not all neighborhoods exhibit this trend (Figure 9). Many of the tracts in the SJMA, particularly many in northern San Juan and in the outskirts of the region, have been shown to be increasing in population between 2016 to 2019. The tracts with the steepest levels of population loss are scattered throughout the SJMA, with no clear pattern in their location.

Figure 9: Average percent population change in the SJMA, 2016–2019



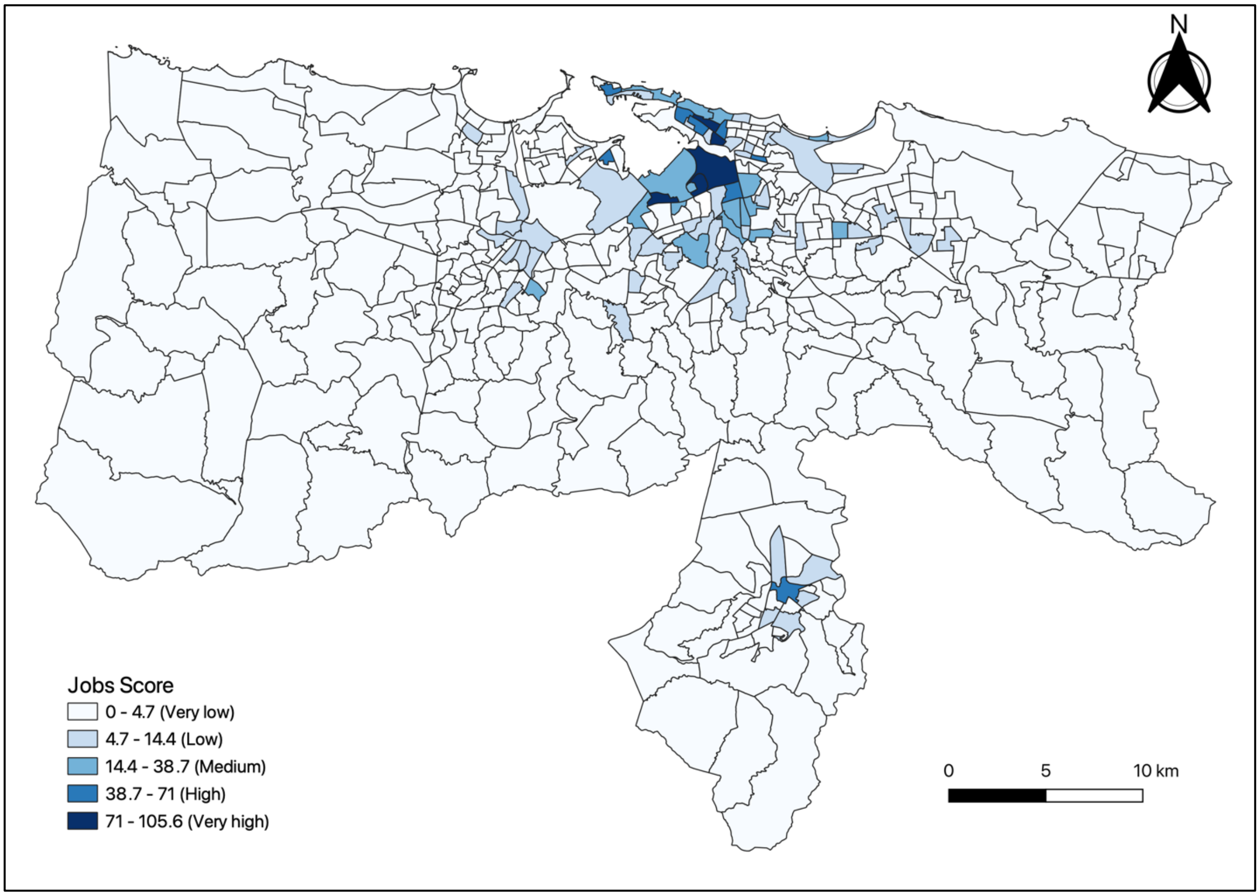
Source: PRCS

Opportunity Analysis

To establish a standardized and unitless measure of neighborhood opportunity, we used the variables of job, school, and crime density and divided them by the median regional value of each one. This yielded a jobs, school, and crime score for each of the tracts in the SJMA. We then added the jobs and school scores and subtracted the crime score to determine the opportunity score of each tract. Once the opportunity scores were estimated, we then conducted a correlation analysis to assess how the opportunity scores relate to each one of the dependent variables used as measures of neighborhood change.

