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Climate Impacts in Environmental Justice (EJ) Areas: How Smart Growth Planning Helps Prepare for Increased Impacts in Overburdened Communities?

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Abstract

Environmental justice (EJ) has risen to the forefront in the United States over the last few years. Climate change affects nearly every aspect of natural and societal systems. It does not explicitly target EJ areas but minority concentrations in coastal areas and large cities combined with capacity to respond to climate risks equate to residents of these communities bearing an undue proportion of climate impacts. Effort taken to identify and then track climate-related indicators helps local, state and federal governments and stakeholder groups plan for potential mitigation and adaptation.

The authors chose three large cities in the United States, one on each ocean coast, and one in the Great Lakes region, to summarize some of the projected impacts to EJ areas within the country over the coming years. The U.S. Environmental Protection Agency's (EPA) climate indicators provide a framework for considering current impacts and EPA's Social Vulnerability report serves as the basis for all impact projections. We then delve into a discussion of resiliency and climate planning in each city. Can resiliency actions minimize potential risk in EJ areas by reducing vulnerability to these impacts? Are there distinct mitigation actions that can be taken to equate to benefits to urban heat island effects and flooding rates? Since cultural and economic makeups vary depending on location, so should the makeup of local EJ working groups. Los Angeles groups spend a large portion of their time on working conditions for migrants and targeted campaigns and chlorpyrifos, while groups in Detroit or Philadelphia may focus on CSOs and lead pipes in drinking water. States often share best practices and pull guidance from federal agencies, but usually prefer to create specific state resiliency and smart growth plans to better combat their precise impacts matrix. These state-specific plans must focus on overburdened communities, those least responsible for climate change, but projected to bear a greater share of the negative effects from associated impacts.

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Definitions, Units, Symbols, and Abbreviations

Adaptive Capacity: Ability for a set geographic unit to respond to climate impacts; CODE: Center for Open Data Enterprise; CSO: Combined sewer outflow, where both rainwater and sewer pipes share the same routes below the surface; EJ: Environmental Justice; Exposure: Likely climate impacts at a set geographic unit; GIS: geographic information system; NGO: non-governmental organization; $PM_{2.5}$: Particulate Matter less than 2.5 microns in diameter; Sensitivity: Underlying socioeconomic conditions in that set geographic unit that make its inhabitants more open to feeling climate impacts; UHI: Urban Heat Island; USEPA: United States Environmental Protection Agency; Vulnerability: The capacity of a local geographic unit, city, town, state, to respond to the risk of climate impacts and mitigate or minimize those impacts where possible

Introduction

The EPA defines environmental justice as the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies [1]. Over the last few years, many states have elected to beef up their EJ programs, with New Jersey taking the lead in September 2020 as they passed what some refer to as the "gold standard" program. Under New Jersey's EJ law [2], the New Jersey Department of Environmental Protection (NJDEP) is now required to deny permits for expansions or new facilities if that facility is located in an overburdened community and projected to have an undue impact that cannot be mitigated through permit conditions and controls. The law does not name climate change as a driver but helps build local resiliency toward future potential impacts.

The CODE climate risk matrix in Table 1, [3] examines the intersections of capacity to respond to a climate hazard and the likelihood of that hazard occurring in a distinct community. Risk grades are assigned based on position on the matrix and range from HIGH RISK, the intersection of high likelihood of hazard occurrence and low capacity to respond, to LOW RISK, the intersection of low likelihood and high capacity. Many projected climate impacts are associated with sea level rise so we break down the distribution of socially vulnerable populations in Table 2 [4] to identify potential areas that may have a low-capacity rating per the CODE matrix. The USEPA described this phenomenon similarly in the below graphic, with vulnerability equaling the sum of exposure, sensitivity, and adaptive capacity. Each of these terms is defined in the previous section for context and included in the graphic below.

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	High Likelihood of Hazard	Low Likelihood of Hazard
Low Capacity	High Risk Communities that have poor infrastructural and financial capacity and face high likelihood of exposure to climate-related hazards.	Medium Risk Communities that have low likelihood of exposure to climate-related hazards but also low infrastructural and financial capacity.
High Capacity	Medium Risk Communities that have strong financial and infrastructural capacity and relatively high threat of exposure to climate-related hazards.	Low Risk Communities that have strong financial and frastructural capacity and face low likelihood of exposure to climate-related hazards.

