Climate Risk Management 34 (2021) 100354

Contents lists available at ScienceDirect

Climate Risk Management

journal homepage: www.elsevier.com/locate/crm

Is flood resilience planning improving? A longitudinal analysis of networks of plans in Boston and Fort Lauderdale

Sierra Woodruff [a], Sara Meerow [b,*], Philip Gilbertson [b], Bryce Hannibal [d], Melina Matos [a], Malini Roy [a], Matthew Malecha [a], Siyu Yu [a], Phil Berke [c]

[a] Texas A&M University, Landscape Architecture and Urban Planning
[b] Arizona State University, School of Geographical Sciences and Urban Planning
[c] University of North Carolina, Department of City & Regional Planning, and Institute for the Environment
[d] U.S. Census Bureau, 4600 Silver Hill Rd Suitland, MD 20746, United States

A R T I C L E I N F O

Keywords:
Flooding
Sea Level Rise
Network of plans
Longitudinal
Plan Integration for Resilience Scorecard
Resilience

A B S T R A C T

As climate change increases flood risk, there is growing recognition that the multiple plans cities adopt often work at cross purposes and encourage development in areas at risk of current and future flooding. There have been calls for a more coordinated approach to planning for current and future flood risks, but is planning rising to the challenge? We apply the Plan Integration for Resilience Scorecard (PIRS) methodology to spatially evaluate policies that would impact physical vulnerability to flooding in the network of different city plans that shape land use and steer development in Boston, MA and Fort Lauderdale, FL. Unlike previous applications of this approach, we look at how the plan network is changing over time. Between 2015 and 2019, attention on climate change grew in both cities, as did the number of plans and policies across the network with the potential to decrease physical vulnerability. New types of plans, such as climate change adaptation plans, play an important role in reducing flood risks. However, plans perpetuate past disparities in policy attention. As the first study to analyze how city networks of plans and their potential impact on resilience evolve over time, this work has important implications for planning scholarship and practice as well as hazard and climate change governance more broadly.

1. Introduction

Coastal communities are experiencing ever greater flood damages. Flood costs are increasing as a result of rising sea levels and more intense storms caused by climate change and continued development in flood-prone areas (Central, 2019; Hallegatte et al., 2013; Kousky, 2014; Moser, 2012). This problem is widely recognized in both research and practice, and has sparked calls for more proactive planning to reduce flooding risks in coastal communities (Aerts et al., 2014; Brody et al., 2007; National Research Council, 2014). High-profile initiatives such as the 100 Resilient Cities program and National Disaster Resilience Competition have channeled millions of dollars into coastal cities like New York City to ostensibly reduce vulnerability to flooding, among other hazards (Finn et al., 2019).

* Corresponding author.
E-mail addresses: swoodruff@tamu.edu (S. Woodruff), Sara.Meerow@asu.edu (S. Meerow), pggilber@asu.edu (P. Gilbertson), bryce.hannibal@census.gov (B. Hannibal), melina_matos@tamu.edu (M. Matos), mr956@tamu.edu (M. Roy), mmalecha@arch.tamu.edu (M. Malecha), yusiyu_1989@tamu.edu (S. Yu), pberke@email.unc.edu (P. Berke).

https://doi.org/10.1016/j.crm.2021.100354
Received 16 February 2021; Received in revised form 12 August 2021; Accepted 22 August 2021
Available online 28 August 2021

Yet it remains unclear whether planning for flood hazards is improving.

Besides climate change, research suggests that a major reason that flooding costs are increasing is because of planning decisions about where and how to develop buildings and other infrastructure (Brody et al., 2007; Burby et al., 1999; Godschalk et al., 1998; National Academies of Sciences, Engineering, and Medicine, 2019). These decisions are laid out in different types of plans that can increase or decrease vulnerability. In addition to comprehensive plans and hazard mitigation plans, communities often have transportation plans, housing plans, and open space plans that influence where and how development occurs (Berke et al., 2015). Collectively, these interrelated plans are referred to as a "network of plans" (Berke et al., 2015). Spatial analyses of policies in plans reveal that they often work at cross purposes and encourage development in areas currently at risk of flooding or at future risk of flooding (Berke et al., 2019a). This recognition has led to calls for a more coordinated approach to hazards planning that considers how vulnerability to hazards is addressed across the full network of plans (Malecha et al., 2019; Yu et al., 2020). Integrating flood mitigation across plans would not only help reduce flood damage costs, but also likely avoid conflict and duplication, increase implementation, and promote synergies across planning efforts (Birchall and Bonnett, 2021; Runhaar et al., 2018).

While assessments of the full network of plans represent an important innovation over studies of a single plan type, they only provide a snapshot in time. The reality is that planning is dynamic, and plans are evolving instruments that undergo continual revisions and updates. Plans adapt over time to changing conditions, needs, and experiences of a community (Brody, 2003). Moreover, in many countries and states communities are required by law to regularly update comprehensive or general plans. In the U.S., the Federal Emergency Management Agency (FEMA) mandates that hazard mitigation plans be updated every five years to remain eligible for grant funding.

At the same time, cities are beginning to create new plans like climate change adaptation plans and resilience plans to address growing flood and hazard risks (Meerow and Woodruff, 2020). For example, the Rockefeller Foundation's 100 Resilient City program provided 100 cities worldwide with funding and resources to hire a chief resilience officer and develop a resilience plan. Cities within the program took very different approaches to organizing these resilience efforts (Fastiggi et al., 2020) and the resulting plans are quite variable (Fitzgibbons and Mitchell, 2019; Meerow et al., 2019; Woodruff et al., 2018b). Consequently, it is unclear how these plans fit within existing networks of plans, and what impact they will have on overall vulnerability to flooding.

