

Chapter 4

Mapping Vulnerability to Weather Extremes: Heat and Flood Assessment Approaches



Zoé A. Hamstead and Jason Sauer

Abstract Assessing present social and biophysical conditions of communities that are at risk of injury due to extreme weather events is an important component of creating future visions of resilience. Spatial patterns of vulnerability to extreme events are manifestations of structural injustice that leave their mark on the built environment and in socio-spatial segregation patterns. Socio-spatial inequity often arises from development practices that favor particular racial and ethnic social groups over others. These segregation patterns are aligned with patterns of exposure to pollution, extreme weather events, and other types of environmental hazards. Spatial vulnerability assessments can be powerful tools for prioritizing where and how cities should make investments for mitigating the impacts of extreme events, and can provide an entry point for asking more fundamental questions about the processes that produce patterns of climate inequity, as well as how to avoid reproducing such processes in the future. Maps express uneven distributions of risk and manifestations of structural inequality in social–ecological–technological systems (SETS). They enable communities to visualize distributional injustice, consider ways in distributions that may be misaligned with cultural values, and develop adaptive practices toward climate justice. Here, we demonstrate approaches for assessing vulnerability to extreme flooding and heat, and show how vulnerability distributions are embedded in landscape patterns that produce uneven risk.

Keywords Climate vulnerability · Vulnerability mapping · Social vulnerability index · Mapping injustice

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Z. A. Hamstead et al. (eds.), *Resilient Urban Futures*, The Urban Book Series,
https://doi.org/10.1007/978-3-030-63131-4_4

4.1 Vulnerability Frameworks and Spatial Vulnerability Assessments for Resilience

Vulnerability mapping is a way of conveying a particular configuration of biophysical and social conditions that bear relation to a particular form of risk. Vulnerability can be understood in opposition to resilience, but the two concepts tend to emphasize different aspects of SETS (see Chap. 3). Resilience is a term with foundations in mathematics, physics (Norris et al. 2008), and the natural sciences, particularly ecology. It generally means a system's capacity to undergo change while continuing to persist and function via adaptation (Berkes et al. 2003). In the context of disasters, it means the ability to withstand, cope, and recover from an event (Brown 2012).

Vulnerability, on the other hand, is a term more commonly used in the social sciences and as a way of articulating how best to prioritize resources deployed in hazards management practice (Cutter 1996; Morrow 1999). It can have a broad range of meanings, generally referring to three main dimensions: exposure, sensitivity, and adaptive capacity (Adger 2006). The Intergovernmental Panel on Climate Change (IPCC) defines exposure as “[t]he presence of people; livelihoods; environmental services and resources; infrastructure; or economic, social or cultural assets in places that could be adversely affected” (IPCC 2012 p. 559). In addition to what is exposed, the term may also refer to an event (disaster) of some intensity and duration as well as the biophysical conditions that attenuate or exacerbate that event. Sensitivities are conditions that predispose people to risk or enable them to cope with stress; these are typically described in terms of demographic risk factors. The IPCC's definition of coping capacity most closely resembles the concept of sensitivities (by way of its opposite): “[t]he ability of people, organizations and systems, using available skills, resources, and opportunities, to address, manage and overcome adverse conditions” (IPCC 2012 p. 558). Adaptive capacity is “[t]he combination of the strengths, attributes, and resources available to an individual, community, society or organization that can be used to prepare for and undertake actions to reduce adverse impacts, moderate harm, or exploit beneficial opportunities” (p. 556). Sensitivity, coping capacity, and adaptive capacity are closely related and often conflated with one another. In practice, sensitivities and coping capacities are generally mapped or statistically presented as static conditions, whereas adaptation may involve short, medium, or long-term processes of reconfiguring those conditions based on abilities that are not limited to coping capacities. Vulnerability mapping most often involves overlaying exposure with sensitivity. It brings socio-spatial inequity to light, as differential vulnerabilities are often associated with development patterns that lead to spatial segregation of racial and other social groups.

Although differential social and geographic risks are manifestations of processes that play out over time, the vulnerability dimensions are often treated as temporally static (though geographically dynamic). Yet, conditions of vulnerability come about as a result of social, economic, and political processes, and those processes themselves can change as a result of extreme events in ways that create differential vulnerabilities to hazards (Wisner et al. 2003). In contrast with the vulnerability

framework, the temporal dimension is conceptually central to the resilience framework. Yet, its application to disasters practice tends to treat a set of system properties rather than processes (Brown 2012) and to oversimplify social dynamics that produce risk. Our approach to vulnerability mapping draws largely from the social science scholarship. However, in our view, the purpose of producing and analyzing static maps that convey patterns of vulnerability is to provide not only an entry point for spatially prioritizing interventions but also for investigating the development, policy, exclusionary, and biophysical processes that produce patterns of vulnerability. We consider both efforts essential for enhancing resilience by building adaptive capacities that address the needs of people most at risk of injuries triggered by extreme events.