Table 1: CODE Climate Risk Framework.
Source: Data for Climate Risk Assessment in Vulnerable Communities. Briefing Paper (2021). Center for Open Data Enterprise (CODE).

Region	Low income (% population)	Minority (% population)	No High School (% population)	65 and Older (% population)
Contiguous U.S. Coast	32	39	13	15
Northwest (Detroit)	26	29	8	15
Northeast (Philadelphia)	26	44	12	15
Southeast-Atlantic	36	51	12	18
Southwest (Los Angeles)	30	63	17	14
Southern Great Plains	37	67	20	11
Southeast-Golf	35	33	12	20

Table 2: Current Distribution of Socially Vulnerable Population in the Costal Countties of the Contiguous U.S.
Source: Whitehead and Kolian (2021) Do climate impacts have a greater effect on EJ communities. Presentation to the A&WMA. Derived from "U.S. EPA (2021) Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts".

Climate impacts do not go hunting for the socially vulnerable but living closer to potential impact sites and not having adequate local resiliency capacity, make these communities more likely to be impacted by the changing climate.

Sustainability policy has often arisen from top-down policy processes, whereas EJ arises from grassroots responses to environmental racism. Climate (sustainability) policy on the international level is driven sustainable development goals (SDGs). The SDGs fail to incorporate an explicit justice focus and EJ is largely absent from the goals, targets, and indicators [5]. Accordingly, it takes state-specific resiliency and smart growth planning such as what was mapped out in PlaNYC to best address the unique challenges in OBCs and throughout the community [6-9].

The Importance of Climate Indicators

Communicating the science of climate change is fundamental to building knowledge, awareness, education and for transitioning toward actionable planning and decisions [10]. In 2021, the United States (U.S.) Environmental Protection Agency (EPA) released a web update of the latest data and indicators related to its, *Climate Change Indicators in the United States* [11], summarizing a key set of indicators related to the causes and effects of climate change. EPA compiles and regularly updates these indicators to track and document relevant measures of climate change in the U.S. Collectively, the indicators represent authoritative information by leveraging the latest science and serve as a key resource for communicating to a broad range of audiences, including educators, decision-makers, and the public. The availability of credible, transparently documented data and information for informing decisions related to resilience and adaptation planning is particularly useful as resources for such wide-ranging efforts are typically constrained.

The signs of climate change are clear in a number of different measures. Increasing global temperatures during the past century have led to many observed changes, including declines in Arctic sea ice, changing rain and snowfall patterns, changes in streamflow and snowmelt-related runoff [8], and more extreme climate events–like heavy rainstorms and record high temperatures. These observed changes are linked to the rising levels of carbon dioxide and other greenhouse gases in our atmosphere, caused by human activities. An indicator, defined simply, represents the state or trend of certain environmental conditions over a given area and a specified period.

Indicator focused efforts often start with a typology that describes interconnections among human activities, their environmental impacts, and the societal responses to these impacts (European Environment Agency, 1999, [12,13]. Watts et al. [14] use a systems thinking approach to select and use indicators related to impacts, exposures, and vulnerability; adaptation, planning, and resilience for health; mitigation actions and health co-benefits; economics and finance; and public and political engagement. Indicators will be more decision-relevant when they can be applied to existing and active policy drivers [11].

A Growing Body of Scientific Evidence

EPA's climate change indicators represent a current and comprehensive resource on climate science. They are based on observations only (no projections) primarily focused on the U.S. with some global changes for context. The resource brings together and highlights federal government data but is also a broader collaboration of over 50 agencies and organizations. The content is both based on peer-reviewed sources of information and undergoes EPA peer-review (cite guidelines). The information is routinely updated and new science and indicators are incorporated. EPA indicators are well-integrated into US Global Change Research Program's Fourth National Climate Assessment [15], and interagency indicator website [11]. EPA's indicators currently include 54 indicators; 140 figures based on over 275 datasets and the content is downloadable, sharable and accessible: data, graphics, interactive tools, and documentation.

Expanded indicators and mapping

EPA has moved several indicators into an interactive platform to support analyses and help facilitate the mapping of social vulnerability to climate. EPA is also currently developing new climate vulnerability indices for Extreme Heat, Wildfire, Flooding, Air Quality, Occupation, and a composite Climate Stress Index. The method combines exposure (climate stressor data) and sensitivity (social and other determinants). The new indices will help answer questions such as: Which counties have higher risk to Extreme Heat according to their demographic characteristic? Where is the largest population at risk to Wildfires?