Few studies examine how plans have evolved over time (Brody, 2003). There is a well-established literature examining the content and quality of the multiple types of plans cities adopt that affect flood risk individually (Lyles and Stevens, 2014; Lyles et al., 2014; Woodruff and Stults, 2016) and a growing body of work also explores how multiple plans interact to affect vulnerability (Berke et al., 2019a; Berke et al., 2019b; Malecha et al., forthcoming; Malecha et al., 2018; Yu et al., 2020), but longitudinal studies are sparse (Brody, 2003). An analysis of Melbourne's and Stockholm's comprehensive plans since 1900 found that plans increasingly recognize ecosystem services, but services of interest change across plan updates, raising doubts about the ability of planning to guide long-term ecological governance (Wilkinson et al., 2013). Maccallum and Hopkins (2011) use discourse analysis to examine how plans in Perth, Australia from 1955 to 2010 reflect persistent themes and changing priorities in larger planning discourse. For instance, all the plans reflect the idea that planning is a technical activity despite the increasing emphasis on economic goals and politicization of planning topics. A case study of seven communities severely affected by flooding found that communities updated their flood policies and programs after the flood, demonstrating learning (Albright and Crow, 2019). In a longitudinal study of 60 local comprehensive plans in Florida and Washington, Brody (2003) found that plans improved between 1991 and 1999.

This lack of longitudinal planning assessments appears to be part of a broader problem: namely that we know very little about how or why city resilience is changing over time. A recent report by the US National Academies of Sciences, Engineering, and Medicine (2019, 9) concluded that there is a critical need for longitudinal research on resilience. "Long-term, periodic, comprehensive resilience assessment remains an unmet need… A new kind of research is needed that: (1) can address the dynamic state of communities and their changes in risk and resilience over time".

This study helps to address this gap by comparing the number and spatial distribution of policies that may affect physical vulnerability to flooding across the network of plans at two points in time. We focus on the following research questions:

How has the network of plans' combined potential effect on physical vulnerability to flooding changed over time? Namely, how have the number and spatial distribution of policies that may increase or decrease physical vulnerability to flooding changed?

What is the influence of new types of plans on vulnerability? Specifically, how has the emergence of climate change adaptation and resilience plans impacted the policies in plans that have the potential to affect physical vulnerability to flooding?

We answer these questions through an analysis of plans from two coastal U.S. cities, Fort Lauderdale, FL and Boston, MA. The next section introduces these two case study cities and outlines the methodological approach. We describe how the assessments of each city's plan network change over time, and discuss the implications of these longitudinal findings for urban planning, hazards, and climate change scholarship and practice.

2. Methods

We apply the Plan Integration for Resilience Scorecard (PIRS) methodology (Berke et al., 2015; Malecha et al., 2019) to spatially evaluate the impact of city plans on physical flood vulnerability in Boston, MA and Fort Lauderdale, FL. We include all plans that were adopted by city agencies that contain policies intended to guide the use, location, density, and design of urban development in flood hazard zones. The PIRS analysis was conducted for plan networks in both cities in 2015 and in 2019.

2.1. Plan integration for resilience scorecard (PIRS)

To determine the implications of policies proposed in plans for long-term flood risk, we used the PIRS. Developed by Berke et al. (2015), PIRS is a tool to spatially evaluate the potential impacts of plan policies on physical vulnerability to flooding. We define physical vulnerability as a function of the exposure and sensitivity of infrastructure (including homes, other buildings, amenities, and transportation). Exposure is determined by geographic location in hazard zones, in this case the current floodplains and future sea level rise zones. Sensitivity refers to the degree to which the asset or system is affected by flooding. Policies may reduce exposure by relocating infrastructure out of flood zones or reducing sensitivity, for example through higher design standards (e.g. elevation requirements) or drainage improvements. We do not assess policies related to social vulnerability, although we recognize that they play an important role in overall community resilience (Cutter et al., 2003). Since it was first developed, the PIRS method has been applied to numerous cities in the U.S. and internationally (Berke et al., 2019a; Malecha et al., 2018; Malecha et al., 2021; Yu et al., 2020) and translated into a practitioner-oriented PIRS Guidebook (Malecha et al., 2019). This is the first study that has used PIRS to evaluate change over time. Specifically, we examine how the number and spatial distribution of policies that may affect physical vulnerability to flooding across the network of plans changes over time.

PIRS is one of the few and the most established methods to analyze a network of plans or the multiple plans that collectively guide development in a community (Woodruff, 2018). PIRS draws on content analysis approaches to identify and score policies (Berke et al., 2015). Building on earlier work to create an information system of plans (Finn et al., 2007), the unique strength of PIRS is spatially assigning and analyzing the coded policies. By spatially mapping policies from multiple plans, PIRS examines the spatial implications of plan policies, how policies from multiple plans relate to each other, and the combined implication of the network of plans for different areas of the community. Using PIRS, we identified policies in each plan that could affect physical vulnerability to flooding and scored the policies on whether they would likely increase or decrease vulnerability, and spatially mapped them. We then spatially layered the policies from each plan to determine the overall potential effect on physical vulnerability.

First, we divided each city into *district-hazard zones*. By dividing cities into smaller districts, we could examine how plans and policies may affect neighborhoods differently. In Boston, we used neighborhoods produced by Boston Redevelopment Authority as the basis for districts. In Fort Lauderdale, we used the 2010 Census block groups, since the city did not have clear planning districts, but then added four Regional Activity Centers that were outlined in the city’s 2008 comprehensive plan. These districts were then intersected with two hazard zones – the 100-year floodplain and projected sea level rise for 2100. The 100-year floodplain, or the area that has a 1% chance of flooding in a given year, was included to examine how plans potentially address or increase current flood risk. To map the 100-year floodplain, we used data from FEMA. We included the sea level rise projection to understand how city plans affect long-term flood risks. To map future sea level rise, we used the most recent projections from the National Oceanic and Atmospheric

Table 1
Example policies included in the plan integration for resilience scorecard (PIRS) analysis. For each policy, we provide the score and a short justification for inclusion, scoring, and spatial assignment.