Looking at each one of these components separately shows interesting trends. The spatial distribution of jobs score shows that jobs are mostly concentrated in central San Juan, especially in the Hato Rey and Santurce barrios (Figure 10). The categories displayed in the map were designated using Jenks natural breaks optimization.

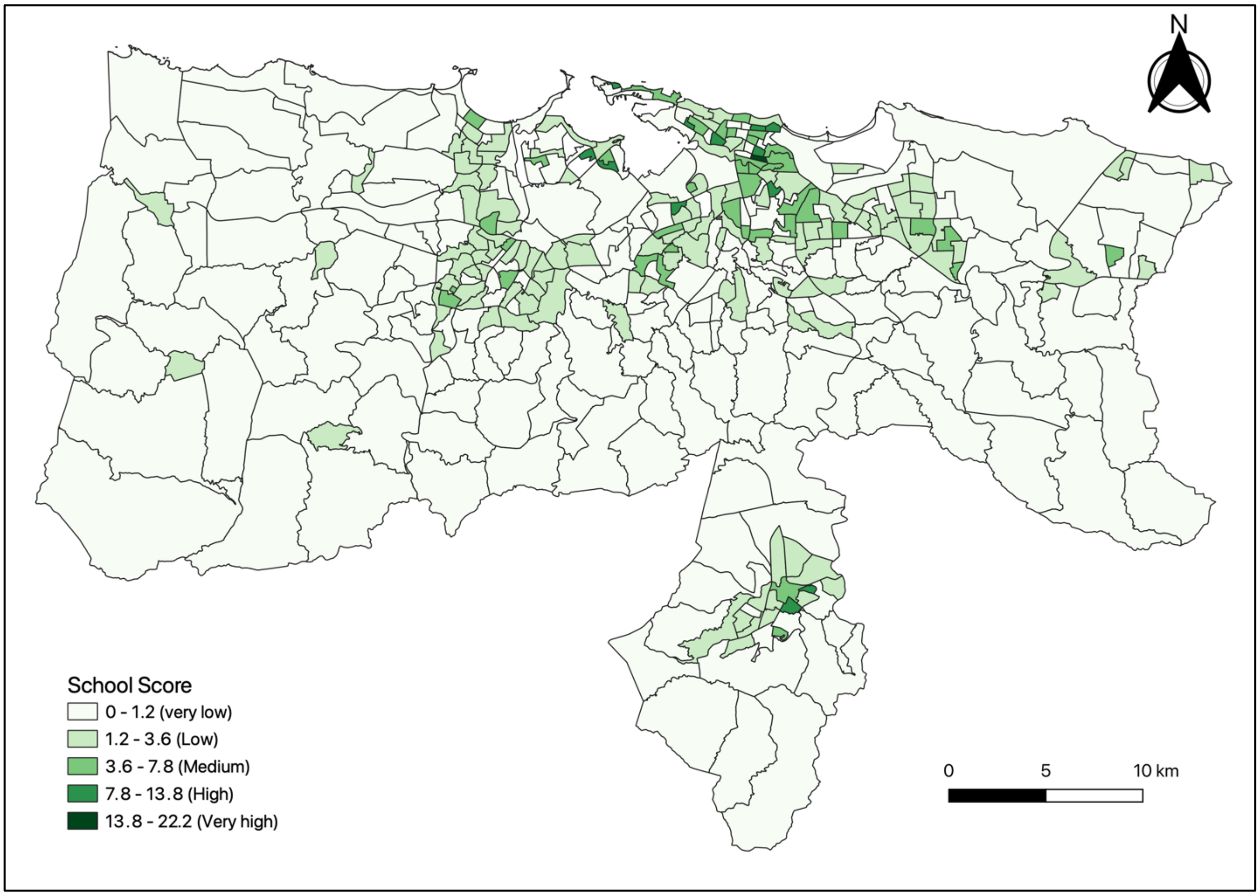
Figure 10: Jobs score in the SJMA



Source: Estudios Técnicos, Inc.

The school scores are less randomly determined than both the jobs score and the crime scores, since public schools were originally built by the government of Puerto Rico to be within reach of the population, regardless of location. Still, the spatial distribution shows that school scores are still highest in central San Juan, Bayamón, Guaynabo, Carolina, and Caguas, reflecting a somewhat similar pattern to the jobs scores (Figure 11). The categories displayed in the map were designated using Jenks natural breaks optimization.

