AN ANALYSIS OF COMMUNITY RESILIENCE AND RESPONSE CAPACITY TO SYSTEMIC AIR QUALITY THREATS IN THE SOUTH BRONX

Final Report

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Project Abstract

The South Bronx continues to be disproportionately affected by poor air quality as a result of a long history of exclusionary planning practices, putting an already vulnerable population at heightened risk of health complications. Using the South Bronx as a case study, this research operates under the assumption that efforts to mitigate the impacts of environmental hazards in vulnerable communities need to be understood in tandem with inherited injustices affecting resilience. It seeks to address the central question: *how to characterize the effects of social vulnerability on resilience-exposure dynamics in the South Bronx?* Our investigation is rooted in understanding the spatial relationships between demographics, infrastructure, health data, and environmental challenges, with the aim to quantify community vulnerability and develop an index for risk assessment.

Introduction

The South Bronx neighborhood in New York City is known for its history of persistent air quality problems, particularly in the Mott Haven area nicknamed "Asthma Alley."[1] The region's environmental challenges have their origins in the fact that the South Bronx, a historic area of New York City, is facing a series of environmental challenges caused by industrialization and urban planning decisions. In particular, the construction of the Cross Bronx Expressway in the mid-20th century, which not only degraded air quality, but also created ongoing social and environmental problems for low-income neighborhoods, and the impacts of these decisions continue to be felt today.[2]

The neighborhood not only suffers significant air pollution due to historical industrial legacies and socioeconomic exclusion, but also faces extreme weather events exacerbated by climate change. This complex set of challenges, coupled with a lack of neighborhood green space, puts the resilience of South Bronx residents to adversity to the test.

Our research focuses on the central question: *how resilient and capable of coping are South Bronx neighborhoods in the face of severe air quality problems and increased climate risks?* We use a diverse methodological framework of spatial analysis, factor analysis, and risk modeling

[1] "'Asthma Alley': Why Minorities Bear Burden of Pollution Inequity Caused by White People." *The Guardian*, Guardian News and Media, 4 Apr. 2019:

[2] Caro, Robert A. 1974. The Power Broker: Robert Moses and the Fall of New York. First edition. New York: Knopf.

assessment to identify community vulnerability and resilience, as well as risks and impacts in the face of unexpected events.

The purpose of this study is to provide urban planners with an integrated perspective to better understand and address environmental justice issues facing the South Bronx. Our findings will guide the community's future sustainability and environmental policies to help the most vulnerable and promote the well-being and resilience of the community as a whole. The hope of this study is that planners will multiply the impacts of different environmental challenges on the community and broaden the knowledge of the people in the community about such issues, and that planning in the context of real-world problems will help the community better respond to possible challenges.

Literature Review

In order to grapple the issues at stake, we turn to the dense body of literature that has contributed to this research's understanding of resilience, vulnerability, and exposure to air pollution. Of particular interest are the differential standpoints and methodologies adopted by the scientific community on one hand, and the planning community on the other. In the early days of climate change research, scientific literature focused on devising modeling strategies to predict changes and outcomes based on natural phenomena while planning literature discussed mitigation strategies using knowledge derived from scientific findings but with little emphasis on reducing pollutants directly. Nonetheless, we have found that in recent years, this gap is closing and research is becoming more integrated in order to account for the multidimensionality of the phenomena at hand.

The first breakthrough in research dealing with assessing air pollution risks came with studies that established correlations between exposure-risk and preexisting social vulnerability. Often undertaken at the national level, those studies examine socio-spatial disparities in the distribution of adverse effects from air pollution. In the context of our study, those were critical in grounding theories of environmental inequity.

> The study *Disparities in Distribution of Particulate Matter Emission Sources by Race and Poverty Status* (Mikati et al., 2018) does a great job at linking disparities to

socio-economic characteristics, emphasizing the unequal burden put on already vulnerable communities suffering from pre-existing compounding health risks. The study identifies PM emitting facilities to quantify the projected burden on different communities. It found that the population living in poverty had a burden 1.35 times higher than the overall population, with the black population specifically reaching a rate of 1.54. Although the methodology only focuses on static sources of emission, it highlights the power dynamics at play behind the inequitable distribution of polluting sites, therefore probing further investigation into other sources of exposure.

Using a similar approach to spatial differentiation, the research of Tessum et al. entitled *Inequity in Consumption of Goods and Services Adds to Racial–Ethnic Disparities in Air Pollution Exposure* reveals that the pollution burden can always be explained by looking at patterns of consumption. The study establishes that exposure to particulate matter (PM) is driven by the consumption of goods and services by a majority white population and disproportionately affects minorities. The approach is very compelling as it attributes sources of emissions to end-users, allowing them to quantify disparities in a meaningful manner.

Using the newfound correlation between vulnerability and aggravated impacts of air pollution, researchers strove to quantify this risk in order to advocate for targeted and prioritized policies. These studies, while attempting to develop preliminary indicators, emphasized on establishing precedents and frameworks for future action plans.

A 2011 study led by Wright & Diab[3] identified the need to develop a risk prioritization framework for policy makers in the eThekwini Municipality located in Durban, South Africa. The study identified five main themes that were to be considered concurrently in order to determine which neighborhoods had more urgent needs for action, including: air pollution sources; air pollution levels; air pollution potential; community awareness; and other vulnerability factors. By giving a score to each ward derived from the five themes, it created a priority list for the proper allocation of resources based on needs. Although this research did not attempt to operationalize the themes and indicators identified beyond

[3] Wright, Caradee Y., and Roseanne Diab. "Air Pollution and Vulnerability: Solving the Puzzle of Prioritization." Journal of Environmental Health 73, no. 6 (February 2011): 56–64.

a simple weighting of importance, it opened the realm of possibilities for further modeling work. Most importantly, it sketched an integrated approach to risk management that relied on multiple sources including scientific and socio-economic data for the development of comprehensive public policies.

Other attempts at quantifying risk for policy-making include a 2020 study by Shearston et al.[4] which examined the impacts of a new warehouse facility in Mott Haven, Bronx, on traffic emissions. Similarly to Wright & Diab, the research is intentionally aimed at quantifying projected increases in traffic in order to inform policy-making. At its core, the study relies on previous literature of exposure vulnerability to argue for the burden caused by traffic-intensive facilities in vulnerable neighborhoods. Over the span of 6 months, the research team employed a method of traffic counts in order to estimate changes in pollutants and found a significant increase in traffic flows following the opening of the facility, up to 40% during the overnight window. This study was one of the first of its kind and continues to be quoted by advocacy groups when protesting the introduction of more facilities into the neighborhood.

In this session, Scholars have turned more to a variety of approaches and insights developed based on the purpose of exploring the critical role of modeling in quantifying vulnerability to environmental hazards, especially those associated with air quality, urban heat, and pollution.

Quantifying the Health Impacts of Air Pollution under a Changing Climate (Sujaritpong et al., 2014) emphasizes the importance of quantifying the health impacts of air pollution under a changing climate to provide evidence for actions to protect future populations. Rather than adopting a simplified approach, as most studies do, the article assesses sources of uncertainty in the health impact estimates by conducting sensitivity analyses that include other factors such as population size, age structure, and assumptions about health burden rates in addition to those involving the integration of climate projections, air quality models, and health impact functions to estimate the health impacts of air pollution under a changing climate in order to estimate the overall health Impacts. A

[4] Shearston, Jenni A., A. Mychal Johnson, Arce Domingo-Relloso, Marianthi-Anna Kioumourtzoglou, Diana Hernández, James Ross, Steven N. Chillrud, and Markus Hilpert. "Opening a Large Delivery Service Warehouse in the South Bronx: Impacts on Traffic, Air Pollution, and Noise." International Journal of Environmental Research and Public Health 17, no. 9 (May 2020): 3208. https://doi.org/10.3390/ijerph17093208.

comprehensive overview of methods for assessing health impacts under changing climate conditions is presented, emphasizing the need for adaptive strategies in vulnerability modeling.

A Social Vulnerability Index for Disaster Management (Flanagan et al., 2011) proposes that social vulnerability is defined as the socio-economic and demographic factors that affect the resilience of a community during a disaster, gives the conclusion that socially vulnerable populations are more likely to be adversely affected by disasters, and develops an SVI by using 15 census variables at the tract level to help identify the most vulnerable locations for effective disaster management. adverse effects and less likely to recover, and the SVI, developed by using 15 census variables at the tract level, helps to identify the locations of the most vulnerable populations for effective disaster management.

Urban Heat and Air Pollution: A Framework for Integrating Population Vulnerability and Indoor Exposure (O'Lenick et al., 2019) explores the role of vulnerability science in the links between epidemiological risk conceptualization, presenting a conceptual and analytical framework that emphasizes the social construction of risk[1]. The importance of considering the indoor environment in health risk analysis and highlights research gaps in this area. The approach involves the integration of different data types, including household survey data, environmental data, demographic data, health data, and building characterization data, and the study recognizes the need to disaggregate vulnerability into components in order to address root causes, with more emphasis on exposure-health relationships, highlighting the importance of vulnerability modeling in urban environments.

A Method for Measuring Coupled Individual and Social Vulnerability to Environmental Hazards (Tuccillo & Spielman, 2022) innovatively provides a more specific and repeatable methodology for quantitative analysis. The authors propose a method that combines individual vulnerability profiles (IVPs) with community social vulnerability profiles (SVPs) to provide a more holistic understanding of vulnerability.

Similarly, *Social Vulnerability to Environmental Hazards* (Cutter et al., 2003) used factor analysis to identify 11 independent factors contributing to social vulnerability, constructed a Social Vulnerability Index (SoVI), and explored the concept of social vulnerability and its implications for understanding the impact of environmental hazards.