Plan	Policy	Score	Justification
Boston 2017 Resilience Strategy	12–2: Strengthen policies that encourage the production and maintenance of deed-restricted low-, moderate-, and middle-income housing….the reuse of surplus City parcels…	−1	Additional development, applied to district-hazard zones containing surplus city parcels
Boston 2014 Hazard Mitigation Plan	Adopt a Wetlands Ordinance that includes sea-level rise and develop new floodplain maps that incorporate projected climate change to mitigate flood hazards	+1	Protects wetlands and their flood mitigation potential, applied to district-hazard zones containing wetlands
2016 Climate Ready Boston	Revise the zoning code to support climate-ready buildings […] ensure regulations on the use, height, and bulk of buildings promote and do not discourage climate- ready new construction and retrofits.	+1	Prepares buildings for flooding and sea level rise, applied to all district-hazard zones
2017 Coastal Resilience Solutions for East Boston and Charlestown	Establish a Flood Protection Overlay District and require potential integration with flood protection systems	+1	Enhances flood protection, applied to all district-hazard zones in small area plan jurisdiction (e.g. East Boston and Charlestown)
Boston 2004 Roxbury Master Plan	The intersection of Melnea Cass Boulevard, Tremont Street and Columbus Avenue [I] is a prominent location in Roxbury. The development of the remaining parcels in this area should take full advantage of Transit-Oriented Development strategies.	−1	Encourages development in area at risk of flooding, applied to district hazard zone containing specific intersection
Fort Lauderdale 2008 Comprehensive Plan	To have the lowest floor elevation no lower than the elevation or the respective area depicted on the 100 Year Flood Elevation Map. Retain the first inch on storm water runoff on-site.	+1	Updates building requirements to reduce flooding, applied to 100-year floodplain district-hazard zones
Fort Lauderdale 2011 Sustainability Action Plan	Encourage infill development or reuse/ rehabilitation of existing structures […] infill will be encouraged in concert with water inundation map that discourages development in low lying, vulnerable areas regarding climate change.	+1	While infill is encouraged, policy specifically notes that this development should avoid areas that are vulnerable to flooding; applied to all district-hazard zones
Fort Lauderdale 2018 Draft Comprehensive Plan	Support further development of marine industries in Foreign Trade Zone No. 241 as administered by the Fort Lauderdale Executive Airport	−1	Encourages additional development in area at risk of flooding, applied to district-hazard zones that intersect foreign trade zone no.241

Administration (NOAA; Sweet et al., 2017). Intersecting neighborhoods with the flood zones resulted in 46 district-hazard zones in Boston and 115 district-hazard zones in Fort Lauderdale.

The second step in the PIRS analysis was to collect relevant policies from plans. Two researchers independently read each plan and collected policies that met three criteria: (1) The policy contains a recognizable policy tool; (2) The policy is spatial (e.g., parks, vacant lots) and can be mapped using publicly available GIS data (including policies that apply across the entire city), and; (3) Implementing the policy in a flood prone area will increase or decrease physical vulnerability to flooding. In this study, we focused on policies that affect physical vulnerability to flooding by influencing exposure (where) and sensitivity (how and what) of development in a city.

Policies were then scored based on their effect on vulnerability. Policies that reduce physical vulnerability received a score of + 1. Policies that increase physical vulnerability received a score of −1. As outlined in Table 1, the policy to "Encourage infill development or reuse/ rehabilitation of existing structures [...] infill will be encouraged in concert with water inundation map that discourages development in low lying, vulnerable areas regarding climate change" from Fort Lauderdale's Sustainability plans is scored '+1' because it reduces vulnerability by limiting exposure of future development. In the Climate Ready Boston Plan, the policy to "Revise the zoning code to support climate-ready buildings" reduces sensitivity of future development and is also scored policies scored '+1'. Policies that increase development in areas exposed to flood hazards but include flood measures to reduce sensitivity were considered to have a neutral effect on vulnerability and were not scored. For example, "Create a Climate-Resilient Waterfront…As new building infrastructure will have an anticipated lifespan of 50 to 100 years, the implementation of climate smart development principles will be a necessity" (Boston Redevelopment Authority, 2017, p 35) increases vulnerability by encouraging development in the highly flood prone waterfront, but also reduces vulnerability by intending to protect new development against future floods. Again, two researchers independently scored each policy.

Each policy was then assigned to district-hazard zones. To help map policies, additional geospatial data was collected as needed. For example, if a policy mentions vacant lots, we collected and mapped geospatial data on vacant lots to help identify in which district-

Table 2
List of plans included in 2015 and 2019 analysis for Boston and Fort Lauderdale.

2015 Scorecard	2019 Scorecard
Boston	
2004 Roxbury Strategic Master Plan*	2004 Roxbury Strategic Master Plan*
2014 Housing a Changing City	2014 Housing a Changing City
2008 Hazard Mitigation Plan	2014 Hazard Mitigation Plan
2008 Open Space Plan	2015 Open Space & Recreation Plan
2014 Greenovate Boston	2014 Greenovate Boston
2011 Columbia Point Master Plan	2011 Columbia Point Master Plan
	2015 South Boston Waterfront Sustainable Transportation Plan
	2015 Blue Hill Cummins Plan
	2016 Climate Ready Boston
	2017 Boston Resilience Strategy
	2017 Downtown Waterfront Municipal Harbor Plan
	2017 Go Boston 2030
	2017 Raymond L. Flynn Marine Park Master Plan Update
	2017 Coastal Resilience Solutions for East Boston and Charlestown
	2017 Imagine Boston 2030
	2018 Capital Planning
	2018 Boston Water and Sewer Commission CIP
	2018 Coastal Resilience Solutions for South Boston
Fort Lauderdale	
2007 Downtown Master Plan	
2007 Davie Boulevard Master Plan	
2008 Comprehensive Plan	2018 Draft Comprehensive Plan
2008 Downtown New River Master Plan	2008 Downtown New River Master Plan
2008 North US1 Urban Design Plan	2008 North US1 Urban Design Plan
2011 Riverwalk District Plan	2011 Riverwalk District Plan
2011 Sustainability Plan	2011 Sustainability Plan
2012 Broward County Enhanced Local Mitigation Strategy	2017 Broward County Enhanced Local Mitigation Strategy
2013 Fast Forward Fort Lauderdale Vision Plan	2013 Fast Forward Fort Lauderdale Vision Plan
2014 Bridges Master Plan	2014 Bridges Master Plan
2014 Downtown Master Plan-Transit Oriented Development Guidelines	2014 Downtown Master Plan-Transit Oriented Development Guidelines
	2015 Canal Dredging Master Plan
	2016 Parks and Recreation System Master Plan
	2018 Press Play Strategic Plan
	2018 Stormwater Master Plan update
	2018 Seawall Master Plan
	2019 FY 2019 Commission Annual Action Plan
	2019 2019–2023 Community Investment Plan

*While the 2004 Roxbury Strategic Master Plan falls outside our 10-year sampling frame, it continues to be the basis for development decisions in the neighborhood and so was included in both scorecards (http://www.bostonplans.org/planning/planning-initiatives/roxbury-strategic-master-plan).

hazard zones the policy would apply.