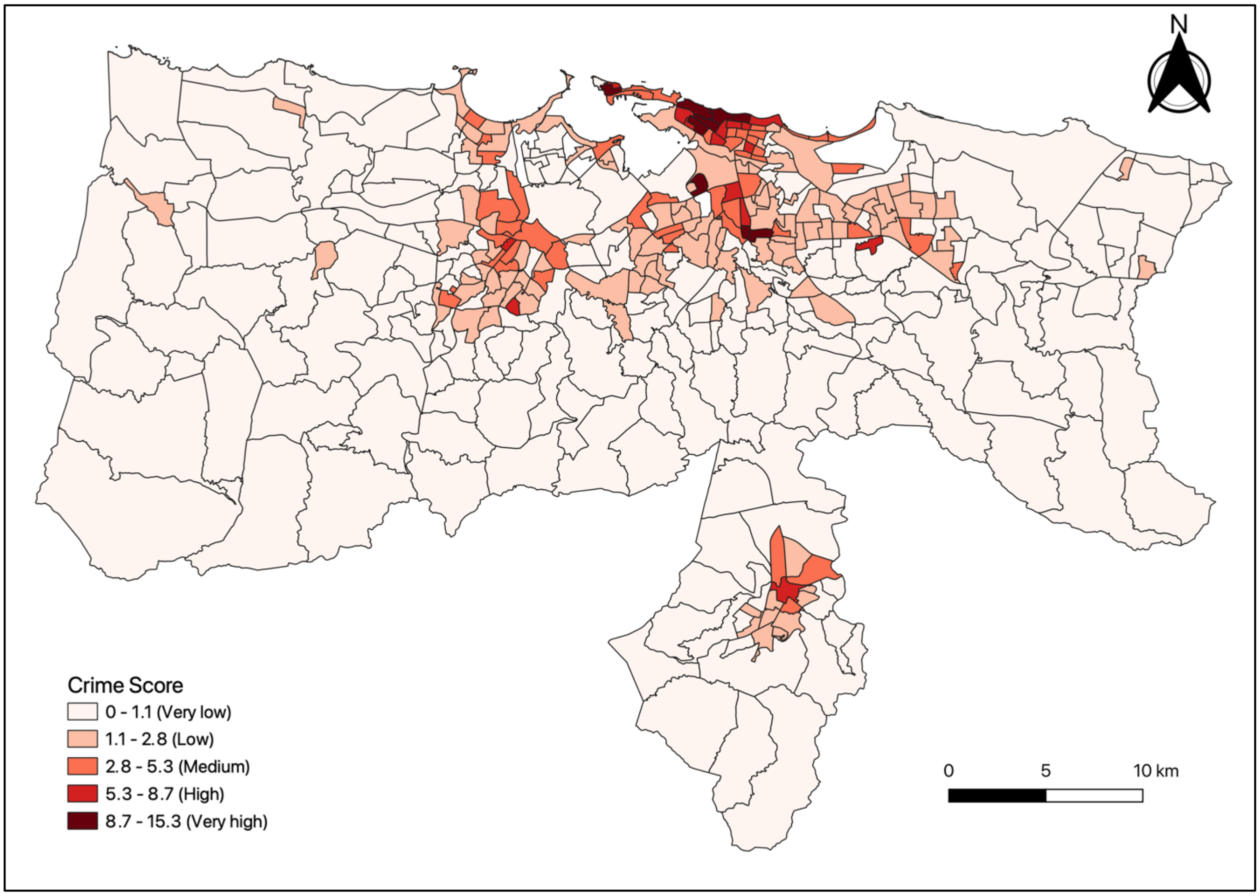
Figure 11: School score in the SJMA



Source: Estudios Técnicos, Inc.

Crime scores also show similar spatial patterns to those of the jobs and school scores (Figure 12), with the some of the largest crime scores recorded in central San Juan, Bayamón, Guaynabo, Carolina, and Caguas. However, the largest crime scores were observed throughout the northern coast of San Juan. The categories displayed in the map were designated using Jenks natural breaks optimization.