Having identified climate risk and social vulnerability, the various mitigation strategies used to address the impacts of environmental risks are of particular importance, especially those associated with air quality, urban heat, and pollution. The articles selected for review in this section therefore focus on providing insights into the different mitigation approaches proposed for different pollution sources and their effectiveness in mitigating the risks associated with air quality and urban environmental challenges.

Traffic-Related Air Pollution and Exposure Assessment (Beevers & Williams, 2020) emphasizes that pollutants such as PM2.5, ozone, carbon monoxide, nitrogen dioxide, and particulate matter quantities have strong evidence of human health impacts as well as significant contributions from transportation sources .. Focusing on the consideration of outdoor and indoor air pollution source scenarios, it is proposed that road transportation is a significant source of air pollution. Possible mitigation strategies therefore lean more towards the clichéd promotion of sustainable transport: encouraging the use of public transport, walking and cycling can reduce the number of vehicles on the road and therefore reduce emissions.

The Roles of Residential Greenness in the Association between Air Pollution and Health (Son et al., 2021) found evidence of a synergistic effect between greenness and air pollution on mortality, and the studies reviewed suggest that greenness can change the association between air pollution and health outcomes. Mitigation strategies considered in light of these findings may include increasing green space and vegetation in urban areas, promoting urban greening initiatives, and implementing policies to reduce air pollution.

Unlike the focus on sources of air pollution and offsetting measures, *Preventing heat-related morbidity and mortality: New approaches in a changing climate* (O'Neill, M.S. et al. 2009) focuses on the human health impacts of heat exposure due to the urban heat island effect caused by differences in air quality, and proposes a number of preventive measures, including the establishment of a heat wave warning system, the provision of cooler environments, public education, the planting of trees and the retrofitting of the built environment.

The literature discussed above underlines key issues that our team has used to develop its research goals and intentions. Of particular interest were the cumulative effects of exposure risk, community vulnerability and resiliency capacity in understanding responses to air quality threats. Our research therefore operates under several assumptions derived from this academic material, namely that the burden of air pollution is carried by the most vulnerable[5] and that proximity to polluting sources increases overall vulnerability[6]. Those socio-spatial considerations led us to believe that spatial and factor analysis would be relevant in understanding the phenomenon of systemic air quality threats. Additionally, air pollution being only one of the many components contributing to environmental injustices in the neighborhood, we thrive to incorporate diverse criteria and multivariate indexes in our risk modeling strategy in order to devise holistic policies and recommendations.

Research Methodology

In constructing a risk model for the South Bronx community against systemic air quality threats, this study anticipates a comprehensive analysis using diverse data sources. Census data provides detailed information on the socioeconomic and demographic characteristics of residents, such as age, gender, race, and education. In addition, data on the health status of community residents, particularly asthma prevalence, serves as a key indicator for assessing community vulnerability and constructing the underlying risk model.

This study also incorporates the impact of green spaces and an air pollution index to rate their impact on community resilience and environmental quality. The distribution of public facilities in the community, such as the location of green space resources such as parks, is used to analyze the contribution to air quality and its potential improvement. The pooling of these data helps

[5] Mikati, Ihab, Adam F. Benson, Thomas J. Luben, Jason D. Sacks, and Jennifer Richmond-Bryant. 2018. "Disparities in Distribution of Particulate Matter Emission Sources by Race and Poverty Status." American Journal of Public Health 108 (4): 480–85.

[6] Shearston, Jenni A., A. Mychal Johnson, Arce Domingo-Relloso, Marianthi-Anna Kioumourtzoglou, Diana Hernández, James Ross, Steven N. Chillrud, and Markus Hilpert. 2020. "Opening a Large Delivery Service Warehouse in the South Bronx: Impacts on Traffic, Air Pollution, and Noise." International Journal of Environmental Research and Public Health 17 (9): 3208.

construct an exhaustive map of spatial relationships to reveal the correlations between various types of data.

After synthesizing these data, a base model will be developed to quantify the state of the community environment, and based on this, the Community Resilience Index and Social Vulnerability Index will be further considered. The ultimate goal is to quantify the community's coping and adaptive capacity in the face of environmental risks through the integrated assessment of these two indices.

In order to test the findings of the model and to come up with holistic recommendations, we developed a set of questions to be sent out to various critical stakeholders, institutions and community-based organizations active in our study area whose work intersects with our inquiry. We developed a set of questions both open-ended (Appendix 1) and standardized (Appendix 2) centered on key issues such as community residents, narratives of resistance, and policy-making.

Altogether this mixed research process led to the development of a set of planning and policy strategies for South Bronx communities that both reflect their unique challenges and have the capacity to cope, based on data support and qualitative cross-referencing.

Data collection

Data Types and Sources

The quantitative analysis for this study is based on a variety of public domain data to ensure transparency and replicability of the analysis.

- Air Pollution Data: from the Department of Health and Mental Hygiene (DOHMH), which provides detailed information on air quality in the South Bronx.
- Public Use Microdata: derived from the American Community Survey (ACS) Public Use Microdata Sample (PUMS), which provides fine-grained demographic characteristics of the community.
- Socioeconomic Data: derived from the Department of City Planning (DCP), contains economic indicators that impact community resilience and vulnerability.

- Green Space Impact Index: provided by the Department of City Planning's (DCP) MapPLUTO database, reflecting the potential impact of green space on the environmental quality of the community.
- Asthma Index: data provided by the Division of Population Health, National Center for Chronic Disease Prevention and Health Promotion (NCCDPHP), indicating the distribution of asthma in the community.
- Community Resilience Data: Data from the Federal Emergency Management Agency's (FEMA) National Integration Center (NIC) Technical Assistance Division, providing an assessment of a community's ability to cope with environmental risks.
- Social Vulnerability Index: From the Hazard Vulnerability and Resilience Institute (HVRI), provides quantitative indicators of a community's sensitivity and ability to cope in the face of disaster.
- Disaster Risk Index: Data derived from the National Risk Index resource provided by the official website of the Department of Homeland Security (DHS), demonstrating the level of risk of different regions to natural hazards.
- Air Quality Complaint Data: Derived from the NYC 311 Services website, which provides reports and feedback from community members on air quality issues.

The integration of the above data will be used to construct a risk model that assesses the resilience and vulnerability of South Bronx communities to systemic air quality threats. Through the analysis of these publicly available data, this study aims to provide data support and policy recommendations for the future sustainability of the community.

Methods

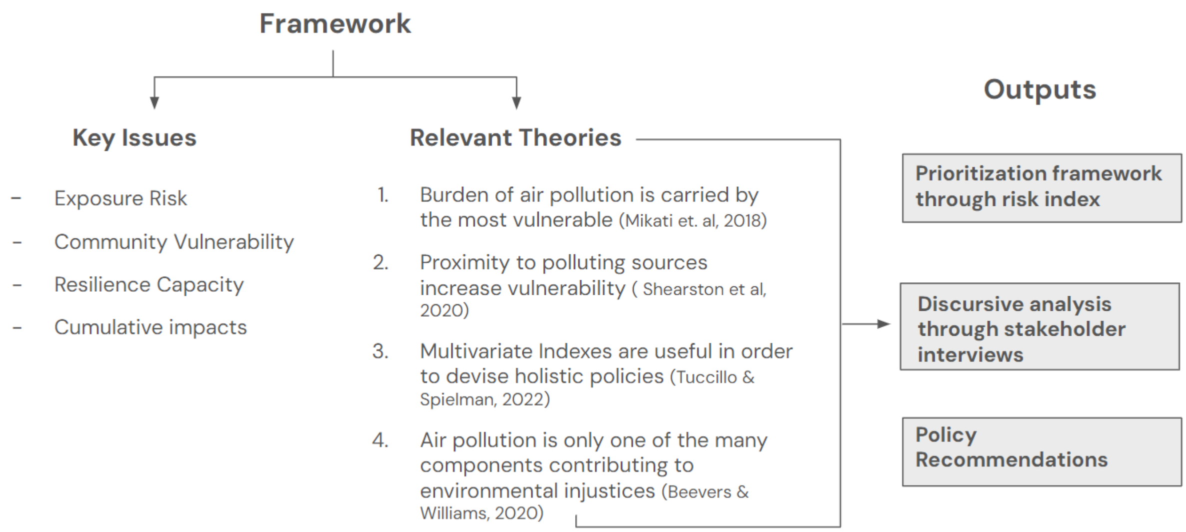


Figure 1. Overall Methodological Framework

Description

The purpose of this study is to explore how social vulnerability affects the resilience and exposure risk dynamics of South Bronx communities in the face of air quality threats. To do so, we constructed a conceptual framework that encompasses multiple dimensions of the physical and social environment, community resilience, and social vulnerability, and connects these dimensions to the natural and anthropogenic risk factors that communities face. The type of quantitative data we collected covers key elements such as air pollution, socio-economic indicators, green space effects, and asthma prevalence. These data were sourced from publicly available web-based databases, ensuring transparency and data reliability of the study. To accommodate the specific scope of the study area, all data were cropped and reconstructed to ensure accurate application in computational modeling.

The study employs a variety of methods such as spatial analysis, factor analysis, and risk modeling to comprehensively assess and analyze the data. Spatial analysis will reveal geographic variability within the community, factor analysis will help identify potential factors affecting community resilience and vulnerability, and risk modeling will assess the impact of these factors on the community's overall risk tolerance.

Our study is based on several relevant theories, including the burden of air pollution, the increase in vulnerability due to proximity of pollution sources, the role of multivariate indices in the development of comprehensive policies, and air pollution as one of the many factors contributing to environmental injustice. These theories support our research hypotheses and guide the direction of our analysis.