To illustrate the process, Boston's housing plan includes a policy to "Identify and make available City- and State-owned surplus land for developers to build mixed-income housing" (City of Boston, 2014b, 11). We include this policy because the policy tool, build mixed-income housing, will have a tangible impact on physical vulnerability to flooding and can be spatially assigned to surplus land GIS data. If surplus land in the current or future flood zone is developed, it would increase physical vulnerability so we scored this policy −1. We then assigned this policy to the 12 district-hazard zones that contain city-owned surplus lots, using geospatial data available from the City (Boston Planning and Development, 2021). We excluded policies that were not spatial like "Ensure developers, owners, and tenants understand how climate change will impact housing and provide guidance on preparing their homes and buildings for these impacts" (City of Boston, 2014b, 106) or where the effect on physical vulnerability to floods was unclear like "Create new, permanently affordable units to serve extremely low-income households by converting at least 1,700 Section 8 mobile vouchers into project-based assistance" (City of Boston, 2014b, 7).

As with all content analysis methods, there is some subjectivity in each step of the PIRS method. To ensure reliability, researchers were trained using the PIRS guidebook and tested the approach on a shared set of training plans. Through this process, we established more detailed, common guidelines to select and score policies. For example, we defined "spatial" to include policies that apply city-wide and determined that adding sidewalks, bike lanes, and trails does not have a meaningful potential to impact vulnerability. To further ensure reliability, two researchers separately completed each PIRS stage. Researchers discussed and reconciled differences in policy selection, scoring, and spatial assignment by referring to these common guidelines. Disagreements were tracked and lingering disagreements were discussed by the entire research team.

We report the total number of policies in each plan that may increase or decrease vulnerability. For each district-hazard zone, we sum the score of the policies to calculate the net policy score. We also report average policy scores by averaging net scores across district-hazard zones.

2.2. Case study cities

Since we are interested in how planning is changing in response to current and future flood risk, we apply PIRS to two cities highly vulnerable to coastal flooding. Both Boston and Fort Lauderdale experience regular flooding and face increasing flood risks due to sea level rise. Both are also widely regarded as leaders in resilience planning, although they have taken different approaches. Boston released its first stand-alone climate change adaptation plan in 2016 and, since then, has developed neighborhood-scale adaptation plans as well as integrated policies to address sea level rise and increased flooding into new city-wide plans. On the other hand, Fort Lauderdale has focused on integrating sea level rise considerations into its existing planning framework. These cities also represent an opportunity to combine work from an early PIRS study (Berke et al., 2019b) and new data from an analysis on social and plan networks.

Boston is facing up to 1.5 feet of sea level rise by 2050. In 2050, the area at risk of a 100-year flood would expand to include over 2,000 buildings, representing $20 billion in real estate value (City of Boston, 2016). Areas at risk of future flooding are also those of projected growth and development. Boston joined the 100 Resilient Cities program in 2014, and in 2017 they released their resilience strategy. As Boston developed their resilience strategy, they prepared their first comprehensive plan in 50 years. Additionally, Boston released their first climate change adaptation plan in 2016.

For 2015, members of our research team identified six relevant plans in Boston, MA (following Berke et al., 2019a). Table 2 provides the full list of plans analyzed. For each analysis, we aim to include all plans that influence where, how, and what development occurs, and which consequently have the potential to shape physical vulnerability to flooding. Following earlier PIRS studies (Berke et al., 2015), we include plans that were adopted or updated in the ten years before we started the analysis (2005 for the first analysis and 2008 for the second). In some cases, we included older plans that were still guiding development. The plan lists were validated with city officials. While including all plans adopted in the last ten years results in substantial overlap between the 2015 and 2019 scorecards, it provides a complete picture of the relevant policies at each time point. When we repeated the analysis for 2019, Boston had adopted 14 new plans, including its first comprehensive plan in more than 50 years, a resilience plan, a climate change adaptation plan, two neighborhood adaptation plans, and an updated hazard mitigation plan. This represents a unique opportunity to examine how the effect of plans on vulnerability to flooding is changing over time and, in particular, how new types of plans fit into existing networks of plans. In total, 20 plans were analyzed in Boston.

Fort Lauderdale has over 300 miles of coastline and inland waterways, is already experiencing climate change impacts including higher storm surge, tidal flooding, and saltwater intrusion, and is expecting about two feet of sea level rise by 2050 (City of Fort Lauderdale, 2018). The city is committed to reducing vulnerability to flooding and adapting to sea level rise, as indicated by Fort Lauderdale's vision: "We Are Ready". While not part of the 100 Resilient Cities program, Fort Lauderdale is part of the Southeast Florida Regional Climate Compact, which is recognized as a national model for regional climate collaboration (Vella et al., 2016)

For 2015 we analyzed 11 plans the city had adopted since 2005 (Berke et al., 2019b). For 2019, we analyzed 16 plans including two updates of previous plans and seven new plans. In the 2019 analysis, we did not include plans that were adopted before 2008 – the *Downtown Master Plan* (2007) and the *Davie Boulevard Master Plan* (2007) – because they did not fall in the ten-year sampling frame and were no longer considered relevant for development.

2.3. Limitations

While this paper begins to address how planning is evolving to respond to increasing flood risks, there are limitations to recognize.