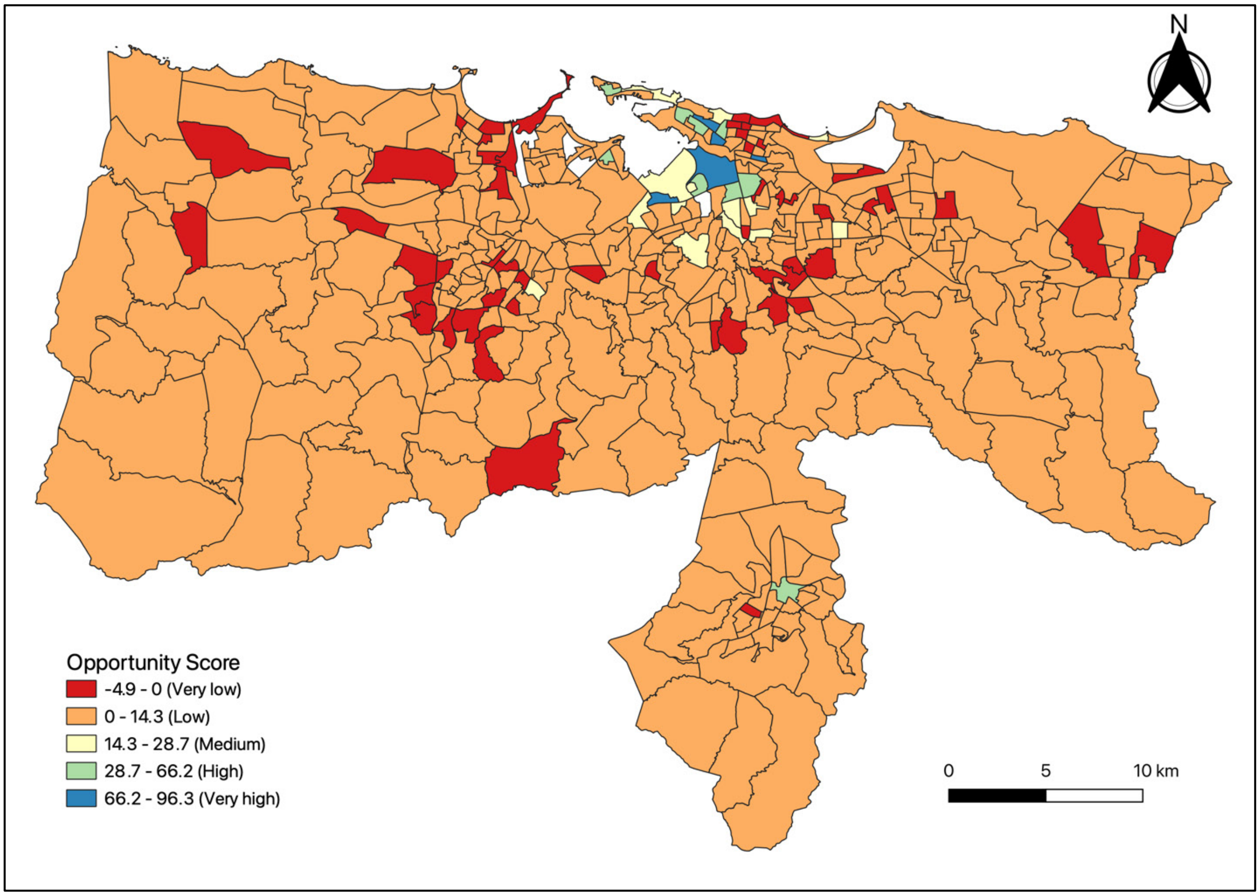
Figure 12: Crime score in the SJMA



Source: Puerto Rico Police Department.

The final opportunity score shows that the SJMA is highly unequal (Figure 13). The vast majority of tracts have either very low or low opportunity scores, while almost all tracts with medium, high, or very high scores are located in central and northern San Juan. The categories displayed in the map were designated using Jenks natural breaks optimization.

Figure 13: Opportunity score in the SJMA



Source: Estudios Técnicos, Inc., Puerto Rico Police Department

Results

Storm Impacts and Neighborhood Change

The regression results (Table 3) show that storm impacts are associated with neighborhood change in a myriad of ways, controlling for local opportunity measures and demographic characteristics. With regards to segregation measures, high-income concentration is negatively associated with average pending need, albeit at the 90 percent confidence interval, where a $1,000 increase relates to a 0.02 percent decrease in high-income concentration. Poverty concentration is negatively associated with percent of damaged homes. The model for dissimilarity yields a positive association with average pending need, which suggests that an increase of the magnitude of damage tends to be related to an increase in the share of low-income households in a given census tract.