Previous studies and reports describe the importance of coupling physical climate variables with human and social systems data. Indicators of climate vulnerability and adaptive capacity span across a range of sectors and spatial scales and must track the impacts on human systems (human health, economic) [16]. It's important to link existing data on physical, ecological, social, economic, and health variables to develop "new" data and key indicators "for estimating climate change vulnerabilities and informing responses to limit and adapt to climate change." [16] Vulnerability mapping methods to better connect climate to human health impacts [17]. Methods for "geo-referencing" existing social and environmental databases informing local and regional vulnerability assessments. Having the individual socio-economic, health, and built environment vulnerabilities for each hazard is beneficial. Figure 1 provides county-level climate and existing social vulnerabilities overlaid together for four primary impacts (extreme heat, wildfire, flooding, air quality).

Combining exposure layers consisting of sensitive population and social determinates and other variables with the climate-related hazard data allows for users to quickly understand areas with a higher or disproportionate risk. While some users such as city and community planners may need higher resolution information than county, these types of products are great for planning and positioning resources. These types of assessment efforts often are being done to inform the development of some type plan: climate resilience or adaptation plan, emergency response plan, planning for public / community health interventions.

It is important to look at the co-occurrence of climate change stressors and EJ defined communities and allow for the overlay of multiple stressors on a given geography and how that affects EJ communities. Better understanding who and where impacts are greatest and how, communities can take steps to protect the most vulnerable going forward. As the demand for credible, climate information continues to increase, it is important to examine whether and how climate indicators are used to support U.S.-specific vulnerability assessments and decision-making.