Ultimately, this study will output a prioritization framework based on risk indices, discourse analysis through stakeholder interviews, and policy recommendations. These outputs will provide a quantitative assessment of the South Bronx community's ability to respond to air quality threats and guide future planning and decision making.This methodological description of the study ensures that the research is systematic and scientifically sound, enabling us to provide evidence-based strategies and solutions to environmental challenges unique to the South Bronx community.

In this study, we adopt a multidimensional, interdisciplinary methodology to analyze the impact of social vulnerability on the resilience-exposure dynamics of South Bronx communities in the face of systemic air quality threats. The soundness of this methodology is demonstrated as it integrates a wide range of data on the community's physical environment, socioeconomic conditions, health indicators, and environmental quality to ensure a comprehensive understanding of the community's condition. Through the application of spatial analysis, we were able to reveal geographic differences within the community and their potential impact on the health of residents and the overall resilience of the community. Meanwhile, factor analysis helped us identify key factors that influence community resilience and vulnerability and assess the interactions and compounding effects of these factors, which are critical to understanding and problem solving.

In addition, by constructing a risk model that combines social vulnerability and community resilience indices, we were able to assess the overall level of risk faced by the community, which provided a quantitative assessment and clear areas of prioritization for risk management. The theoretical framework of this study builds on existing theories of environmental justice and community resilience, ensuring the scientific validity of the analysis while providing a solid theoretical foundation for our empirical analysis. Ultimately, our goal is to generate practical findings, including a risk prioritization framework and policy recommendations, that are designed to provide practical tools and strategies to address the challenges facing communities, thus demonstrating the practical application of the research methodology.

Limitations

While we did our best to minimize biases in our methodology, we want to acknowledge certain potential limitations pertaining to our research. For one, we faced difficulties in obtaining substantial qualitative data and have developed a model that heavily relies on quantitative sources. Shall this research be taken further, it would be appropriate to develop a stronger qualitative framework against which to test our resilience and risk models. This lack of qualitative data partly stems from non-responses during our interview phase. We reached out to a total of 11 stakeholders and were met with 2 positive responses, including 1 who did not follow up with responding to our interview questions. We did our best to accommodate this gap in data but do recognize the limitations this presents.

In addition, spatial analysis, while revealing geographic differences, may not adequately capture micro-variations within a community or the everyday practices of community members. And factor analyses, in attempting to quantify the complex factors that influence community resilience and vulnerability, may not fully capture the dynamic relationships between these factors. Potential margins of errors exist within our computation model, and compounding factors that may not have been accounted for can still remain.

Despite these limitations, this study provides insights and potential solution strategies to the environmental challenges facing South Bronx communities through an integrated and innovative methodology. Future research should synthesize these limitations to deepen the understanding of the problem through improved methodology, data quality, and the use of multimethod fusion, and to provide more scenic and practical guidance for sustainable development in the community.

Risk Assessment Model

The South Bronx has a complex historic environmental context, where industrial heritage, urban planning decisions and socio-economic factors combine to pose ongoing challenges to public health and community resilience, particularly in the area known as Asthma Alley. The complexity of these factors requires a multidimensional computational approach to fully interpret the challenges that the community may be experiencing or may be susceptible to, as well as to capture the nuances of environmental justice issues through a holistic approach to analyzing factors such as the social and physical environments.

We therefore propose an integrated modeling approach as shown in Figure 2. Initial social-environmental conditions are first obtained by integrating such social health factors as Public Use Microdata, Social Economic situations, and Asthma Rates, which are most closely linked to air quality propositions, and initial physical-environmental conditions are obtained by integrating the Air pollution index and green space environmental impact factors. Physical environmental conditions are obtained by integrating Air pollution index and green space environmental impact factors. At the same time, through a unified numerical standardization matrix, these influencing factors that constitute the physical and social environment are quantitatively scaled from 0 to 10, and finally, through the calculation of the sum, quantitatively aggregated to obtain the basic "Base Model", which interprets the intrinsic value of these factors on a scale of 0 to 50. This scaling indicates how "good" or "bad" the base conditions are, with smaller values indicating higher vulnerability of the base environment itself, and higher values indicating higher stability.

However, the Base Model only represents the objective base conditions of the physical and social environments and cannot be directly interpreted as the resilience of the community, while the FEMA Community Resilience Challenges Index (FEMA CRCI) is limited to population, health care, economic capacity of residents, and the relationship between residents and the community. The FEMA Community Resilience Challenges Index (FEMA CRCI) is limited to the percentage of community resilience obtained from the four dimensions of population, health care coverage, resident affordability, and resident connection to the community, which is not a sufficiently broad category of data to represent the true resilience of South Bronx for this study. Therefore, this study utilized the FEMA CRCI to obtain the Community Resilience Index and multiplied it by the Base Model to obtain an Adjusted Capacity Model with our corrections. This model index expresses the Carrying capacity of communities to cope with disruption, and community resilience is positively correlated with the value.

Next, we constructed a Risk Model, as opposed to a Resilience Model, to calculate the potential disaster impacts on the South Bronx. Since natural disasters not only cause high energy damage, they also have an impact on environmental quality, including air quality. The impacts are not equally distributed among different stakeholders when facing the same disaster. Therefore, to account for the nuances of climate justice and to compare it to community resilience, we re-assigned the Hazard data on a quantitative scale of 0-50 and multiplied it by the CDC/ATSDR Social Vulnerability Index to obtain a Risk Model, where the higher the value, the higher the risk. the higher the risk, the higher the risk.

Finally, community resilience was solved by two adjusted models: dividing the Adjusted Capacity Model and the Risk Index to obtain the Risk Coverage Model, which is a ratio model reflecting South Bronx's ability to cope with potential risks when responding to air quality issues, with the larger the ratio, the greater the ability to cope. The larger the ratio, the better the response.

These models are designed to dynamically assess how the community responds to changing conditions, and represent an innovative aspect of our methodological framework, integrating spatial analysis, factor analysis, and risk modeling to provide a comprehensive assessment.

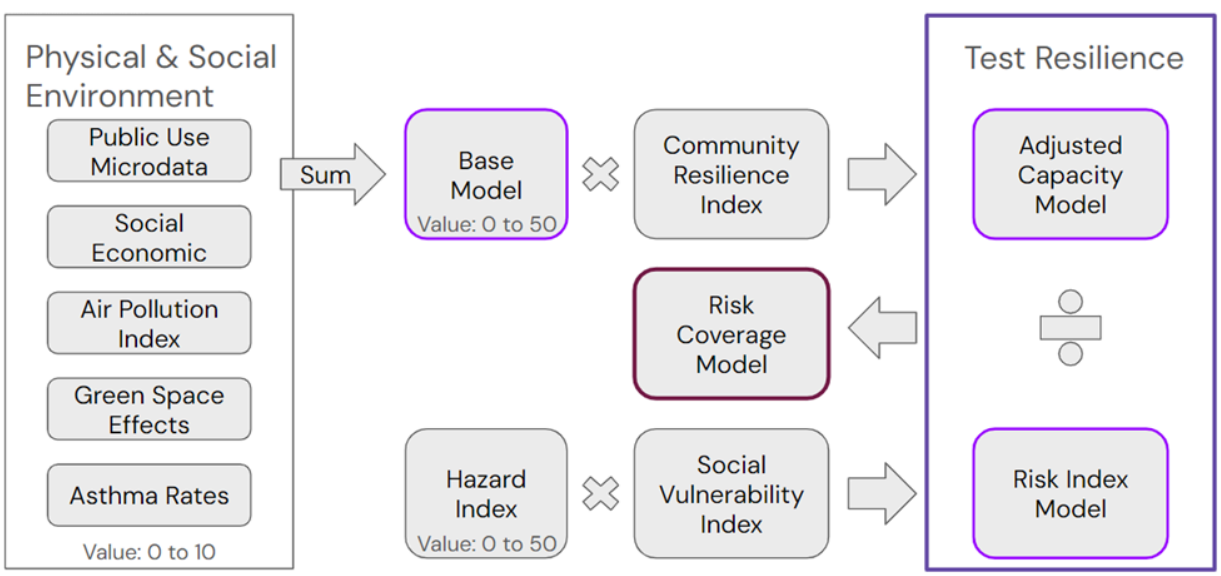


Figure 2. Conceptual Framework for Risk Model

Numerical Standardization

In conducting the environmental risk assessment, this study adopts a comprehensive numerical matrix model that meticulously quantifies the different levels of environmental safety and risk. The model is built on two key measures: the current value of pollutant concentration and the rate of change of pollutant concentration. By jointly considering these two measures, the model is able to reveal not only the current state of the environment, but also to capture trending risks that evolve over time.

The model initially applies the Mann-Kendall trend analysis and statistical analysis methods to determine the initial safety level for each pollutant, based on the available pollutant concentration data. Then, the model adjusts the risk level for each pollutant by evaluating the annual average trends of pollutant concentrations over the past decade, whether they are rising or falling. This adjustment reflects the reality that even if the current pollutant concentration is within the safe range, if it is increasing rapidly, it may indicate a rising risk in the future; conversely, if the current pollutant concentration exceeds the safety threshold but is decreasing rapidly, it may suggest that environmental conditions are improving.

Ultimately, we obtain a numerical risk assessment framework that provides a quantitative description of different aspects of environmental conditions. This model provides a more dynamic and comprehensive view of environmental risk assessment by taking into account the current status of the pollutant concentration as well as its increasing and decreasing trends over time. This quantitative approach helps to capture risk trends that may be overlooked by single point-in-time measurements and emphasizes the need for a dynamic and adaptive methodology for environmental planning to ensure that planning decisions can effectively anticipate and respond to future environmental changes.