4.1.1 Extreme Heat Vulnerability

Vulnerability to extreme heat is characterized by local climate variability and land cover patterns (biophysical exposure); social constraints (neighborhood socioeconomic sensitivity); and individual and household-level social capital, knowledge, and practices (capacity to change behaviors and conditions in response to heat threats) (Wilhelmi and Hayden 2010). Owing to prevailing design decisions, cities absorb a majority of incoming solar radiation. Compared with less urban areas, cities have less capacity to moderate temperatures via ecological processes. Together, these features contribute to a phenomenon known as the urban heat island effect, or the phenomenon that cities are detectably hotter than their surrounding peri-urban and rural areas. That is, if one were to look at a temperature map of a region, the urban areas would appear as islands of hotter temperatures in a sea of cooler, more rural areas. However, research into the heat island phenomenon emphasizes that even within a given urban heat island there is substantial spatial heterogeneity. The differences in temperature between these micro-urban heat islands and the coolest areas of a city may be as great as those of the broader urban heat island and its surrounding rural region. Accordingly, this spatial heterogeneity of temperature produces differential effects. Since thermal properties (e.g., absorption, storage, radiation) are closely linked to the composition of built and natural materials, the presence of such materials can be used to understand variation in heat exposure and the extent to which landscapes contribute to such exposures (Hamstead et al. 2016). People who live in neighborhoods replete with asphalt parking lots and little tree canopy are exposed to higher temperatures and are consequently at disproportionate risk of heat-related illness.

At the same time, the characteristics of the urban social system produce sensitivity and adaptive capacity, and these system parameters interact. Klinenberg's (2002) study of the heat wave that struck Chicago in 1995 found that people living in social isolation tended to be most affected, though a more full account of why over 700 people died during that heat event and why some neighborhoods were more affected than others had to do with broader economic and policy forces, including economic cycles of community abandonment and lack of disaster management response. Other

factors linked to heat-related mortality, illness, and distress calls at the individual and neighborhood levels that include surface temperatures, impervious land cover, green space, minority race and ethnicity, linguistic isolation, age, level of educational attainment, income, disability, housing conditions, housing values, vacant households, and rates of access to air conditioning in the home (Hattis et al. 2012; Madrigano et al. 2015; Rosenthal et al. 2014; Smargiassi et al. 2009; Uejio et al. 2011).

4.1.2 Flood Vulnerability

Vulnerability to extreme flooding is characterized by local climate variability, topography, and drainage infrastructure (biophysical exposure); social constraints (neighborhood socio-economic sensitivity); and individual and household-level social capital, knowledge, and practices (capacity to change behaviors and conditions in response to flooding threats). Delineating biophysical exposure to urban flooding is complex in both theory and practice. It involves interactions between regional climate and weather, as well as local topographic and drainage system characteristics. There are numerous types of flood exposure that may result from common or unique sources. Coastal flooding is due to tidal or storm surges bringing water into the city; fluvial flooding is due to overtopping riverbanks or levees, driven by rainfall across the relevant watersheds; pluvial flooding is due to rainfall intensity exceeding the performance capacity of the city's stormwater management system, or from evading this system entirely or in part. In many cities across the United States and the globe, it is generally expected that cities develop drainage and levee infrastructure to prevent or manage exposure to flooding from all sources. This expectation has been met primarily through technological measures such as pipes, canals, and hardened shorelines.

However, cities operate with limited information and resources, and in highly dynamic circumstances. Regional precipitation patterns change, sea levels rise, impermeable surfaces proliferate, and drainage infrastructure ages or proves to be maladapted to evolving urban configurations; cities must contend with several or all of these dynamic exacerbators of flood exposure. Further, a range of governmental and non-governmental actors engage in flood mitigation, from individuals physically rerouting pluvial flood water from homes and businesses by placing sand bags in front of building entrances, to neighborhoods ensuring adequate drainage system performance by coordinating pre-storm trash and debris removal efforts.

Differential social and demographic factors can cause differential impacts of extreme flooding on populations, even given the same forms and degrees of exposure. Home renters, for example, may have little to no agency to make modifications to the structure of their homes, relying instead on the diligence of the landlords who may not adapt their properties to address tenant flooding concerns (Morrow 1999). At the same time, the potential agency of landlords may be stymied by factors such as low income from rents, an unpaid mortgage on the building, advanced age, and disability (Cutter et al. 2003).

4.2 Role of Vulnerability Maps

Spatial vulnerability assessments are a way of conveying distributional patterns of exposure, sensitivity, and (to a lesser extent) adaptive capacity along the spatial dimension. They emphasize the overlay of social, ecological, and technological contexts of that vulnerability. The process of mapping vulnerability involves identifying appropriate indicators of the hazard, people, infrastructure, and ecosystems that are exposed to that hazard, varying levels of sensitivity and adaptive capacity, and aggregating all of this information. The ability to map these indicators depends on spatially-explicit data, which may not be available for all cities or for all areas of a single city. Sensitivity and adaptive capacity indicators are place-based. What constitutes as low income or racial minority, and as governance processes or emergency response protocols can vary widely in cities across the globe. Thus, the particular indicators used in vulnerability mapping are only transferable to a limited extent from one city to the next.

Ideally, cities would use current vulnerability maps as a baseline from which to plan for managing vulnerabilities over the long term, integrating results from regional climate models, a comprehensive suite of exposure models, and projections of future demographics. For instance, climate and weather models that forecast intensities and durations of storms could be used to produce estimates of runoff generated by various urban surfaces (such as through the rational runoff method), the locations and depths of flooding in the city's land surface depressions (Balstrøm and Crawford 2018), and measurements of the flooding that occurs along and outward from the stormwater drainage system through which stormwater is routed (such as via the United States Environmental Protection Agency's Storm Water Management Model, or SWMM). Demographic changes—such as an aging population—are also important for projecting relationships between flood exposure and capacities for coping with flooding. Spatial planning for managing these vulnerabilities includes climate and human population dynamics.