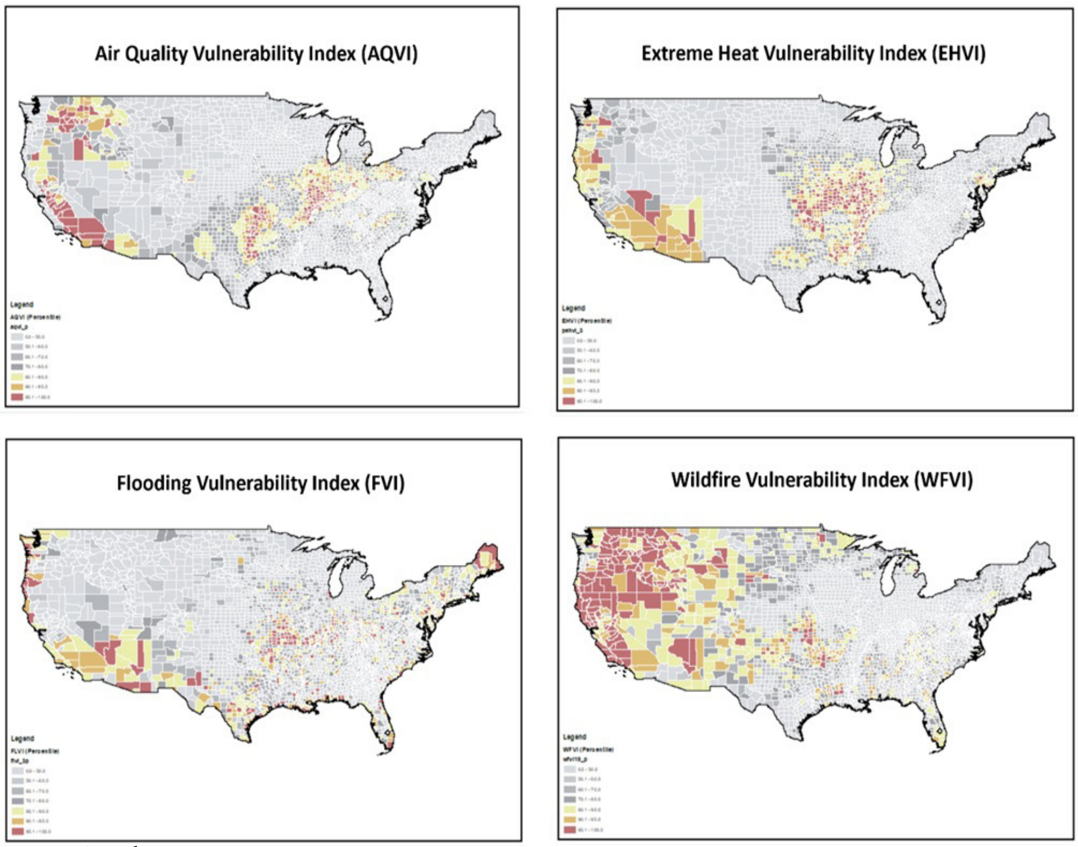

Figure 1: A Look at Four Primary Impacts.
Caption: The figures represent four vulnerability indices which highlight U.S. counties where the combined percentage of the sensitive population (at the county) is high, along with the intensity of climate impact (air quality, extreme heat, flooding, wildfires). Red and orange colors represent counties with index values above 90th percentile in the 2015-2019 timeframe.

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EPA's Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts

Complimentary data from modeling are important for planning and characterizing risks from a variety of hazards. EPA's new, peer-reviewed report, Climate Change and Social Vulnerability in the United States: A Focus on Six Impact Sectors, [4] shows the degree to which four socially vulnerable populations defined based on income, educational attainment, race and ethnicity, and age—may be more exposed to the highest impacts of climate change. Impacts are quantified for six sectors. The effort represents one of the most advanced studies to date that looks at how projected climate change impacts may be distributed across the American public. This effort yields data for the remainder of this paper.

Materials and Method

This project examines the projected climate impacts in three major United States cities at 2°C and 4°C global average ambient temperature increase relative to a 2005 baseline -

- Philadelphia, PA,
- Detroit, MI and,
- Los Angeles, CA.

We discuss any differences in projected impacts in each city versus the average ambient and detail various conditions in EJ areas that may act as multipliers to further impact the local communities. Finally we discuss resiliency efforts in each city and propose a hierarchy of EJ area mitigation efforts, a potential roadmap to effect the greatest gains in the shortest period of time.

We have chosen to examine the following impacts that were projected in the recent EPA Social Vulnerability reportn [4]. All analytical methods used to derive impact ranges are detailed at length in the report, but common among these were a focus on census data, a lengthy literature review, and the use of modeling where appropriate, such as with Flood Factor - the First Street Foundation's flooding risk model [18], the National Coastal Property model (NCPM) [19], or the USEPA's Benefits Mapping and Analysis Program - Community Edition [20].

- Average Annual Temperatures Associated with Global Warming of 2°C and 4°C
- Annual Childhood Asthma Diagnoses Due to Climate-Driven Effects on $PM_{2.5}$
- Projected Changes in Annual Premature Deaths due to Climate-Driven Effects on $PM_{2.5}$
- Projected Increase in Annual Premature Mortality Rates due to Extreme Temperatures
- Property Loss Related to Coastal Flooding
- Property Loss Related to Inland Flooding
- Coastal Flooding Traffic Delays

The cities were chosen due to their location on coastlines, their spacing throughout the country, and the prevalence of EJ areas within their boundaries. City resiliency and environmental justice offices in each city were contacted for their input as well as numerous environmental justice groups. As of the time of this writing, each city has dedicated environmental justice offices, EJ working groups in the community, and dedicated state-based GIS EJ mapping systems. EJSCREEN [20] was used to illustrate potential vulnerabilities inherent in each city that would make them more susceptible to the climate risks bulleted above.

We describe a general hierarchy based on four principal criteria: (1) the magnitude and (2) immediacy of mitigation potential, (3) cost-effectiveness and (4) co-benefits [21]. None of these mitigation decisions happen in a vacuum and none of them happen overnight. We suggest that cities who see the greatest returns from such mitigation actions are those that commit to long term strategies and assign themselves achievable key performance indicators (KPIs).

More affluent areas will be better equipped to combat climate impacts, even though they likely will not experience the majority of these impacts. In 2010, the most affluent 10% of households emitted 34% of global CO_2, while the 50% of the global population in lower income brackets accounted for just 15%. By 2015, the richest 10% were responsible for 49% of emissions against 7% produced by the poorest half of the world's population. Affluent households travel more, use more electronic devices, eat out at restaurants more often, and have the financial flexibility to absorb price fluctuations without sacrificing standard of living. Often, these more affluent households with larger carbon footprints are concentrated in affluent areas but the pollution associated with their activities do not stop at neighborhood borders, and spill into the less affluent areas [22].