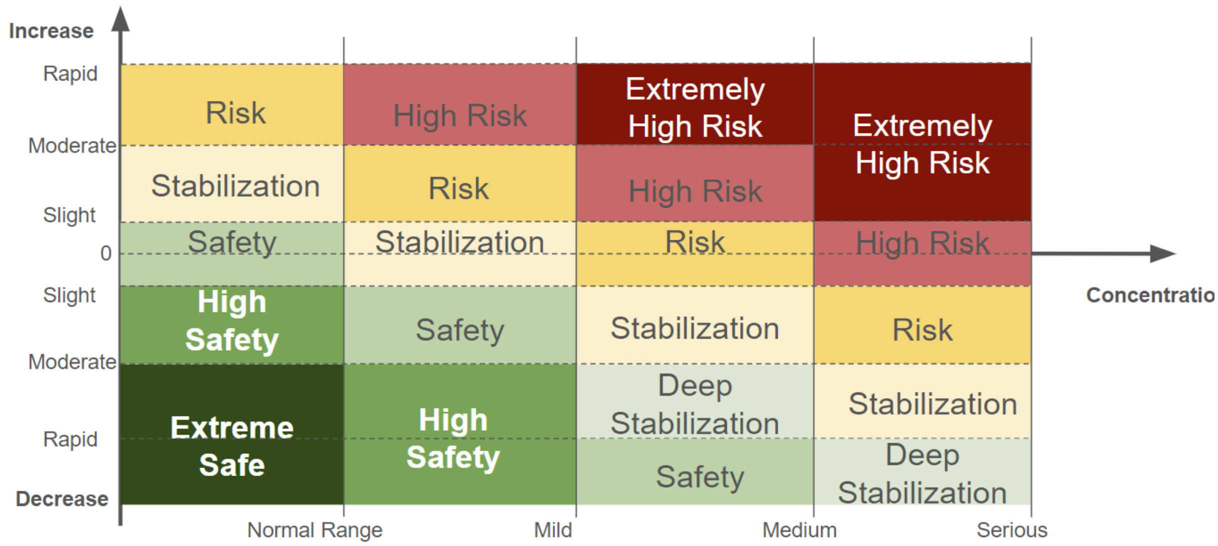


Figure 3. Base Model Indexes Standardized Matrix

<u>Model Analysis</u>

The Base Model (figure 4) of the South Bronx demonstrates the spatial representation of community resilience and vulnerability in the context of physical and social factors. Green indicates higher values and red indicates lower values, summarizing the multifaceted nature of environmental stability.

Areas with a predominantly green and blue color scheme are often highly coupled with a relative abundance of green space and educational facilities, factors that contribute positively to public health conditions and are critical to the resilience of communities. In contrast, the red and orange colors indicate areas that are close to industrial sites, warehousing and logistics sites, and major roads, where natural conditions are mostly exposed to the harmful effects of pollutants and heavy traffic. These conditions often exacerbate health risks, as the history of the "Asthma valley" warns.

The spatial pattern of stability and vulnerability is generally clear, with the more stable areas characterized by the presence of green spaces and schools, and the vulnerable areas characterized by industrial warehousing and traffic-related pollution. This spatial interpretation can assist decision makers to be able to target interventions more effectively to promote climate justice.

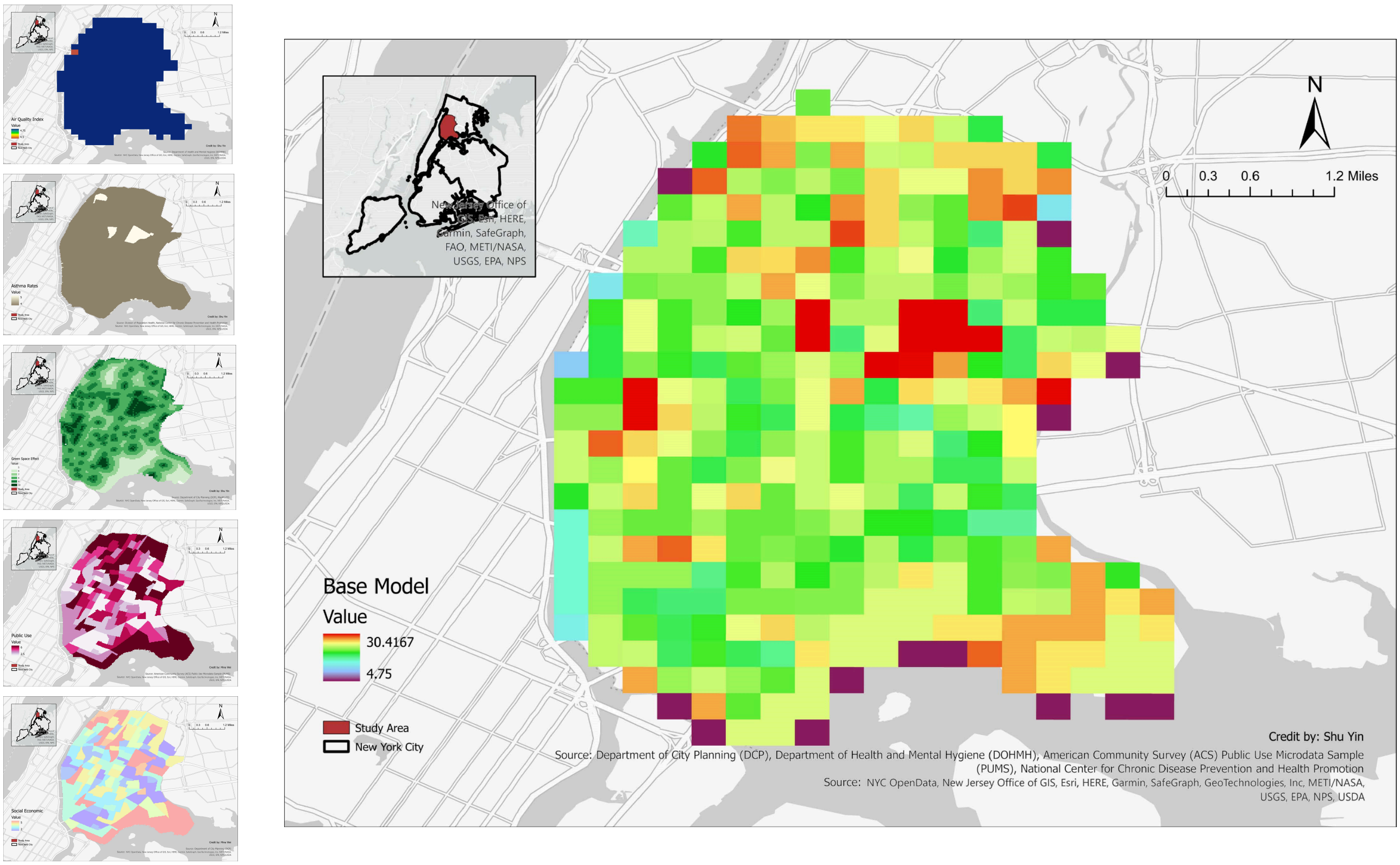


Figure 4. Base Model Indexes

In the assessment of a community's capacity to withstand disruptions, the model's outputs indicate a clear socioeconomic divide. Areas with higher economic status, as inferred from the affordability-oriented maps, exhibit a greater resilience to environmental and social disruptions, reflecting a more robust capacity to absorb and recover from adverse events. Conversely, regions characterized by industrial activities and categorized as environmental justice ghettos display lower resilience, suggesting a reduced ability to cope with and adapt to disruptions. This disparity underscores the critical role that economic factors play in shaping a community's resilience and highlights the importance of addressing socio-economic inequities in urban planning and environmental justice efforts. (Figure 5)

The differences revealed by the Adjusted Capacity Model emphasize the intertwined nature of socioeconomic status and environmental resilience. In order to build a more resilient urban fabric, its roots are more closely aligned with addressing underlying economic inequalities, thereby reducing the potential for greater risk to certain marginalized and disadvantaged communities.

Consequently, in order to achieve climate justice, traditional approaches that focus solely on environmental factors can hardly make a significant contribution, and comprehensive economic and social strategies that level the playing field cannot be ignored. Resilience is not only a product of environmental design, but urban planning decision makers need to empower the social and economic frameworks within which urban communities are organized in the planning process.