First, it looks at two cities in two time periods. Given our limited sample size, we cannot draw generalizable conclusions. Future work should apply the scorecard longitudinally in more cities, both in the US and internationally. We look at how the scorecards changed in a four-year period; a longer time horizon would give a better sense of planning trends, since many plans are only updated once or twice a decade. As discussed, the scorecard focuses on policies that could impact physical vulnerability, but plans include other types of policies that influence preparation for current and future flood risk such as capacity building policies (IPCC, 2014). Moreover, our scoring scheme does not assess the differing impact of policies on flood risk. Lastly, this analysis focuses exclusively on plans and their policies, not implementation. Indeed, recent work suggests that many climate adaptation plans are unlikely to be implemented or have a major impact (Olazabal and Gopegui, 2021), although research on sustainability plans suggest they do spark action (Liao et al., 2020). Future studies should explore which policies in networks of plans actually get implemented and what their impact is on flood resilience. While these limitations are important to recognize, the approach used here has been tested in multiple jurisdictions (Berke et al., 2019a; Malecha et al., 2018; Malecha et al., 2021; Yu et al., 2020) and is being refined for wider use by practitioners (DeAngelis et al., 2021).

3. Results

3.1. Changes in Boston's network of plans

From 2015 to 2019, the number of policies in Boston's plans that may affect physical vulnerability to flooding dramatically increased from 59 to 243 policies. Fig. 1 shows the number of positive and negative policies for each plan from the 2015 and 2019 analyses. The increase in the number of policies is due to the creation of new plans and, in general, the approach of adopting stand-

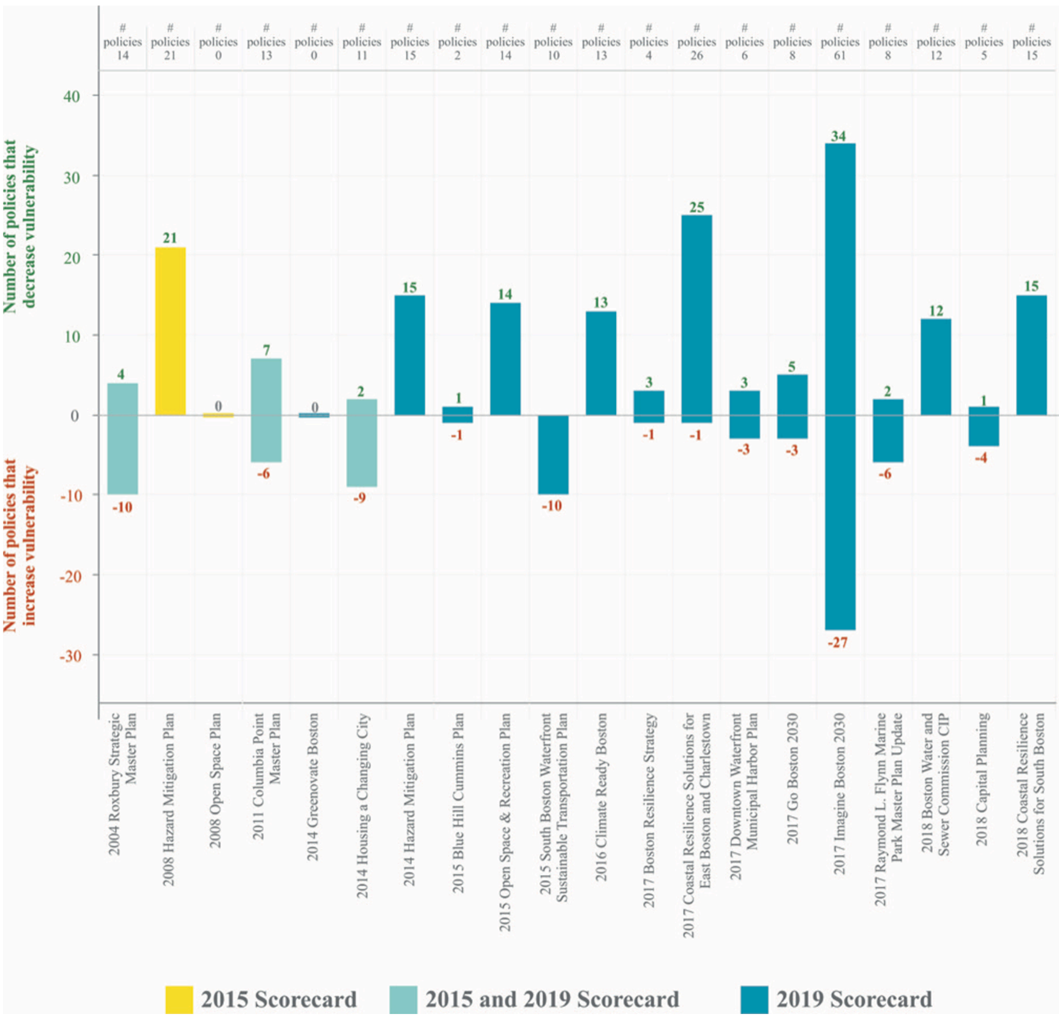

Fig. 1. Number of policies that will affect physical vulnerability to flooding in each Boston plan for 2015 and 2019 Plan Integration for Resilience Scorecards. Positive policies have the potential to reduce vulnerability to flooding, negative policies could increase vulnerability.

alone climate change and resilience plans. In the four years between our analyses, Boston adopted 14 new plans (only two of which were updates of older plans – the hazard mitigation and open space plans). In addition to an increase in the total number of policies that may affect physical vulnerability, we found the proportion of policies with the potential to reduce vulnerability increases. In 2015, approximately 58% of plan policies reduced vulnerability. In 2019, that grew to 64%.