The racial wealth gap is a main driver in climate vulnerability disparities. Minorities are paid less than their white counterparts, even when they have college degrees, so they are less likely to have funds for comfort items like air conditioners. They are also more likely than whites to live in cities and be exposed to UHI, where ambient temperatures are higher than in less populated suburbs and there is less of a temperature drop at night. The nighttime cooling is essential, but less common in cities as asphalt and impervious pavements retain heat from the day [22-24].

How do cities choose from the menu of smart growth options [25] to fit their specific local needs? How do cities learn from each other and use planning documents from one location as a basis for their own city plan? Much of this coordination is done through regional working groups like the Regional Greenhouse Gas Initiative (RGGI) in the northeast, the U.S. Conference of Mayors, or through non-profit organizations like the Natural Resources Defense Council (NRDC).

Figure 2 details the current socio-economic breakdown of coastal communities [4] in the United States as a whole then in specific geographies across the country. The three case study cities are highlighted in parentheticals on the Table. This data is a critical guide as many states have come to define an OBC in part by a combination of various socio-economic conditions linked together by an "or" modifier. As an example, New Jersey lists three such conditions with an area only having to meet one to satisfy that portion of the applicability test. The New Jersey example is listed below. Please note in Figure 2 that many areas around the United States would meet the New Jersey definition of an OBC for this part of the applicability test.

1. at least 35% of the households qualify aslow-income households; OR
2. at least 40% of the residents identify as minorityor as members of a state-recognized tribalcommunity; OR

3. at least 40% of the households have limited English proficiency [2].

Numerous states such as New Jersey, Massachusetts, Minnesota, and California [26] have been developing compliance programs to monitor environmental conditions in each OBC. For various reasons industrial sites have tended to cluster in or around OBCs beyond the potential beneficial use of these facilities for the surrounding community. When this occurs the OBC becomes and EJ area and demands an elevated level of oversight in order to bring ambient environmental conditions back in line with Non-OBC areas within each state.

Results and Discussion

Table 3 details projected impacts for each metric listed above at 2°C and 4°C global average ambient temperature increase in each of the three case study cities. Projected ambient temperature increase is higher in each case study city than the projected global ambient increase [4]. Interestingly, the projected increase remains stable for Philadelphia from 2°C to 4°C but jumps considerably for Detroit and Los Angeles over those same intervals. There are numerous reasons for this difference, with perhaps the chief among them being changing weather patterns and percent green cover. Natural cover has extensive cooling effects as well as localized air purification benefits and recreational opportunities [22].

In the case of childhood asthma diagnoses, Detroit actually projects a growing decrease over the temperature interval while Philadelphia and L.A. project steady or slightly growing increases. Such a rate decrease could be indicative of an increase in resiliency projected over time. Often as mitigation begins from a lower starting point, we will see higher percentage rate gains in the near term. Things get better faster once effective changes are made, but that rate tends to level off over time [27,3,28]. A similar growing decrease is projected in premature annual deaths in people over the age of 65 due to climate-driven effects on $PM_{2.5}$ is seen in Detroit while the other two case study cities see steady gains over the temperature increments.

Projected increase in annual premature mortality related to extreme temperatures sees similar growing increases in Detroit and Philadelphia but remains steady over the temperature intervals in L.A. Perhaps this is because L.A. has a higher percentage of outdoor workers than the other two cities and has been working on related resiliency issues for longer.

Projected average annual labor hours lost per weather-exposed worker varied a bit in each case study city but then saw comparable percentage increases at the highest temperature interval. The highest of the three case study cities was L.A. in both cases. Logically this is due to more workers in their census blocks performing jobs directly linked to exposure to extreme temperatures.

Coastal flooding only applied to Philadelphia and L.A. since Detroit is not located on an oceanic coast. Philadelphia had the highest projected impact in coastal flooding traffic delays at 2°C but L.A saw a higher jump from 2°C to 4°C by percentage. Property loss in coastal areas similarly saw a larger jump in L.A. from 2°C to 4°C by nearly a factor of three to one.

Inland flooding property loss is projected to slowly decrease at the 2°C interval in Detroit, but then climb to a marginal increase at 4°C.