In practice, cities may have only coarse spatial resolution of land cover and temperature data, no estimates of how the regional climate is changing, exposure estimations from only one hazard model, no estimation of the future drainage network or land cover, and no spatially explicit projections of demographic changes. Even if a city does have a model for estimating current flooding exposure, the drainage system likely does not perform according to its design standards, due to structural deterioration or fouling of waterways by debris. Such limitations as these leave cities unable to give a full accounting of their current biophysical exposure and social vulnerability, let alone that of their future forms. Thus, cities tend to plan according to their current configuration, or for a similar configuration in the short term. For instance, New York City prioritized street tree planting in communities that rank high on an of-the-moment social vulnerability index (SVI) for heat (City of New York 2017).

In addition to providing a baseline from which to engage in future spatial planning, vulnerability assessment may also simply raise the visibility of disproportionate burden of extreme events and the socio-spatial distributions of risk (Walker 2009) in

ways that—along with direct information about people’s experiences—provide an evidentiary basis for community conversations about environmental justice. Moreover, mapping can be part of an inductive approach whereby patterns of socio-spatial segregation can be used to generate hypotheses about the economic, exclusionary, and policy processes that are producing and reproducing uneven risk in cities.

4.3 Urban Resilience to Extremes (UREx) Assessments and Mapping Methodologies

4.3.1 Vulnerability Assessments

As mentioned above, the selection of exposure and sensitivity variables is an imperfect process, and one which generally relies on published literature or expert opinion. Ideally, sensitivity indicators are selected on the basis of studies showing which risk factors are most closely related to an undesirable outcome, or on input from residents who experience such outcomes. For instance, many studies identify risk factors of heat-related mortality, illness, and distress calls (Bell et al. 2008; Hattis et al. 2012; Hondula et al. 2015; Kovats and Hajat 2008; Madrigano et al. 2015; Medina-Ramón et al. 2006; Rosenthal et al. 2014; Smargiassi et al. 2009; Uejio et al. 2011) and high financial burden due to flood-related property destruction (Balica et al. 2012). However, indicators of risk are highly contextual. In most U.S. cities, heat-related fatality rates are higher in low-income communities of color, but these constructs are not necessarily meaningful in all U.S. communities, let alone in Global South contexts. Vulnerability assessments that lack scientific or community experience-based informational resources from which to draw may be conducted on the basis of geographically-proximate studies or more general consensus about what factors are related to the production of environmental risk. Once indicators of vulnerability are constructed, they can be aggregated into a single vulnerability index (e.g., Johnson et al. 2012), and spatial clusters of vulnerability can be identified (e.g., Hamstead et al. 2018; Inostroza et al. 2016). Spatial scales at which indices are assessed include the census tract (Chow et al. 2012; Reid et al. 2009; Rinner et al. 2010), census block group (Bradford et al. 2015; Johnson et al. 2012; Uejio et al. 2011), Canadian dissemination area (e.g., in Canada; Rinner et al. 2010), or an even finer block scale where available (e.g., in Santiago, Chile; Inostroza et al. 2016). Here, we describe an application of heat and flooding vulnerability assessments in Hermosillo, Mexico.

4.3.1.1 Hermosillo Heat Vulnerability Assessment

To assess heat vulnerability in Hermosillo, Mexico we extracted the Landsat 8 thermal band for September 19, 2013 in order to produce a surface temperature image, and

used the Senora 2010 census data at the block-level to derive an estimate of populations exposed to hot microclimates. The temperature and total population were transformed to indices on a 0 to 1 scale and aggregated into an index of exposure.

To more precisely map locations of people who are sensitive to extreme heat, we first created population maps at a finer scale than the census block-level data available for Hermosillo. Block groups and other enumeration units include all residential and non-residential areas, and rarely reflect actual population distributions (Sleeter and Gould 2007). Dasymetric mapping is an interpolation technique that disaggregates population data by empirically sampling population values in an ancillary dataset (typically of land use) which represents the population statistical surface at a finer scale than that of the original population data. Based on this sampling procedure, weights are assigned to the classes of the ancillary dataset, and population values are disaggregated from the original spatial resolution to the finer resolution according to these derived weights (Mennis 2003). Since geographic units of analysis are often arbitrarily defined in relation to their applications and analyses, this approach is particularly useful for addressing ways in which the modifiable areal unit problem (MAUP) can mask problems of environmental justice (Mennis 2002).

The following variables comprised the sensitivity index: population <5 years of age, population >65 years of age, houses without electricity, houses without tap water, houses with at least one vehicle, illiterate adult population over 15 years, population without health services, unemployed population, disabled population, and total population. These variables were disaggregated using a land use parcel dataset which indicates high, medium, and low-density residential parcels, as well as mixed use and non-residential. Using the indexing procedure described for exposure above, we created indices for disability, quality of life (no tap water, no electric, age index, education/literacy index, health service access, vehicle access index), and economic constraint. These were then normalized and combined to an overall sensitivity index, which was then combined with a normalized exposure index to generate an index of overall vulnerability (Fig. 4.1).