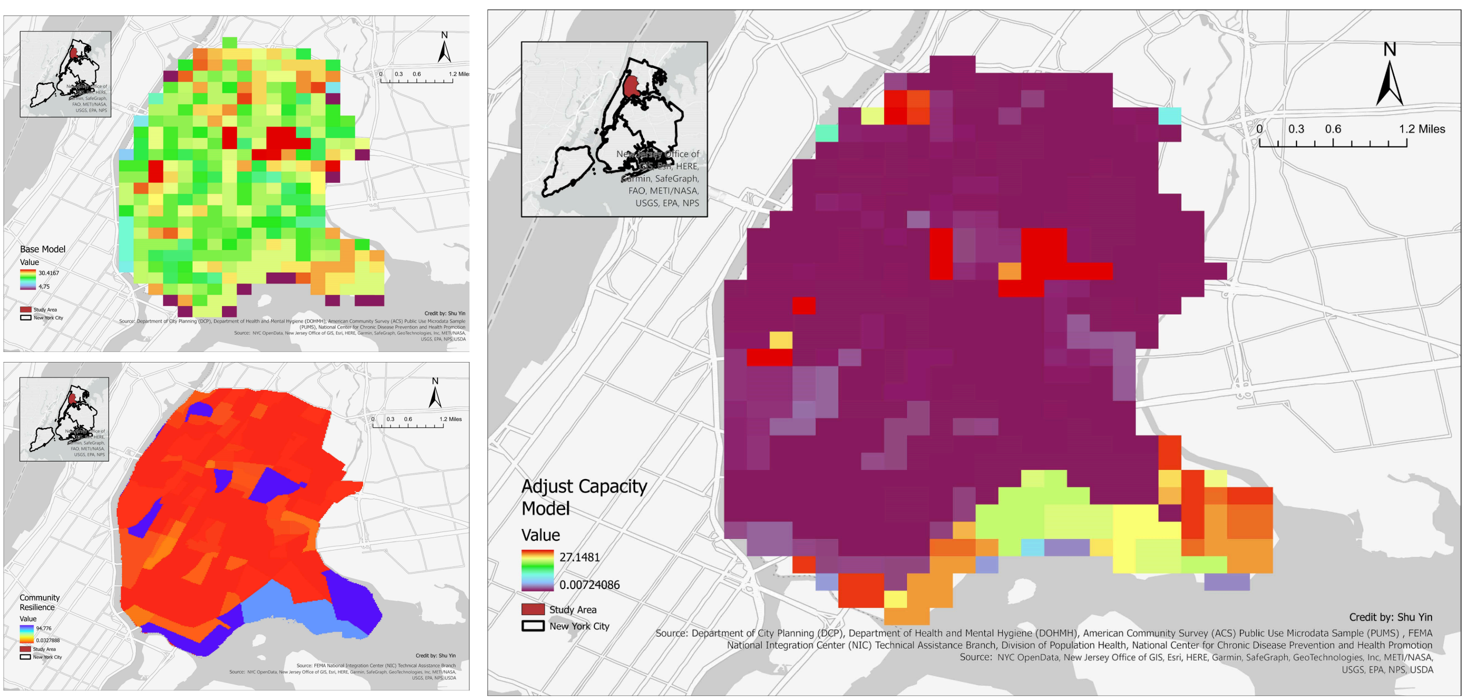


Figure 5. Adjusted Capacity Model

The risk distribution model emphasizes the apparent vulnerability to natural hazards in areas where the built environment is close to natural boundaries. These areas, which are usually delineated by the junction of human infrastructure and natural landscapes, have been identified as high risk areas due to their susceptibility to environmental events that can exacerbate existing vulnerabilities. (Figure 6)

This risk is a result of the interaction between man-made infrastructure and natural systems, yet the current planning system is one in which these two systems are designed to coexist less harmoniously, especially under the stress of extreme weather events. Potential risks are not evenly distributed, with certain communities bearing a disproportionate burden.

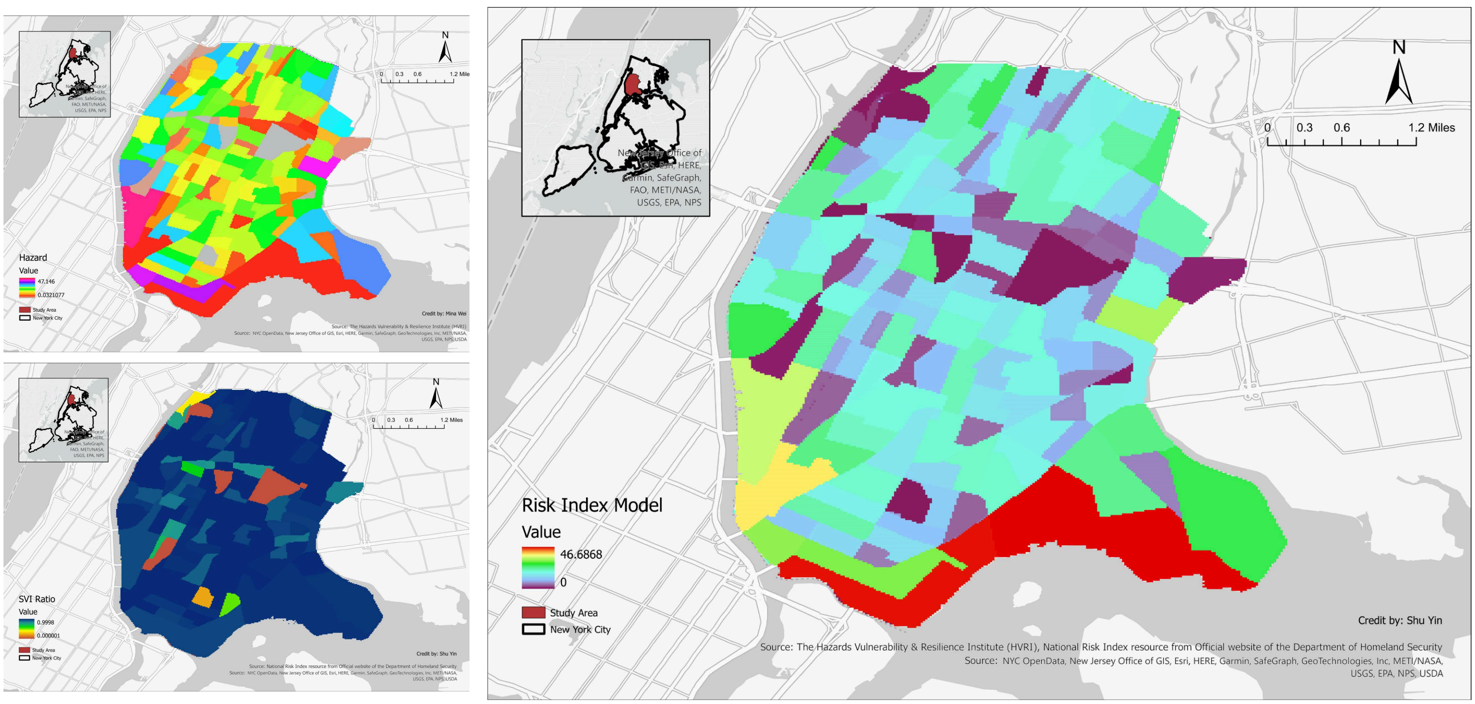


Figure 6. Risk Index Model

The risk coverage model presented here reveals the gap between a community's ability to withstand disruption and its actual exposure to risk. The model shows that certain areas within the community have lower risk coverage values, indicating a significant gap in the community's social resilience. This indicates that these areas are less able to recover from adverse events, highlighting an important area of concern for urban development and resilience planning. The deep purple color indicates areas where risk exceeds resilience and where efforts need to be focused on improving the community's ability to respond to and recover from potential disasters. In addition, high values are all schools or parks with green space (Figure 7).

The model suggests that schools and parks, represented by high-value green and red spaces, act as bastions of resilience that can greatly enhance a community's ability to cope with air quality challenges. Green spaces are critical for providing open space, social engagement and overall well-being, and act as natural buffers to pollution and urban stressors. They reflect the positive impact of urban greening in increasing resilience to environmental risks.

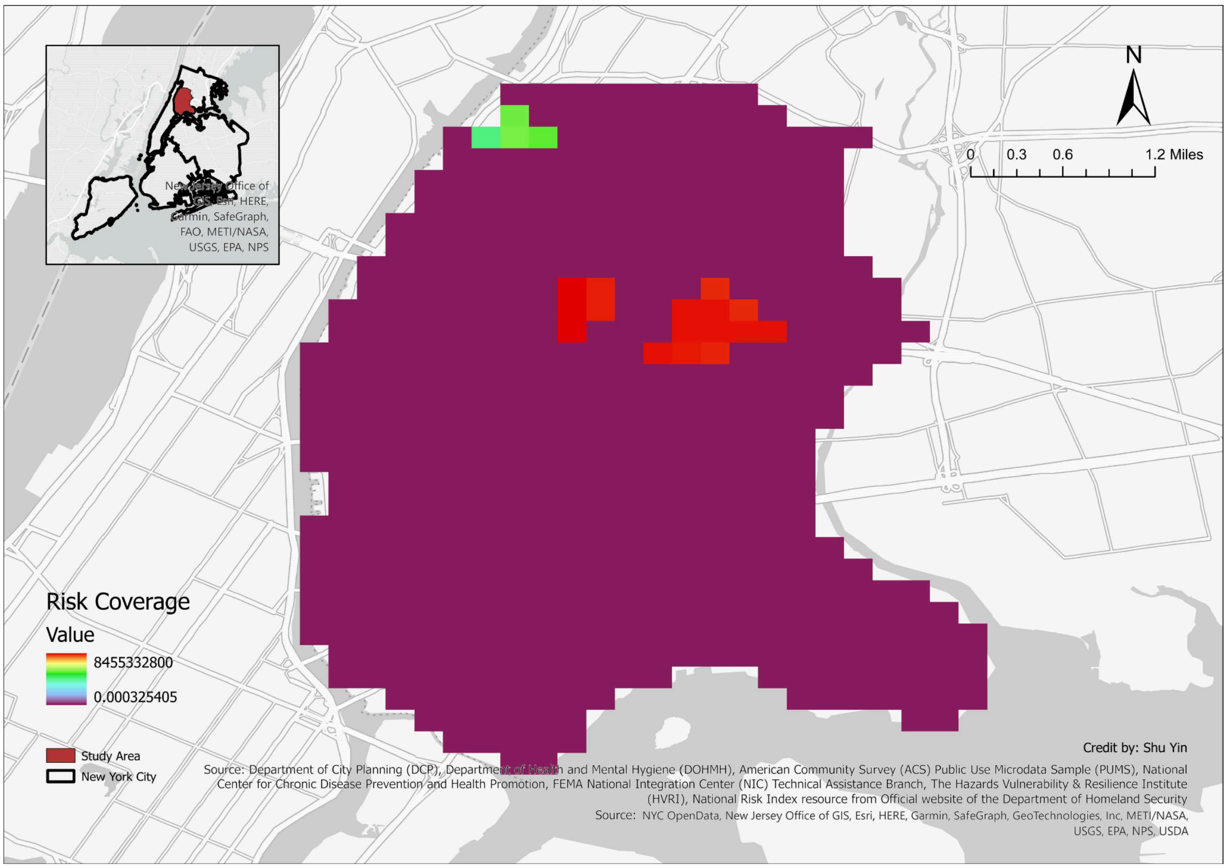


Figure 7. Risk Coverage Model

Interview Results

As previously noted, we were unsuccessful in yielding responses from stakeholders during our interview phase. We were nonetheless able to obtain written responses from Cesar Yoc, a board member of the Bronx Community District 1 and the founder of the Bronx Institute for Urban

Systems. Overall, Yoc's familiarity with the study area was of great importance and his deep-rooted understanding of environmental justice issues very clearly got across.