Cities	Average Annual Ambient Temperature Increase	Annual Childhood Asthma Diagnoses Due to Climate-Driven Effects on $PM_{2.5}$ (*per 100,000 Individuals 0-17)	Projected Changes in Annual Premature Deaths due to Climate-Driven Effects on $PM_{2.5}$ (per 100,000 People Age 65 and Older)	Projected Increase in Annual Premature Mortality Rates due to Extreme Temperatures (per 100,000)	Extreme Temperature Labor Hours Lost (per Weather-Exposed Worker)	Coastal Flooding Traffic Delays (Hours Per Person per Year)	Coastal Flooding Property Loss (Projected Population and Property Value in Coastal Areas at Risk of Inundation)	Inland Flooding Property Loss (Expected Annual Inland Flooding Damages ($/yr))
Philadelphia								
2C	3 and 4°C	0 and 10	0 and 10	4 and 6	7	15	$10k - $2b	$0-$50k
4C	3 and 4°C	10 and 20	10 and 20	6 and 8	24	42	$465k-$27b	$0-$50k
Detroit								
2C	3 and 4°C	0 and -10	0 and -10	4 and 6	11	N/A	N/A	$0-$100k
4C	6 and 7°C	0 and -20	0 and -10	6 and 8	30	N/A	N/A	$0-50k
Los Angeles								
2C	1 and 2°C	0 and 10	0 and 10	0 and 2	17	3	$31k-$.5b	$0-$50k
4C	4 and 5°C	0 and 10	0 and 10	0 and 2	34	24	$296k-$17b	$50k-$100K

Table 3: Projected Local Impacts at Global Average Ambient Increases of 2°C and 4°C.
*Number sets with "and" or "-" between them indicate the true variable of this set lies between the range limits
*All values are relative to the 1986 and 2005 baseline period
Source: United States Environmental Protection Agency. (2021) Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts

Meanwhile in Philadelphia, losses are expected to be static at 2°C and 4°C while gaining momentum in L.A. from 2°C to 4°C [29].

Each of these indicators offers a projected glimpse into the future for the case study cities. As more flooding and heat waves are projected, so are workdays lost, and property loss, and other related factors. The sooner local governments begin a smart growth plan, the more resilient they will be to these potential impacts.

Identifying and Monitoring EJ Areas

The EPA released the first version of EJSCREEN [20] in 2015 and since that point various states have chosen to develop their own state specific EJ mapping tools. EJSCREEN includes 11 environmental indicators, six demographic indicators, and 11 EJ indexes to provide color-coded maps indicating potential EJ areas that require increased remediation actions [20]. In 2019, a graduate team from the University of Michigan (U of M) sought to examine the state of environmental justice in Michigan [30]. One of their key findings was detailing potential benefits that a Michigan-specific EJ mapping tool could have for the state. The team went further to propose a heat map model that not only identified potential EJ areas but used darker color shades to signify areas in greatest need of action. One of the models that the U of M team studied for their paper was CalEnviroScreen, which is still used in California to identify communities disproportionately burdened by multiple sources of pollution. The California Office of Environmental Health Hazard Assessment developed the tool as a means to identify communities with higher densities of industrial facilities. These sites contribute to the contamination of air, water, and soil and are indicated on CalEnviroScreen via a color-coded scale with red being the highest pollution burden areas and green being the lowest. As of 2017, approximately 40% of the land area in Los Angeles County earned a red designation [31].

Proponents of a state-specific GIS mapping tool would argue that such a step is needed to adequately access economic and health disparities in local populations. EJSCREEN is a useful starting point, a broad metric to examine cities against others within the United States. However, developing such a tool can take years and require many rounds of stakeholder input. Then once the tool is up and running and geographic areas are highlighted for potential remediation or rulemaking, one must expect further stakeholdering and administration time. It is often said that for something to be measured, it first has to be monitored, and for it to be regulated we need to measure trends. All of this takes time and manpower, sadly two things that some community groups lack.

Table 4 shows the EJSCREEN Index percentiles [20] for the three case study cities, with each percentile showing what portion of the US population lives in a block group that has a lower value for that indicator. As an example, Los Angeles has a traffic proximity and volume percentile of 99, meaning that 99% of block groups in the US have a lower traffic score than Los Angeles. Also worth noting here is the fact that percentiles for each indicator vary wildly across the three case study cities. What may be a huge issue in one city, may not be that big of a focus in another. There must be a tailored approach in each city to combat their most pressing indicators. Vulnerability in any of these areas will only be exacerbated by climate change as more excessive heat waves and more flooding events could potentially impact each indicator.