Table 3: Regression results. Standard errors clustered at the tract level

	High-income concentration	Poverty concentration	Dissimilarity	Housing sales volume	Log median housing unit price	Log median rent	Vacancy rate	Percent change population
Median age	-1.18E-04	-4.00E-05	7.77E-05	-1.51E-04	-0.005	0.001	0.002	-0.001
	(4.06)***	(3.89)***	(2.78)***	(5.79)***	(2.43)**	(0.65)	(6.57)***	(2.19)**
Job density	1.30E-08	-7.33E-09	-2.03E-08	-9.59E-10	1.84E-06	-1.43E-06	7.33E-07	-1.42E-07
	(0.37)	(0.91)	(0.062)	(0.03)	(0.58)	(0.54)	(1.46)	(0.20)
School density	-1.28E-04	-5.75E-05	7.06E-05	-7.46E-05	-6.25E-04	-0.019	0.0003722	0.003
	(1.86)*	(1.68)*	(0.920	(0.75)	(0.05)	(2.66)***	(0.27)	(1.73)*
Crime density	1.40E-06	-2.80E-06	-4.20E-06	3.53E-06	0.002	1.39E-04	-0.0000232	0.0000415
	(0.27)	(2.58)**	(0.86)	(1.19)	(5.37)***	(0.44)	(0.44)	(0.72)
Average pending need	-1.76E-07	5.53E-08	2.31E-07	-5.19E-07	1.91E-05	-1.29E-05	6.35E-06	-1.16E-06
	(1.83)*	(0.87)	(2.14)**	(3.76)***	(1.98)**	(1.06)	(3.29)***	(0.45)
Percent damaged	4.29E-04	-7.62E-04	-0.001	6.89E-04	-0.067	0.127	0.02	0.003
	(0.58)	(2.24)**	(1.53)	(0.96)	(1.19)	(2.48)**	(1.34)	(0.23)
Post-storm	3.03E-04	0.0001661	-1.37E-04	0.002	-0.019	0.012	0.005	-0.002
	(1.44)	(1.59)	(0.61)	(8.00)***	(0.94)	(0.53)	(1.21)	(0.42)
Poverty rate	-0.012	0.003	0.015	-0.017	-0.683	-1.669	0.081	-0.078
	(8.57)***	(4.96)***	(9.70)***	(14.35)***	(6.96)***	(16.15)***	(4.19)***	(5.14)***
Percent immigrant population	-7.99E-05	-0.004	-0.004	7.53E-04	-0.459	0.989	0.001	-0.035
	(0.04)	(3.14)***	-1.69	(0.33)	(1.56)	(5.54)***	(0.03)	(1.02)
Percent non-white population	-0.005	0.002	0.007	-0.003	-0.461	-0.105	0.055	0.005
	(4.27)***	(2.21)**	(4.77)***	(2.69)***	(3.67)***	(1.09)	(2.43)**	(0.27)
Constant	0.012	0.002	-0.01	0.02	5.007	6.88	-0.07	0.045
	(7.20)***	(4.56)***	(6.08)***	(13.76)***	(53.43)***	(52.54)***	(3.69)***	(1.92)*
Municipal fixed effects	Included	Included	Included	Included	Included	Included	Included	Included
R^2	0.41	0.52	0.55	0.42	0.31	0.61	0.34	0.04
N	1,564	1,564	1,173	1,460	1,457	1,499	1,564	1,173

Note: * p<0.1; ** p<0.05, *** p<0.01. T-statistics in parenthesis

Storm impacts also have varying effects over measures of housing affordability and gentrification. The model for housing sales volume shows that it is negatively associated with average pending need, where a $1,000 increase in this measure results in an 0.04 percent decrease in total sales volume per tract. This result notwithstanding, the model also shows that housing sales volume is positively associated with the post-storm period, which suggests that housing markets have tended to “heat-up” in post-disaster times. On the other hand, the median unit housing price is positively associated with average pending need, which contrasts with the trend found for housing sales volume. Finally, and in a similar fashion, median rent is positively associated with percent of damaged housing units, where a 10 percent increase in damaged housing units is related to a 12.7 percent increase in median rent, suggesting a rent hike driven by a damage-driven supply constraint.

When it comes to measures of neighborhood decline, the results show that storm impacts, in the form of average pending need, is positively associated with Census tract vacancy rates. When examining population change, however, the model shows that it is not significantly associated with any measure of storm impacts, contrary to findings from previous studies. This suggests that structural factors in Puerto Rico likely play a much larger role than storm impacts in determining population change at the tract level. This finding merits further research.