4.3.1.2 Hermosillo Flood Vulnerability Assessment

For flood vulnerability, we used the city's high-resolution topographic information (1 m resolution LiDAR) and estimates from the localized constructed analog (LOCA) model to develop a blue spot model for flooding (Balstrøm and Crawford 2018). This blue spot model combines a digital elevation model (DEM) input and the sum of precipitation that occurs over the course of a rainfall event of some return period of interest (in our case, a 100-year return period storm), and the results are a shapefile of the locations of depressions in the landscape that fill to capacity, and tabular information about the depths of these filled depressions. We produced a final relative exposure map by calculating the percentage of a given census block covered by areas that experience blue spot flooding (Fig. 4.2).

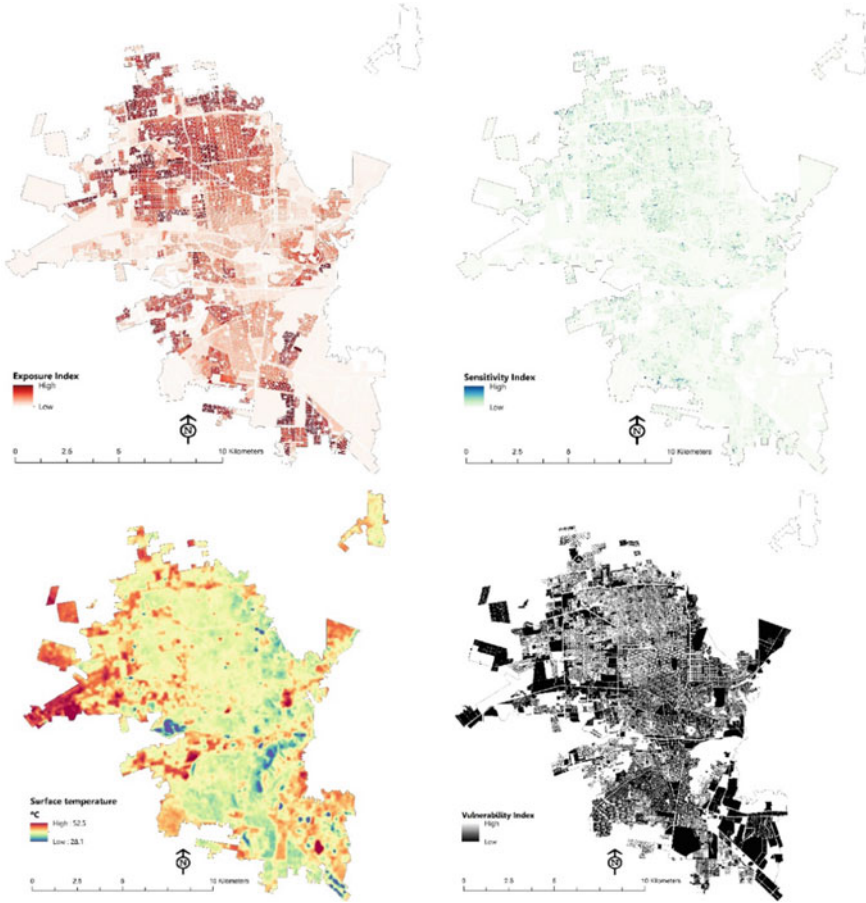


Fig. 4.1 From upper right to lower left: Exposure index, sensitivity index, surface temperature, and overall vulnerability index

Additionally, we considered technological sources of flooding in the city, specifically those which might be caused by failure of the drainage infrastructure. Engineers who worked with us relayed that older, narrower pipe elements of the drainage network would be more likely to fail or be overwhelmed than newer, wider ones. Thus, using a polyline file provided by the city that included the pipe diameter and age, we determined the relative exposure of the city to flooding due to differences in the age and dimensions of pipes in its drainage network (Fig. 4.3).

For sensitivity indicators, we used an inductive approach and polled local flooding experts on the social and demographic factors they saw as critical for determining differences in sensitivity and adaptability among populations (Table 4.1).

We used a 2010 census data shape file that aggregated these factors at the census block level. We assigned factors equal weight, normalized them between 0 and 1

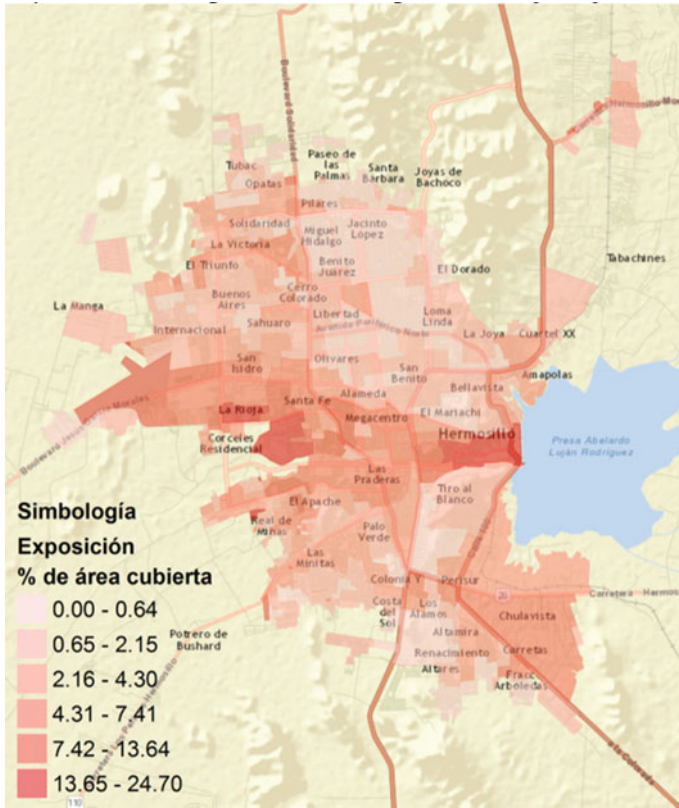


Fig. 4.2 Relative flood exposure map indicating the percent area of each census block covered by estimate flood areas according to the blue spot model