City	$PM_{2.5}$	Ozone	NATA for Diesel PM	NATA Air Toxics Cancer Risk	NATA Respiratory Hazards Risk	Traffic Proximity and Volume	Lead Paint Indicator	Superfund Proximity	RMP Proximity	Hazardous Waste Proximity	Wastewater discharge indicator
L.A.	95	95	97	96	97	99	91	94	98	98	98
Detroit	72	71	79	71	70	90	83	71	77	80	80
Philadelphia	47	48	29	45	45	7	19	16	12	7	0

Table 4: EJSCREEN Index Percentiles in the U.S.
Source: www.epa.gov/ejscreen
Notes: A percentile in EJSCREEN tells us roughly what percent of the US population lives in a block group that has a lower value (or in some cases, a tied value). This means that 100 minus the percentile tells us roughly what percent of the US population has a higher value.
Indexes listed appear in the basic EJScreen report for each city.

As the Earth warms temperatures tend to rise more on large land masses and areas near the poles. Water reflects much of the sun's energy back into the atmosphere, while land masses absorb much more of that energy [32]. This amplifies within large cities as manmade structures such as roads and buildings hold even more radiant energy and take longer to cool once the sun goes down. Often the greater percentage of built space within the city, equates to little natural green space. This is the urban heat island (UHI) effect [33,34].

As ambient temperatures rise, our oceans also warm, causing them to expand and take up more space on our planet. This basic rule of physics accounts for some of the coastal and inland flooding that we have seen in recent years. Warm water feeds storm systems, hurricanes and typhoons around the world, causing a direct correlation between increased onland storm impact damages and ocean temperature increase. This is amplified as ambient temperature increases contribute to ocean warming and polar ice melting, which then lead to coastal and inland flooding [4, 28,35,36].

Planning for Remediation Actions

Each case study city has identified their OBCs and has tools like EJSCREEN [20] or state-specific GIS tools like the NJ EJ Mapping Tool [2] or Michigan's equivalent [30]. Next comes planning to funnel available funds to areas that need them most. Here we see a hierarchy of actions with those toward the top being the most potentially damaging to sensitive receptors in the area over any set period. Remove the factors actively causing acute health impacts and then build up resiliency to chronic health and climate impacts. In Figure 2 below the red points below address sources of immediate environmental detriment while the yellow and green points suggest potential smart growth measures that can be adopted to improve resiliency. For the latter there must be a localized effort involving stakeholders and local government to determine what financial costs they are willing to incur to address their specific remediation and smart growth priorities [9]. While mitigation actions can and should be occurring through each of these three general levels at any given time, primary consideration must be given to the potential acute impacts in the red category before proceeding toward the yellow or green.

Each of the case study cities have taken actions that follow this model, and as detailed in Table 4, each has a different matrix of environmental challenges to combat. Local officials have to decide where to allocate their funds best, and what appetite their community has for mitigation measures. As the Smart Growth report [36] indicates, there are many mitigation options available for each projected impact, ranging in cost and effectiveness, but also in impact to everyday life in that area. As an example, if your community is prone to flooding events, the most impactful mitigation option may be to build a flood wall and move some buildings out of flood prone areas. But it is very unlikely that this is the most cost-effective and sustainable solution. Any actions that we take must also be beneficial for the local economy and have some measure of support from the community.

Superfund site remediation has to be toward the top of any such wish list. Even on clear days, outside of any climate impacts, such sites pose numerous potential hazards and developmental hindrances for a community. When weather impacts these sites highly toxic chemical and compounds can then spill into the community and threaten citizens with various cancers or developmental disabilities [37]. Thankfully the Superfund program is run through the USEPA and once a site gets placed on the National Priority List, there are mandated steps that must be taken to remediate that site, while understanding that it will likely be a lengthy process [26]. This is critical for EJ communities because as Kramar states in his 2017 work, "the closer you are to a superfund site the more likely you will find African American families. Moreover, the results found in this study support current research indicating that minority populations are at a significantly greater risk of environmental health issues" [27,38,39].