Boston's hazard mitigation and open space plans were both updated between 2015 and 2019, allowing for direct comparisons in how plans change. Both the 2008 and 2014 hazard mitigation plans only contain policies with the potential to decrease vulnerability, however, the number of policies included in our scorecard dropped from 21 to 15. Mirroring the drop in the number of policies, the average policy score per district decreased from 5.59 to 4.09 in floodplain zones and 4.88 to 3.88 in sea level rise zones. The decrease in policies is likely due to the inclusion of a broader set of policies in the 2014 hazard mitigation plan and limitations in the scope of our analysis. The 2008 plan emphasizes physical measures to address existing flood risks, such as constructing floodwalls, updating storm drains and pumps, dredging waterways, and encouraging green infrastructure. All of these types of policies are included in our analysis. Recognizing the growing threat of climate change, the 2014 plan includes a broader range of strategies that are not included in our analysis because they would not directly impact physical vulnerability, even though they could be effective in enhancing resilience in other ways. For example, the 2014 policy to "Assess vulnerability of the electrical grid […] to natural hazards likely to be increased by climate change in order to develop mitigation measures" (City of Boston, 2014a, 127) and to "convene a cabinet level Climate Preparedness task force" (City of Boston, 2014a, 132) are not included in our analysis because they do not directly affect physical vulnerability. Paradoxically, the emphasis on climate change in the 2014 plan reduced the number of policies in our analysis because the climate change policies largely lay the groundwork for future action by conducting studies and creating new governance structures rather than directly addressing physical vulnerability.

Comparing the 2008 and 2015 open space and recreation plans similarly shows a growing emphasis on climate change. In this case, however, it results in a large increase in the number of policies that could decrease physical vulnerability, from 0 to 14. The 2008 plan focuses on more traditional open space goals of improving parks "through capital rehabilitation, maintenance, programming, and other system operations" (City of Boston, 2008, 8–1) to ensure that they continue to meet the needs of a growing and changing city. While the plan recognizes that environmental protection provides multiple benefits, it does not discuss the potential for parks and open space to decrease flood vulnerability. Nor does the plan mention climate change. In contrast, "climate change and resilience" (City of Boston, 2015, 1) is a central theme of the 2015 plan. Creating parks or preserving open space in hazard zones prevents development from being located in these risky locations (Burby, 1998). Parks and open space additionally provide ecosystem services like retention and infiltration of flood waters (Brody and Highfield, 2013; Highfield et al., 2014). Boston's 2015 *Open Space and Recreation* plan seeks to maximize these benefits to help adapt to climate change. For example, the plan lays out a strategy to "create open space in coastal areas and flood zones that can also serve as protective infrastructure as the climate changes" (City of Boston, 2015, 398). The plan calls to "improve the quality of ecosystems in the city by understanding existing functionality and establishing benchmarks related to climate preparedness, habitat and biodiversity, and human access" (City of Boston, 2015, 398).

In addition to growing emphasis on climate change in plan updates, between 2015 and 2019 Boston adopted multiple new plans focused on climate change and reduction of flood risks. Most prominently, *Climate Ready Boston* adopted in 2016 includes 13 policies to reduce physical vulnerability to flooding. While the number of policies is modest compared to other plans, many policies are broadly applicable across the city, resulting in an average score of 11.76 per district - the highest in our sample. Policies to "revise the zoning code to support climate-ready buildings" (City of Boston, 2016, 135) and "establish flood protection overlay districts" (106) not only have a large geographic footprint, but may also transform the built environment by setting higher standards for new development. These policies are also echoed in other plans. The comprehensive plan, *Imagine Boston 2030*, for instance, includes a policy to "Upgrade our building regulations and develop climate ready zoning to prepare districts for future risk" (City of Boston, 2017, 451). *Coastal Resilience Solutions for South Boston* includes a policy to "Develop a Flood Resilience Overlay District that establishes design guidelines based on anticipated future flood levels" (City of Boston, 2018, 212). To support *Climate Ready Boston*, the city has also created neighborhood plans like *Coastal Resilience Solutions for South Boston* that translate the goals and strategies from *Climate Ready Boston* into specific projects. These neighborhood plans have high scores, including numerous policies that could reduce vulnerability. *Coastal Resilience Solutions for East Boston and Charlestown* includes 25 policies to reduce physical vulnerability to flooding.

Reducing vulnerability to climate change and hazards is also a central theme of *Resilient Boston*, the city's resilience strategy developed as part of its participation in 100 Resilient Cities. Rather than focusing on physical measures to reduce exposure to hazards, the plan focuses on addressing racial inequity and drivers of social vulnerability. The plan includes actions to provide financial education and services, advance the work of community-based organizations that are advancing racial equity, enhance mental health and trauma resources, and fund community-led resilience projects. These actions are critical to build resilience (Meerow et al., 2019; Shi et al., 2016), however, since our focus is on policies that affect physical vulnerability to flooding, most were not included in our analysis. Based on our criteria, *Resilient Boston* includes three policies that could reduce physical vulnerability and one policy that may actually increase vulnerability. Policies to reduce vulnerability build on strategies set out in *Climate Ready Boston* including expanding green infrastructure and updating zoning and building regulations. The one policy that may increase vulnerability expands affordable housing by reusing surplus city parcels, some of which are unfortunately located in the floodplain.

The tension between expanding affordable housing and reducing development in risky locations manifests in multiple plans. The housing plan, *Housing a Changing City*, has the lowest net score of −7. Housing affordability is a critical issue for Boston. Rapid population growth and housing demand has resulted in rising housing costs. Twenty percent of all households in the city are severely housing-cost burdened—spending 50 percent or more of their income on housing costs. High housing costs in the city disproportionately impact low-income residents (City of Boston, 2017). The city has estimated that to accommodate projected growth and stabilize the housing market would require the creation of 53,000 new housing units by 2030, a 20% increase in housing stock (City of

Boston, 2014b). To achieve that goal, policies in the housing plan encourage infill and redevelopment to provide mixed-income housing. Unfortunately, many of the areas available for growth and development are located in current or future floodplains. A recent study found that over 3,000 existing affordable housing units would be at risk of annual flooding by 2030 (Buchanan et al., 2020). Recognizing the threat that climate change and flooding pose to affordable housing, the housing plan includes policies to “ensure that Boston Housing Authority Buildings are prepared for the impacts of climate change” (City of Boston, 2014b, 119) and “support developers, owners, and tenants in taking climate preparedness actions” (117).