(where 0 was the lowest value of a given factor across the entire city and 1 was the highest value of a given factor across the entire city), and aggregated them. Thus, census blocks with greater totals had greater relative vulnerability than census blocks with lower totals (Fig. 4.4).

These blue spot exposure, technological vulnerability, and social vulnerability indicators were combined such that:

$$\text{Combined vulnerability} = \text{blue spot exposure} * (\text{technological vulnerability} + \text{social vulnerability})$$

This combined vulnerability was then normalized between 0 and 1, such that 0 was the lowest overall vulnerability value among all the census blocks, and 1 was the greatest overall vulnerability among all the census blocks (Fig. 4.5).

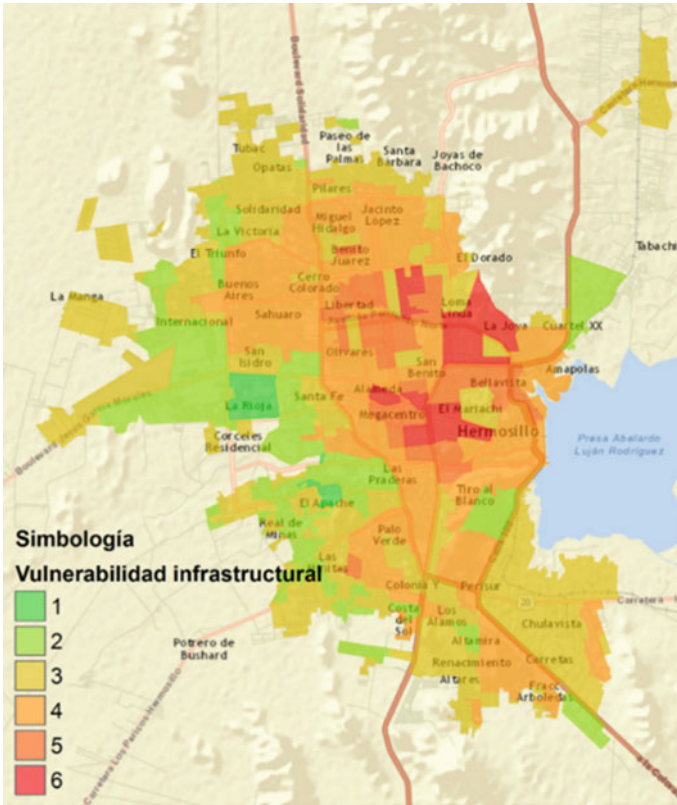


Fig. 4.3 Relative infrastructural vulnerability map indicating areas more (red) and less (green) at risk of being overwhelmed or failing due to extreme rainfall

Table 4.1 Types of social vulnerability indicators used in assessing overall social vulnerability of the city, as well as the forms of vulnerability (sensitivity or adaptability) they represent

Selected social vulnerability indicator	Type(s) of vulnerability
Percent population illiterate	Adaptability
Percent population with some different capacity	Sensitivity/Adaptability
Percent infants (1 to 12 months)	Sensitivity
Percent older than 65	Sensitivity
Household density	Sensitivity
Impoverished (“marginación social”)	Sensitivity/Adaptability

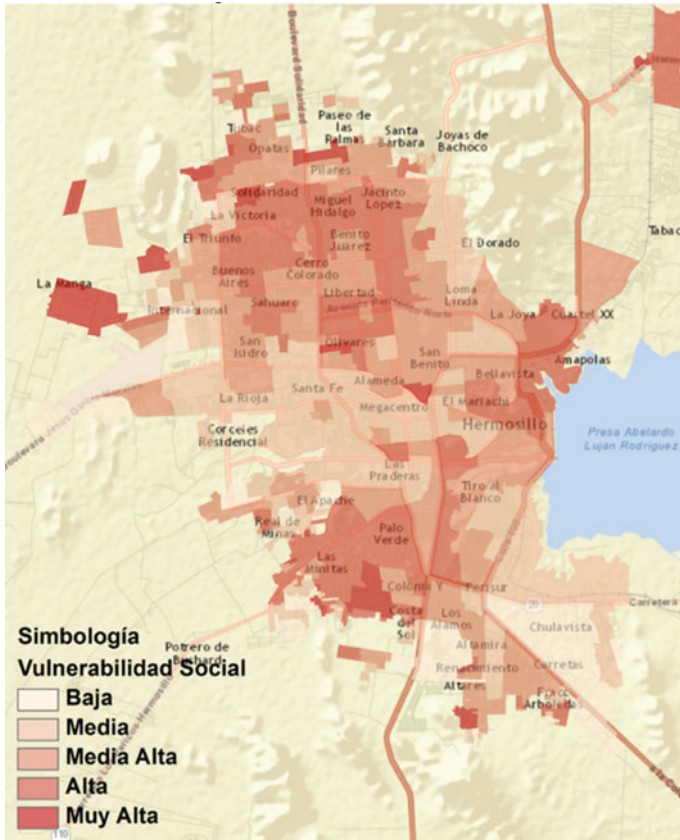


Fig. 4.4 Map showing relative social vulnerability at the census block level. “Baja” indicates low social vulnerability; “Muy Alta” indicates very high social vulnerability