Since early 2016, the Sustainable Remediation Forum (SURF) has led research to examine (1) the impacts of climate change and extreme weather events on hazardous waste sites, and (2) how we can mitigate these impacts and create value for communities. The SURF team found that climate change and extreme weather events

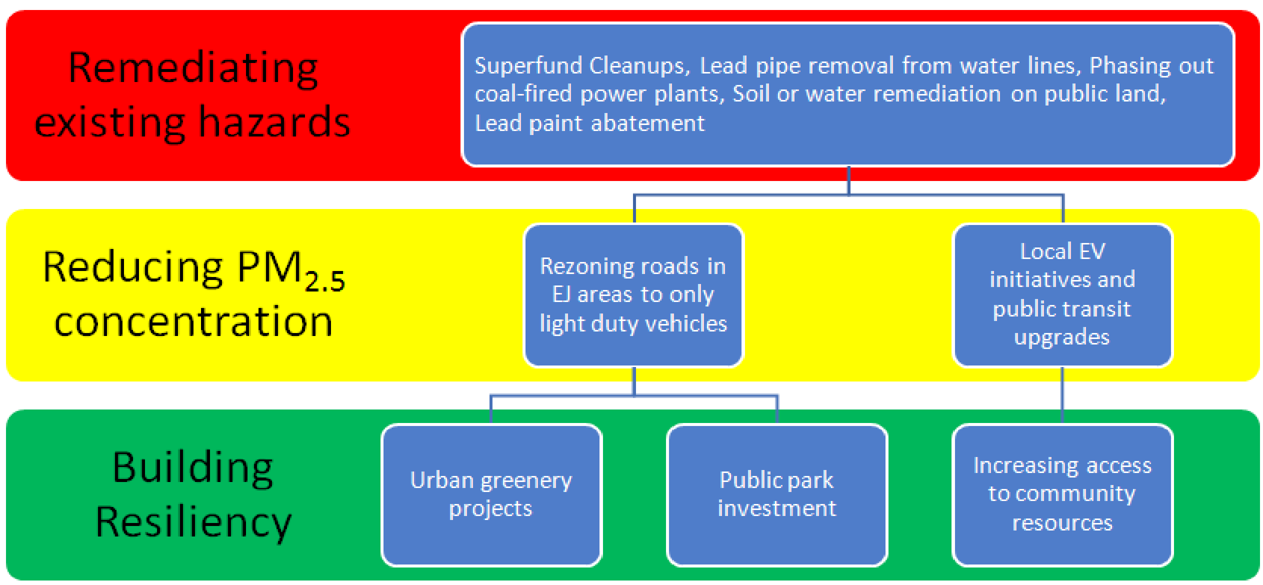

Figure 2: Mitigation Hierarchy: Acute threats to building resiliency.
Source: Whitehead, Chris and Michael Kolian (2022). Original Work.

can undermine the effectiveness of the approved site remediation. Further, failure to consider social vulnerability to climate change could compromise remediation and adaptation strategies. SURF's recommendations for resilient remediation build on resources and drivers from state, national, and international sources, and marry the practices of sustainable remediation and climate change adaptation. They outline both general principles and site-specific protocols and provide global examples of mitigation and adaptation strategies [12]. The mitigation hierarchy comprises four broad actions step that are designed to be implemented sequentially: (1) avoid, (2) minimize, (3) remediate, and (4) offset [40]. The first three are most preferable as they go furthest to improve local health outcomes but even offsetting potential impacts with increased benefits in the community can in the long run have a net benefit effect.

Conclusions

Our planet is a network of interconnected life cycles that all depends on stable weather patterns. Once the weather patterns change, corresponding changes then filter down to the individual cycles and systems below. This process is blind to socio-economic status, but vulnerabilities within our socio-economic systems place a higher percentage of minority populations in the path of increased impacts. Much of this occurs along coastlines and within cities and follows impact paths from coastal flooding and storm damage and UHI associated health impacts.

Climate indicators are important trends to map to help planners best prepare for likely future impacts in their communities. Investments in smart growth initiatives and environmental justice policy can help alleviate the burden on OBCs. Each of the case study cities has a state-specific GIS mapping tool. This allows planners to identify areas in the most need of mitigation, then plan funding allocations to meet resiliency plans. State and federal tools are updated semi-regularly as science evolves and capacity to develop the tools expands. This is one of many reasons why local smart growth plans should be revisited every few years. Many states have looked to New York City as an example for this, as their model, PlaNYC [7] is now on its second iteration and the city issues annual progress reports on the status of their KPIs.

Competing Interests

There are no competing interests to note as this paper has no economic avenues and was compiled solely to highlight recent work on climate indicators and show the benefits of smart growth planning to alleviate burdens on pockets of our communities.

Author's Contributions

Mr. Kolian contributed the climate indicators section and acted as a technical review resource for the remainder of the article. Mr. Whitehead led the city case study and is responsible for the formatting and methodology of the article.

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