Access to Opportunity and Neighborhood Change

Results from the correlation matrix (Table 4) show that the tract-level opportunity score is negatively and significantly correlated with poverty concentration and the dissimilarity measure, suggesting that access to opportunities tend to favor higher income households.

The matrix also shows, somewhat contradictorily, that the opportunity score is positively correlated with median housing unit prices, but negatively correlated with median rent. Although the former finding is expected, the latter is counterintuitive, although mildly encouraging, since rents in San Juan tend to be lower in high-opportunity places. However, given the increased housing prices in these places, it is likely that rents will increase in the near future.

Lastly, the correlation matrix shows that the opportunity score is positively correlated with vacancy rates. Although this might seem at odds with expectations at first glance, it likely suggests that, given the increased median housing prices in high-opportunity areas, homeowners would keep property units vacant rather than renting them, possibly hoping for larger windfalls from future sales.

Table 4: Correlation matrix for opportunity score and dependent variables

	Opportunity score	High-income concentration	Poverty concentration	Dissimilarity	Housing sales volume	Median housing unit price	Median rent	Vacancy rate	Percent change population
Opportunity score	1.0000								
High-income concentration	0.0175	1							
Poverty concentration	-0.1674*	-0.0582*	1						
Dissimilarity	-0.0755*	-0.9349*	0.4086*	1					
Housing sales volume	-0.0042	0.5230*	-0.2902*	-0.5791*	1				
Median housing unit price	0.2458*	0.3071*	-0.2336*	-0.3619*	0.3739*	1			
Median rent	-0.0522*	0.5139*	-0.3491*	-0.5917*	0.5035*	0.2993*	1		
Vacancy rate	0.1755*	-0.1621*	-0.0098	0.1447*	-0.2677*	-0.0600*	-0.1818*	1	
Percent change population	-0.0103	0.1003*	0.0096	-0.0883*	0.1272*	0.1161*	0.1067*	-0.0975	1

Note: * $p<0.05$

Policy Implications

The findings from this research suggest the following with regards to storm impacts and neighborhood change: (1) storm impacts are associated with increased socioeconomic segregation; (2); storm impacts are also associated with higher real estate activity in certain areas and (3) storm impacts are associated with increased vacancy rates. Post-disaster periods, therefore, are characterized by substantial neighborhood change in the form of increased socioeconomic segregation, increased likelihood for gentrification in some places, and increased neighborhood decline in others. This trend could have implications for legacy cities in post-disaster settings, in spite of the fact that they are experiencing overall decline. Thus, neighborhood-level changes matter for post-disaster reconstruction works.

Considering that local access to opportunities is closely correlated with increased housing prices, increased segregation, and increased vacancy rates, it is important that post-disaster reconstruction planning can discern how to prioritize reconstruction spending. For example, given that living in high-opportunity areas in a post-disaster context becomes increasingly less tenable for low-income households, the government of Puerto Rico should prioritize locating its affordable housing construction projects, financed with CDBG-DR funding, in these areas. At the same time, low-opportunity areas should be given priority for infrastructure improvemenst, community lifelines, hazard mitigation, workforce development, and local business aid spending programs. This would substantially reduce the likelihood of vulnerable communities undergoing increased segregation, gentrification, and displacement during post-disaster reconstruction.

There are important caveats that we should highlight, which limit the generalizability of our research. First, our research does not follow a strict causal design. This is because operationalizing storm impacts as a binary treatment variable would force us to ignore varying levels of damages across neighborhoods, which we believe provide important nuances to inform policy and program designs. Second, the time period of our study is relatively short. Hurricane María is a relatively recent event, but extending our period of study to 2020 or 2021 would make it hard to discern adverse associations between storm impacts and neighborhood change given the COVID-19 pandemic. Lastly, our instruments for measuring opportunity across geographies are still somewhat rudimentary. We expect to continue this research and further refine our variables and define a more sophisticated and robust opportunity score.

These limitations notwithstanding, we believe that the findings in this research can help jumpstart important conversations with local planners and policymakers to improve post-disaster planning, devise useful scenario planning exercises, and inform ongoing reconstruction work in Puerto Rico. We are also confident that this ongoing research can also provide important lessons for legacy cities that are increasingly at risk of suffering the harmful effects of natural disasters due to climate change.

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