Cesar Yoc recognized the importance of addressing air quality threats in the area, deploring the increased rate of construction projects combined with remaining hazardous sites such as the Peaker plants in Port Morris and the waste stations near the Bruckner Expressway. Within this urban context, he identified car traffic, idling trucks and fossil fuel use as the most crucial contributors to air pollution vulnerability but warned us of not considering these as standalone issues, but rather as part of a larger systemic milieu, what he calls "holons within holons" in his own research. According to him, conceptualizing this integrated environment is key to developing targeted and innovative solutions in a neighborhood that is otherwise rather uninvolved. The main threats identified by Cesar correspond to those identified in our model, with an emphasis on proximity to polluting infrastructure and high-density traffic areas.

When asked about community participation in the fight against environmental injustices, Yoc acknowledged that to his dismay, many residents did not have the time nor the resources to get involved in those matters. He noted that the main burden fell onto volunteers and employees of local organizations, which creates a noticeable gap in advocating for policy change. This issue ties into thinking critically about data-driven approaches like ours in the fight for environmental justice. Cesar argued that data collection has been prevalent for a very long time in the area, but that it cannot exist on its own without innovative policies and ways to involve residents who are already not active in this fight. Developing models is not enough and should instead be accompanied by creative sets of tools and long-term goals to which residents can relate. In the context of our study, this highlights the importance of remembering that models are stepping stones rather than end goals.

Words to describe the neighborhood:

GENTRIFICATION, JUSTICE, DIVERSITY

	Very satisfactory	Satisfactory	Neutral	Unsatisfactory	Very Poor
How would you characterize environmental activism in the neighborhood?		✓			
How would you characterize your interactions with governmental/municipal agencies in promoting climate justice?			✓		
How is the speed of response to residents' demands for air quality as a management and decision-making body?			✓		
How satisfied are you with current environmental policies governing the neighborhood?				✓	

Figure 8: Scale-based questions

The interview also had a component with scale-based questions, and an interesting trend emerged from Cesar's rankings which ties back to the points made during the open-ended questions. While there is a high awareness of the issues at hand and an overall encouraging context for environmental activism, policies do not follow through and inadequately respond to the demands and concerns of citizens. This goes on to show that there is evidently room for improvement in the interactions between policy-makers, local organizations, and citizens in addressing the very real crisis.

Overall, the responses provided by Cesar Yoc were enlightening and, while they served as caution for the misuse of data-driven frameworks, they anchored some of our model findings and methodological approaches.

Findings

The South Bronx is undoubtedly one of the most vulnerable areas in the New York City area, and is characterized by a lack of risk protection that indicates that it will be more traumatized in the face of disasters and emergencies.

Overall, our research confirms that community resilience capacities are negatively correlated with high exposure levels and further compounded by social vulnerability, emphasizing variations at the granular level which deserve to be addressed. Areas that face the most risks are typically close to warehouses and major transportation hubs such as Westchester Avenue and Christie's Wine Auction Warehouse.

Second, our analysis reveals that green space and community wealth are two key factors that enhance community resilience. Green spaces provide important ecological services and recreational space, contribute to improved air quality, and provide physical and mental health benefits to community residents. At the same time, a community's economic status directly affects its ability to invest in environmental improvements and health security, with higher levels of community wealth typically associated with better environmental resilience and lower health risks.

In addition, we find a negative correlation between public awareness of environmental injustice issues and current policies. This suggests that current policies may not adequately consider or reflect public concerns. It will be compelling to take this project further to conduct an in-depth policy analysis and identify variations in order to understand whether there is a correlation with our risk assessment model.

Finally, we recognize that data alone is not enough to trigger change. Data must be public-facing and able to be translated into action in order to realize its potentially powerful impact. This emphasizes the importance of translating data into actionable policies, specifically in higher-risk neighborhoods where residents are lacking resources to be involved in activism.

Recommendations

Altogether, these findings inform the following set of recommendations. While we acknowledge that these are provisional, they can be used as a starting point for further exploration and actions:

- Policies should prioritize the development of green spaces to provide residents with more opportunities to engage with nature, which not only helps improve air quality but also enhances the overall health of the community.
- Develop and use integrated modeling to assess the cumulative impacts of policies so that various factors can be considered comprehensively when formulating policies. Our research is only a stepping stone and we believe that its methodological steps are replicable and can inform policy in other vulnerable areas.

- Emphasize that community participation should be based on reality, paired with the development of innovative and implementable action plans. This will ensure that planners only act as mediators in a grassroot process.
- Policies to be developed are to ensure that environmental remediation efforts receive equitable funding and resource allocation.
- Strengthen cooperation between government agencies, communities, and other stakeholders is also one of our recommendations.
- Encourage the development of practical and innovative issues to stimulate citizen participation and enable planners to become active advocates and mediators.

Appendixes

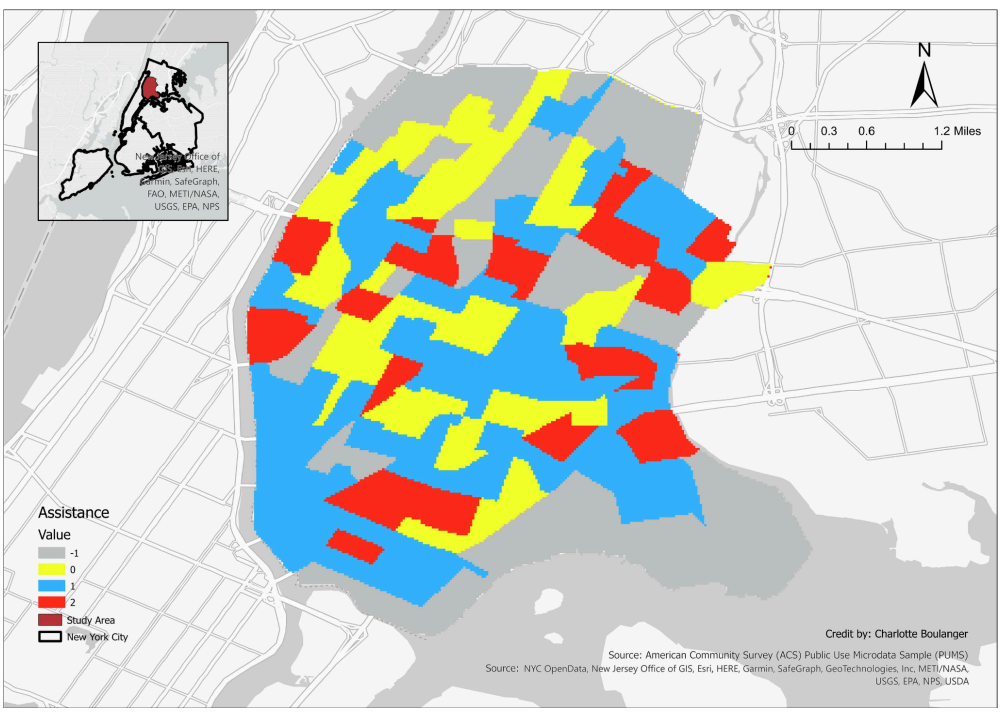
1. Open Questions:
   - Mission and issues:
     - If you had to pick three words to describe the South Bronx area today, what would they be?
     - When it comes to air quality issues in the South Bronx, what do you think are the most prominent issues? Based on your real-life work experience, what issues are equally important but easily overlooked by decision makers?
     - From your experience working on the ground, what do you believe are the most crucial contributors for air pollution vulnerability?
     - In what ways do you see the work of your organization intersecting with other social issues in the neighborhood?
   - Community Residents:
     - How important is the role of community participation and local organizations in improving air quality?
     - How do you see the cooperation between different stakeholders (e.g. government, business, NGOs and residents)? Are there any in particular you engage with?
     - What conditions are met for residents' demands to be fully considered by the relevant organizations and incorporated into their decision-making?
   - Measures and Narratives
     - What is an example of a successful program or project of your organization in or related to the neighborhood? An example of another organization's work?
     - What long-term solutions do you think are needed to address air quality issues in the South Bronx?
     - How do you think future plans and policies should better incorporate the specific needs and vulnerabilities of communities?
     - What stories or histories are important to transfer across generations to understand South Bronx histories and promote climate justice in the neighborhood?
     - To what extent have the relevant organizations been able to address the air quality claims faced by the residents? Are there other plans for problems that cannot be addressed?
   - Role of policymakers
     - What key indicators or data do you think should not be ignored when assessing the impact of air quality on the health of the population in the South Bronx?
     - What are the key factors that need to be taken into account when formulating and implementing policies and plans on air quality?