4.3.2 Mapping Urban Landscapes

To inform potential landscape-based interventions in vulnerable locations, we used a landscape-based heat exposure indicator based on the Structure of Urban Landscapes (STURLA) classification (Hamstead et al. 2016) in UREx cities. (For more information about how STURLA is used in future heat projections, see Chap. 9.) STURLA comprised landscape composition elements—including built and natural components—that are common in a given urban environment. The approach involves constructing landscape classes comprising tree canopy, grass/shrub, water, bare soil, paved, low-rise buildings (1–3 stories), mid-rise buildings (4–9 stories), and high-rise buildings (>9 stories). The most abundant classes are defined as those which comprise a majority of land area. For example, in Portland, Oregon, USA, 12 classes account for 90% of the city’s land area, revealing a range of temperature signatures from 21.4 to 33.4 °C (Figs. 4.6 and 4.7).

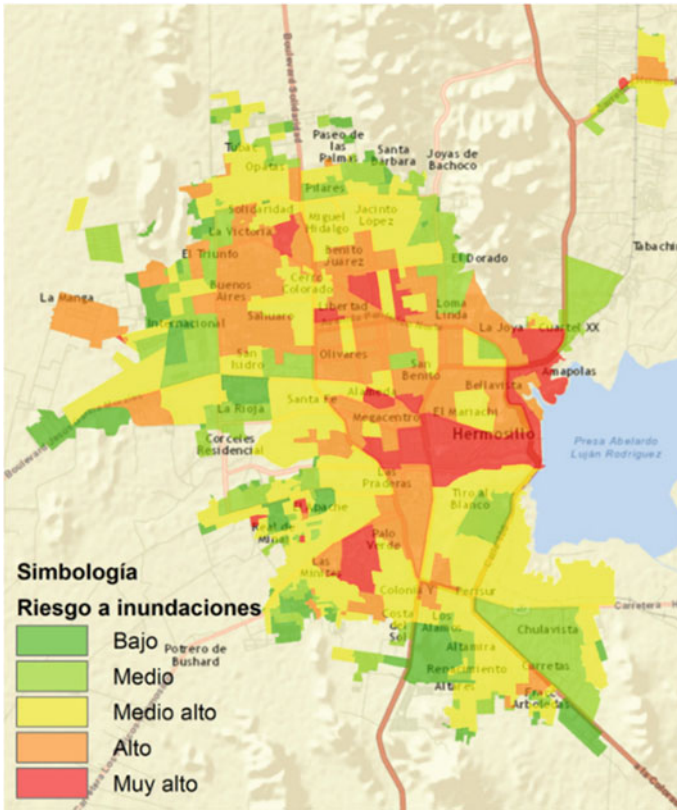


Fig. 4.5 Relative combined vulnerability to flooding in Hermosillo at the census block level. “Bajo” indicates low combined vulnerability; “Muy alto” indicates very high combined vulnerability

Landscape mapping can be used to build on vulnerability assessments by indicating locations where modifiable components of the built environment can be transformed to better support heat mitigation. For instance, areas where pavement predominates could be landscaped with trees, vegetation, and water features, and high-rise buildings could be developed for shade and painted with white roofs in order to reduce albedo. This mapping technique helps to link spatial vulnerability with the built environment features that partially account for it, and inform spatial planning to mitigate micro-urban heat islands.