The city’s comprehensive plan, *Imagine Boston 2030,* further recognizes the dual pressure of housing and climate. Indeed, the plan overlays areas of projected growth and future sea level rise. The comprehensive plan includes 27 policies that increase vulnerability. These policies promote mixed use and transit-oriented development, create affordable housing and develop new job centers. While these policies advance social and economic goals, the increased investment, development, and growth in risky locations has the potential to increase flood costs. To try to avoid these costs, *Imagine Boston 2030* includes 34 policies to reduce vulnerability. The plan proposes structural measures such as flood protection infrastructure and updating building regulations to try and make new development in risky locations as safe as possible. Building on the *Open Space and Recreation Plan*, many of the policies to reduce vulnerability also protect open space and parks.

3.2. Spatial changes in policy attention in Boston

In addition to separately considering each plan, we sum policies across plans to examine spatial changes in policy attention. Fig. 2 maps net scores across districts for 2015 and 2019. In 2015, 15 district-hazard zones had negative net scores indicating more policies that would increase physical vulnerability to flooding than policies that decrease it. In 2019, no districts had negative scores. The lowest net score was 14. The average score per district jumped from 0.68 to 32 in floodplains and −0.67 to 27.83 in sea level rise areas. This shift illustrates the huge increase in the number of policies with the potential to decrease vulnerability across the city’s network of plans. Generally speaking, neighborhoods with low net scores in 2015 also had low scores in 2019. In 2015, the district hazard zone with the lowest net score was the sea level rise inundation area of Roxbury with a score of −8. In 2019, this district hazard zone still had the lowest net score (14). This suggests that while Boston’s network of plans improved overall, lifting up all areas, plans did not specifically target areas where older policies would increase vulnerability. There are some notable exceptions to this trend, district hazard zones in Charlestown and South Boston moved from having relatively low scores to having relatively high scores. Both these

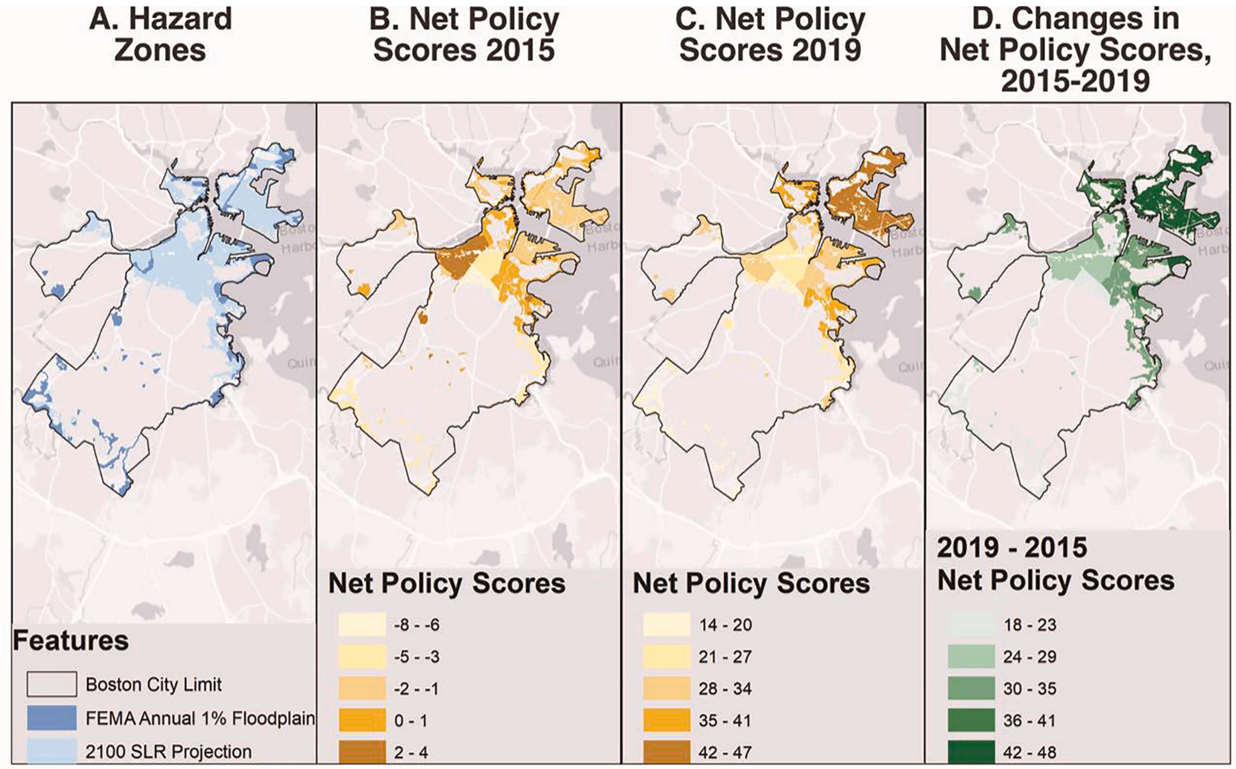

Fig. 2. Maps of hazard zones, net policy scores for the 2015 and 2019 plan integration for resilience scorecard (PIRS) analysis, and change in net scores between the two time points. Districts across Boston experienced a large increase in net policy scores.

neighborhoods, along with East Boston, benefited from neighborhood-scale coastal resilience plans.

Another notable finding is that neighborhoods that saw the largest increase in policies that could decrease vulnerability also saw the largest increases in policies that could increase vulnerability. For example, areas of East Boston benefited from 60 new policies to decrease vulnerability but also had 12 policies that may increase vulnerability. This suggests that there is a general increase in policy attention in some areas. While there are more positive than negative policies, increased policy attention includes some planned investments that would increase development in risky locations. It is not clear why some areas receive more policy attention than others, although given the equity implications, this would be an interesting avenue for future research.