Appendix 1. Open Questions for Interviewees

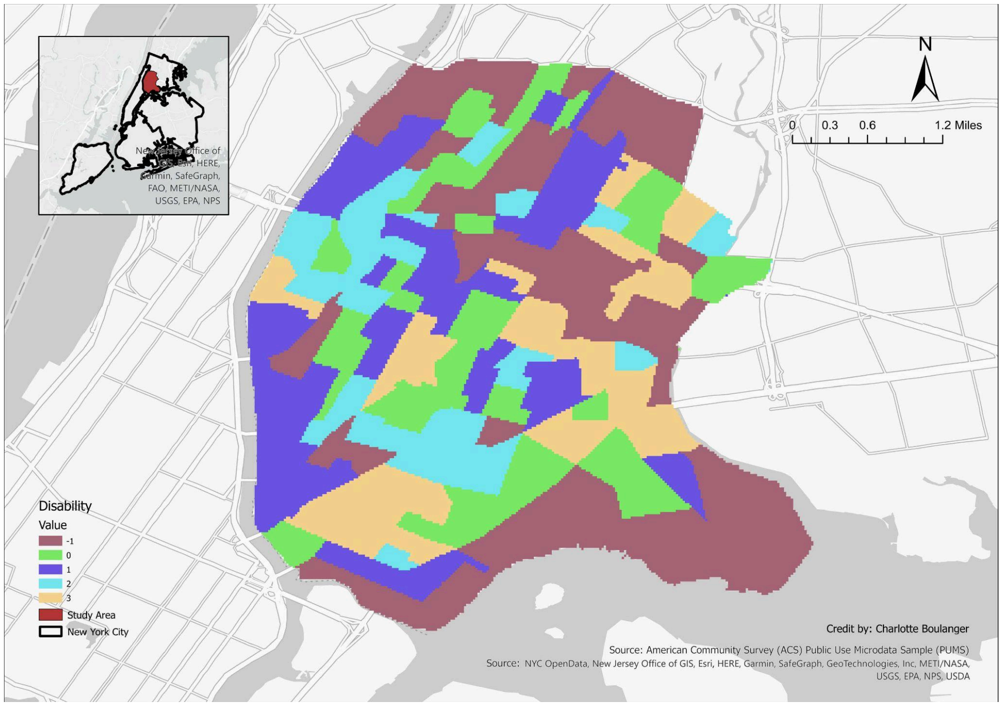
2. Standardized Questions:

Questions	1(bad)----5(good)	Any comments?
How would you characterize environmental activism in the neighborhood?		
How would you characterize your interactions with governmental/municipal agencies in promoting climate justice?		
What is the speed of response to residents' demands for air quality as a management and decision-making body?		
How satisfied are you with current environmental policies governing the neighborhood?		

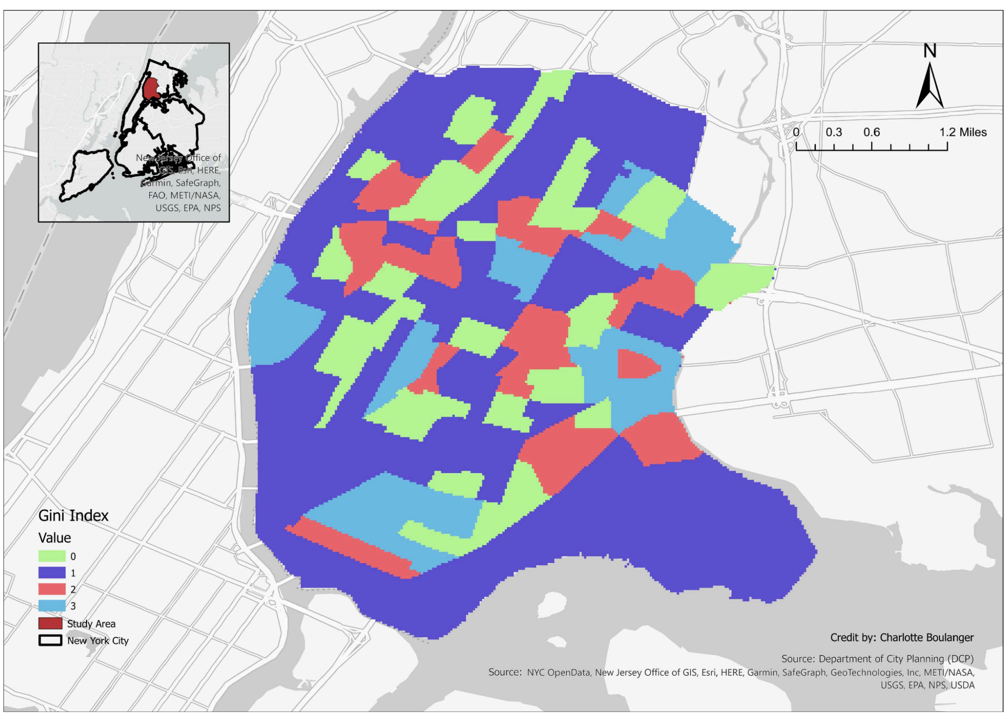
Appendix 2. Standardized Questions for Interviewees



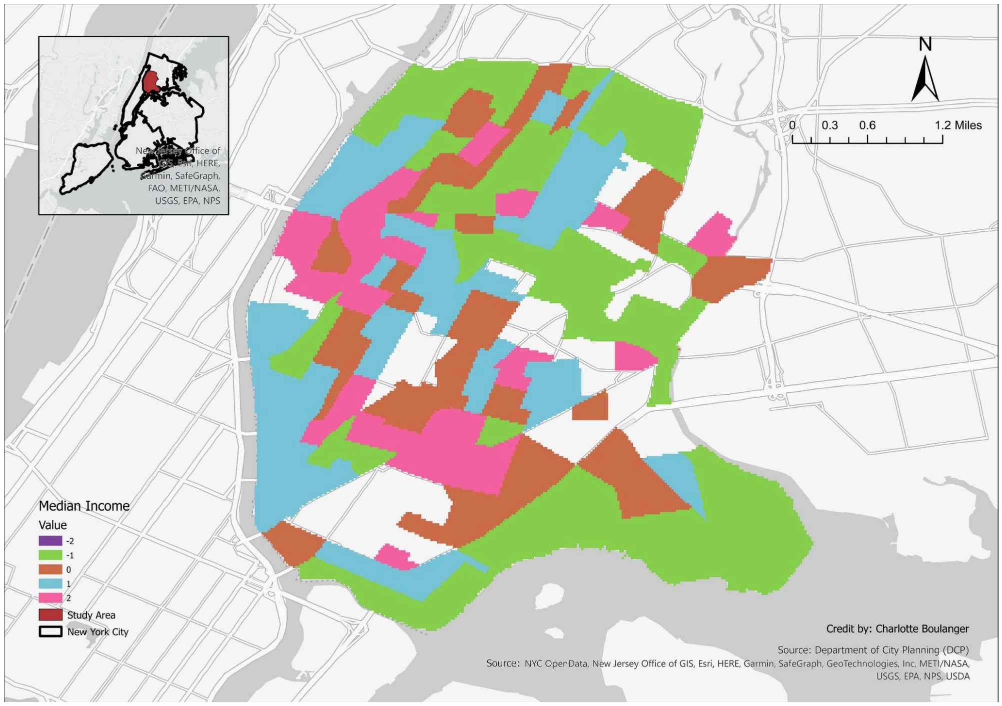
Appendix 3. Public Use Microdata Factors —— Assistance revalue map



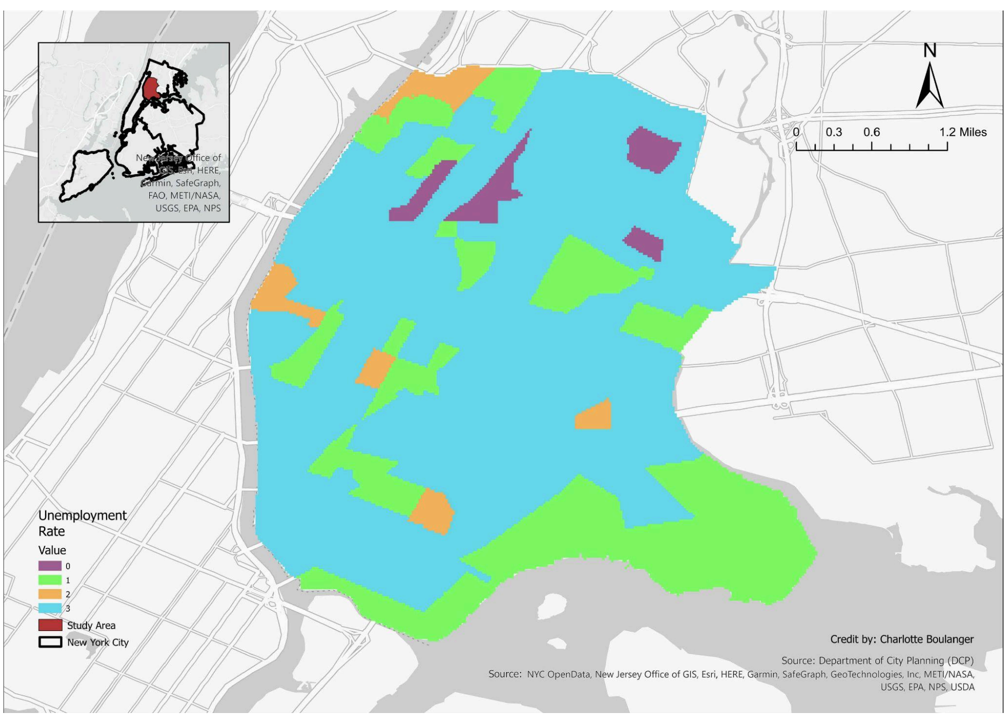
Appendix 4. Public Use Microdata Factors —— Disability revalue map