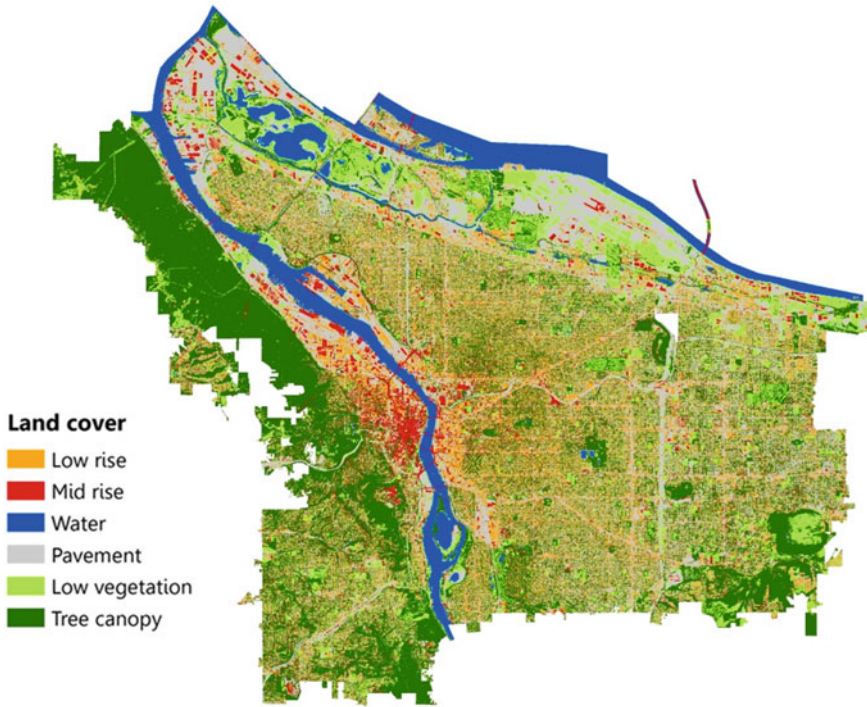


Fig. 4.6 Spatial distribution of land covers in Portland, Oregon, USA

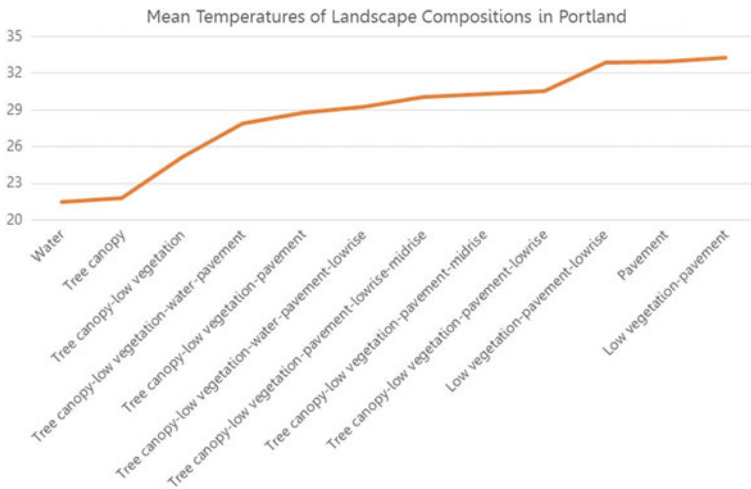


Fig. 4.7 Distribution of temperature across landscape classes in Portland, Oregon, USA. Average temperature (°C) of the frequently occurring landscape compositions, or adjacent land cover combinations that occur across the landscape

4.3.3 Mapping Extreme Event Injustice

We analyzed which populations are disproportionately exposed to hot micro-climates in New York City by performing cluster analysis, which identifies significantly clustered features for which the difference between neighborhood-level values and the sum of all values is too large to be the result of chance. To be a statistically significant hot spot, the feature must have a high value (e.g., high temperature value) and be surrounded by other features with high values. Alternatively, cold spots emerge where features with low values are surrounded by other features with low values. Using this approach, we find that African Americans and Hispanics are more likely to live in hot micro-climate clusters compared with the population as a whole (Figs. 4.8 and 4.9).

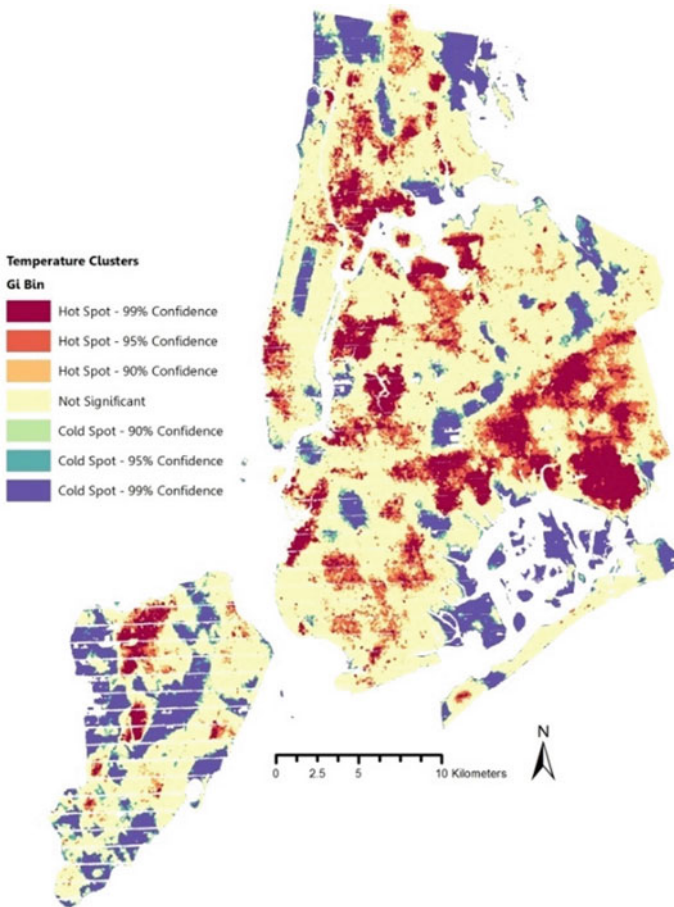


Fig. 4.8 Hot and cold temperature clusters in New York City. Confidence levels indicate the probability that a spatial cluster does not occur due to chance