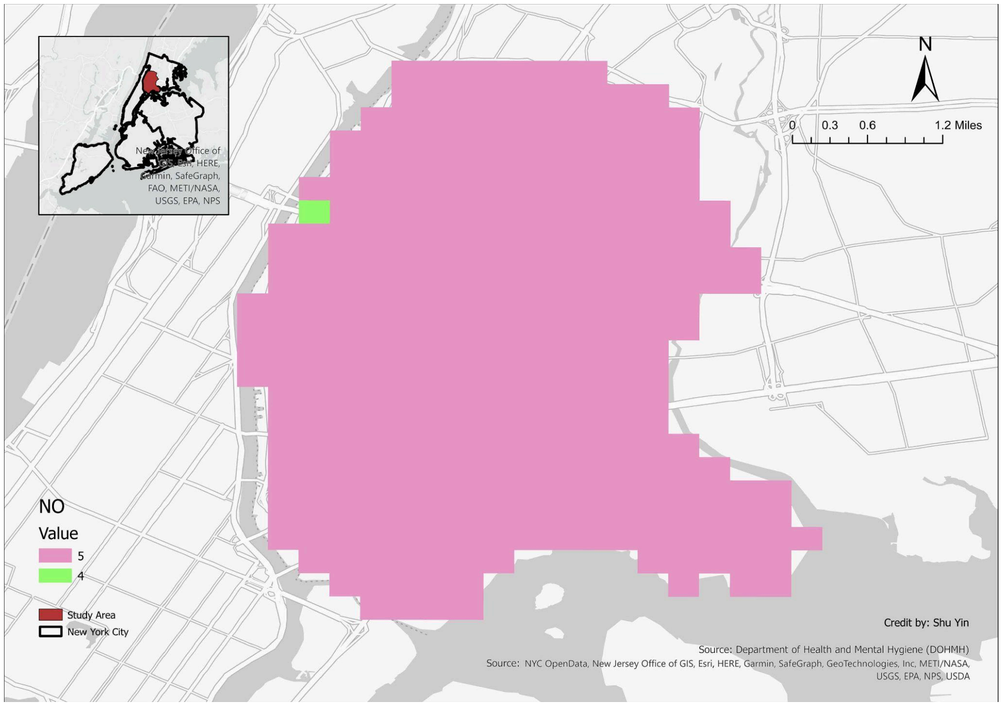
Appendix 5. Social Economic Factors —— Gini Index revalue map



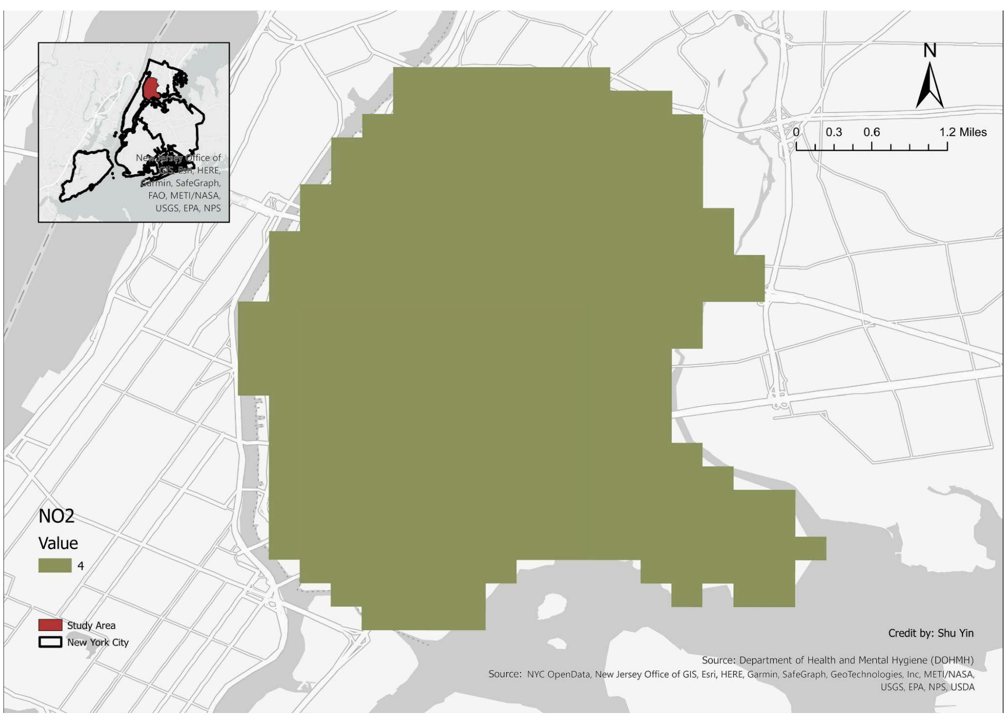
Appendix 6. Social Economic Factors —— Median Income revalue map



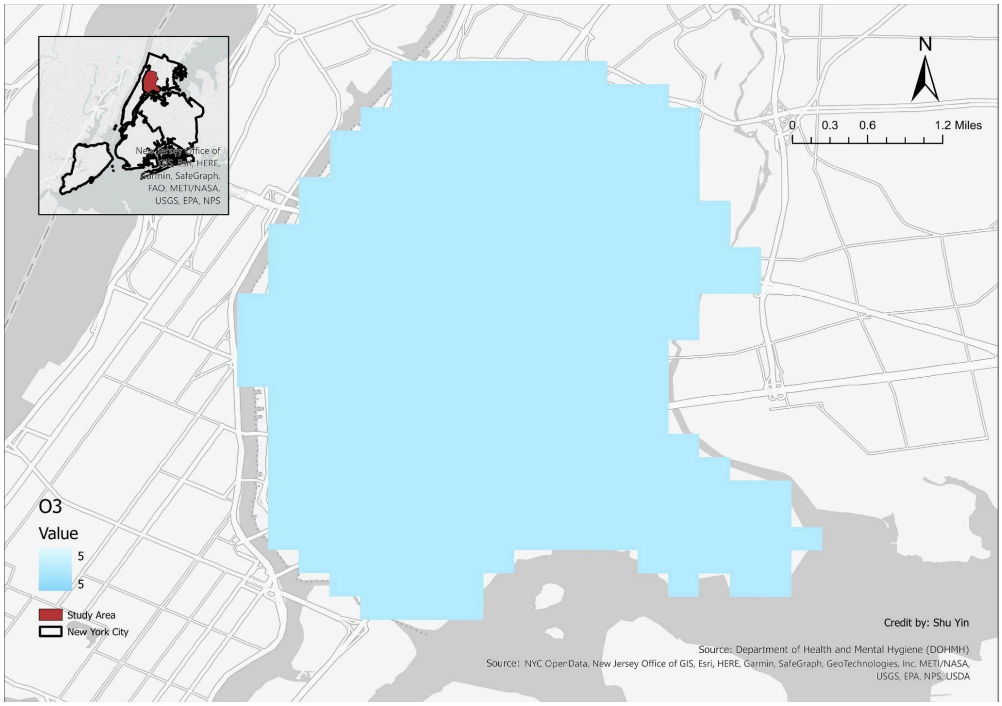
Appendix 7. Social Economic Factors —— Unemployment revalue map



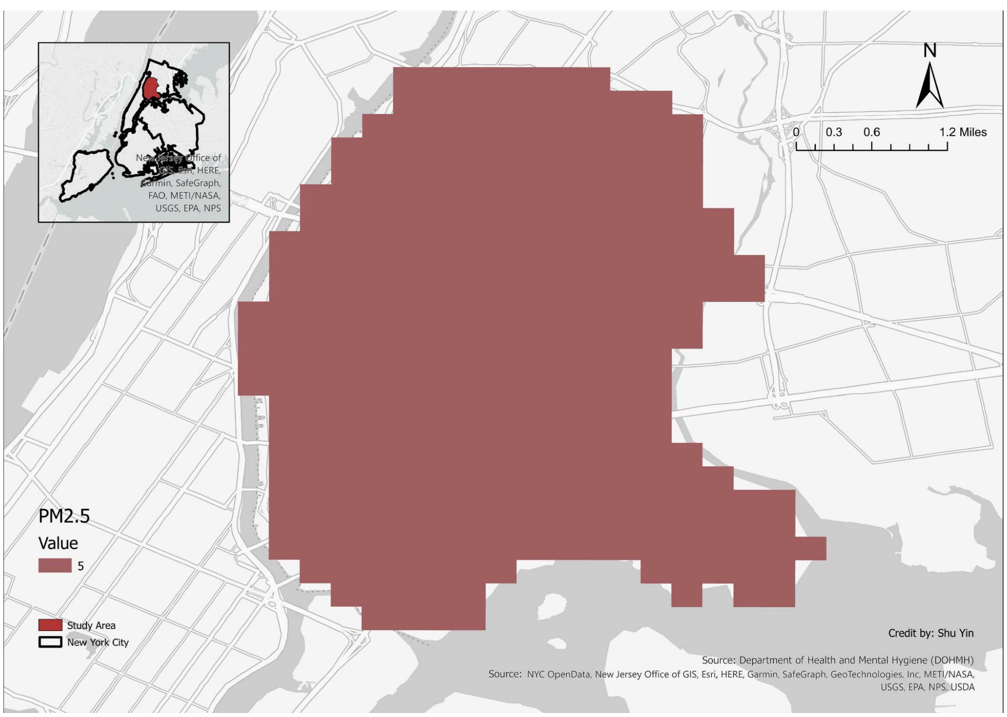
Appendix 8. Air Quality Factors —— NO concentration revalue map



Appendix 9. Air Quality Factors —— NO2 concentration revalue map



Appendix 8. Air Quality Factors —— O3 concentration revalue map



Appendix 9. Air Quality Factors —— PM2.5 concentration revalue map

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