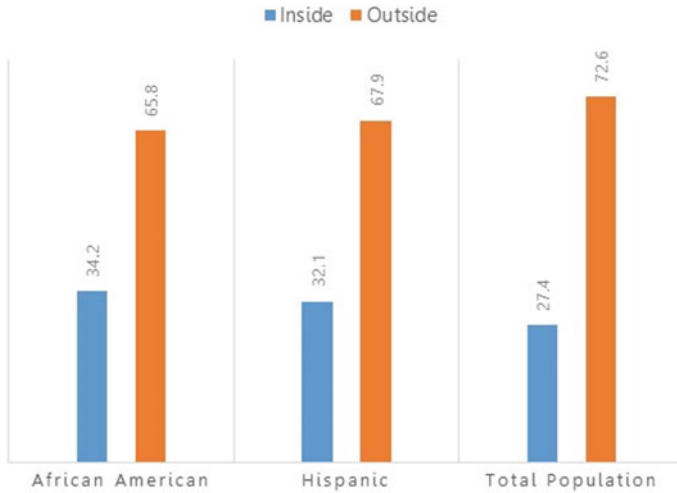


Fig. 4.9 Populations of minority race and ethnicity who live within clusters of hot micro-climates, compared with the population as a whole

Mapping extreme event injustice helps to characterize the extent to which urban development policy has disfavored racial and ethnic groups through both formal and informal policies. For instance, throughout the twentieth century in the USA, racial zoning and mortgage lending practices were used to concentrate African Americans in communities with industrial land uses, and large, heavily-trafficked highways were built through African American communities. These exclusionary housing practices and segregation tactics partially contributed to a landscape of uneven heat burden and likely the discrepancy in heat-related deaths between whites and blacks in the USA (Berko et al. 2014). While vulnerability assessments highlight areas where multiple risk factors overlap, mapping injustice helps to identify which social groups should be most critically engaged to curb the health and economic impacts of extreme events.

4.4 Conclusion

Assessing distributions of risk to extreme weather events in the context of SETS is an important step toward creating future visions of resilience. Maps express uneven distributions of risk and ways in which structural inequality manifests itself in SETS. Maps enable communities to assess ways in which these manifestations misalign with cultural values, and to develop adaptive practices that better represent these values. However, not all values can be expressed spatially, and thus it is important to combine mapping activities with storytelling and other approaches for articulating

values. Moreover, vulnerability mapping often focuses on current rather than future conditions and must be combined with future visioning activities in order to help construct resilient urban futures.

In addition to these inherent limitations of vulnerability mapping, there are also technical difficulties. Increasingly, cities are developing more comprehensive hydrological models that incorporate more potential sources for urban flooding than have been included in past models. FLO-2D, for example, is a hydrological modeling software that allows the user to wrangle surface runoff generation, tidal inputs, and drainage network flow in a way that previously would have required the creative use of several separate hydrological models. However, in spite of the availability of such software, comprehensive flood models have not been developed for most cities due to data limitations or scarcity, the lack of personnel with appropriate technical expertise, and the cost of software. Even when sophisticated models are feasible, they are nonetheless limited by their data, which always has some degree of spatial imprecision and often does not reflect current landscape conditions. Additionally, our interview work in Hermosillo, Mexico made clear to us that models, even when accurate, may provide a very limited basis on which managers can design measures to reduce flood exposure and impact. Modelers and professionals who work with these models should bear in mind the aphorism that “all models are wrong, but some are useful,” (Box 1976) and further that models should be coupled with, rather than displace, on-the-ground and qualitative methods.

An understanding of contemporary vulnerability conditions requires not only a description of the spatial patterns of that vulnerability, but also of the processes which produced it. In cities where socio-spatial segregation is coupled with exposure to extreme weather, there is a need to identify the economic, political, and exclusionary processes that are producing and reproducing uneven risk. Moreover, while scholarship and practice focus on reducing flood and heat vulnerability by limiting or eliminating exposure, evidence suggests that policy actors should focus as much or more attention on reducing vulnerability through the reduction of poverty. In many cities, the impoverished are more likely to live in areas that are exposed to flooding (Winsemius et al. 2018; Mahanta and Das 2017), and impoverished people—who often experience multiple forms of exclusion—are overall more sensitive and maladapted to flooding (Cutter et al. 2000). Moreover, exposure to flooding causes people to become impoverished and deepens the poverty of people who are already impoverished (Mahanta and Das 2017; Carter et al. 2007). Thus, flooding not only disproportionately affects people who are already sensitive to risk but also increases the portion of people who will be sensitive and maladapted to the next flooding event. Intentionally or not, poverty is often presented by vulnerability researchers as a vulnerability metric of equal consideration to other risk factors, which can be optimally reduced in a remotely determined and technocratic way. In contrast, researchers in the fields of political ecology and critical geography have distinguished poverty as a human rights issue, and emphasized that it must be addressed in ways that contend with place-based conceptions of justice (Ajibade and McBean 2014). The rightful naming of poverty as a human rights issue holds cities, states, and nations

accountable for wrongs committed, and has opened successfully pursued pathways to poverty reduction (Bryant 2008).

In addition to coupling vulnerability mapping with practices that enable communities to address the structural inequality that pervades many cities, as well as to orient people toward the future, mapping practices could also be integrated with asset-based community development processes by identifying characteristics of resilience. Conveying the biophysical and institutional assets that help to protect people against extreme weather is important both for providing models of best practices and developing a positive sense of place to serve as a foundation for positive futures.

Acknowledgements This work was supported by the Urban Resilience to Extreme Weather-Related Events Sustainability Research Network (URExSRN; NSF grant no. SES 1444755) and Environmental Protection Agency Science to Achieve Results Fellowship No. 91760801-0. The authors are grateful to Dana Hellman for suggestions on an earlier version of the manuscript.

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