3.3. Changes in Fort Lauderdale's network of plans

In Fort Lauderdale, the number of plan policies that affect physical vulnerability to flooding grew at a modest rate, increasing from 62 policies in 2015 and 82 in 2019. In both years, the overwhelming majority of policies focus on decreasing vulnerability, 81% and 93% respectively. The high ratio of policies that could decrease vulnerability is somewhat surprising given that almost the entire city falls within the floodplain or sea level rise projection and, consequently, almost any policy to encourage development would receive a negative score. As shown in Fig. 3, the increase in policies is largely explained by the adoption of seven new plans since the 2015 analysis. These new plans include the 2018 *Stormwater Master Plan* and the 2019 *Community Investment Plan*, which account for 47 new policies. Most of these policies target specific capital improvement projects such as stormwater infrastructure, tidal valves, and seawall improvements. Despite the overall increase, policies decreased in both the hazard mitigation plan and the city's comprehensive plan. Since both plans were included in the 2015 analysis and updated before our most recent analysis, we were able to directly compare policy changes between them.

Following FEMA guidance to update local hazard mitigation plans every five years, the 2012 *Broward County Enhanced Local Mitigation Strategy* was updated in 2017. Both the 2012 and 2017 hazard mitigation plan only contain policies that decrease vulnerability. However, whereas the 2012 plan includes policies distributed city-wide (111 districts out of 115), policies in the 2017 plan are limited to significantly fewer districts (16 districts out of 115). This difference is largely attributed to the types of policies included. In 2012, 10 out of the 12 policies targeted development regulations, design standards, and siting considerations across most of the city. In the 2017 plan, six of the seven policies relate to stormwater drainage improvements mostly located near downtown and districts just north of the Fort Lauderdale/Hollywood International Airport. Overall, the mean policy score per district in the 100-year floodplain

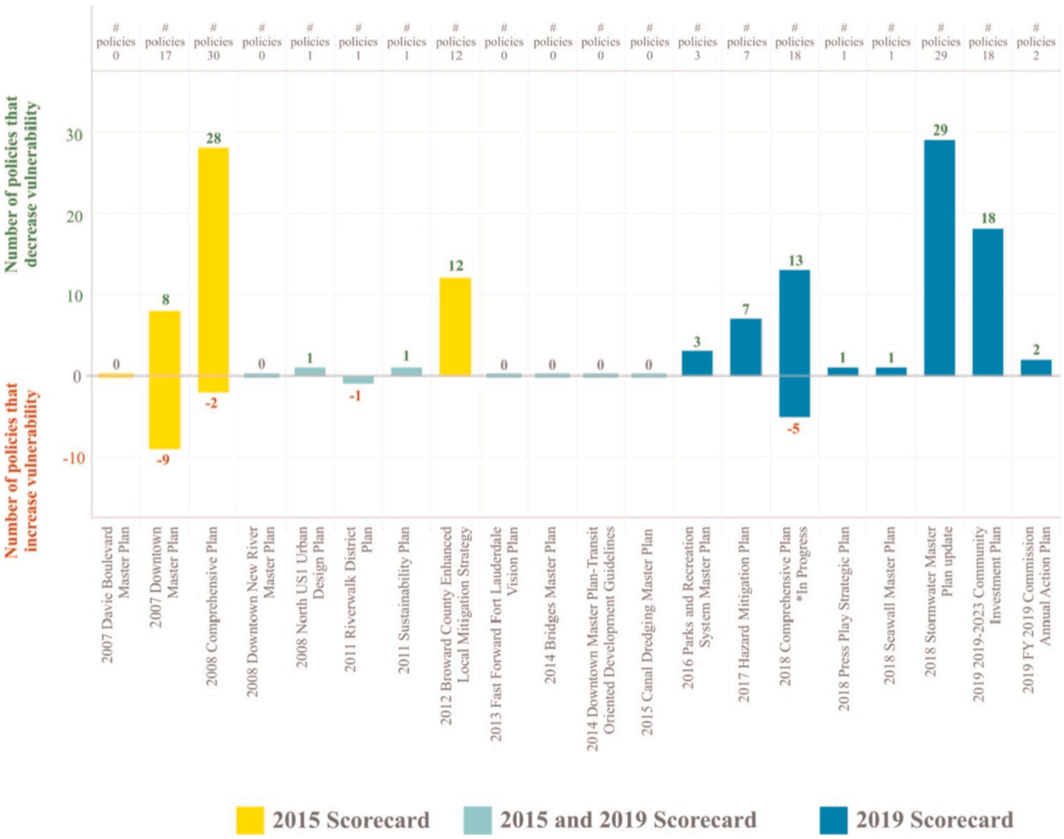

Fig. 3. Number of policies that would affect physical vulnerability to flooding in each Fort Lauderdale plan for 2015 and 2019 Plan Integration for Resilience Scorecards. Positive policies have the potential to reduce vulnerability to flooding, negative policies could increase vulnerability.

dropped from 6.04 in 2012, to 0.25 in 2017. The mean policy score per district in the sea-level rise hazard zone dropped from 1.96 in 2012, to 0.25 in 2017.

Fort Lauderdale has not adopted stand-alone climate change adaptation or resilience plans. Instead, a special climate change element was added to the 2018 comprehensive plan update to address the challenge holistically. At the time of our analysis, the 2018 comprehensive plan was still in a draft form. Only seven of the 16 chapters were available. Our analysis does not include several chapters that may have a large influence on physical vulnerability to flooding including the future land use, conservation, and coastal management elements. Given the draft form of the 2018 plan, it is difficult to directly compare the number of policies in the 2008 and 2018 comprehensive plans.

The 2008 comprehensive plan includes a goal to, "increase the City's resiliency to the impacts of climate change and rising sea levels" (City of Fort Lauderdale, 2008, 5–1). But the associated policies focus on assessing vulnerability, building capacity, and laying the groundwork for future action. Still the 2008 plan includes a wide array of policies that reduce physical vulnerability. These policies range from development regulations that prohibit increased residential densities in coastal high hazard areas, to limiting post-disaster reconstruction in risky locations, to protection of beach vegetation and wetlands, to improving building codes. These policies are rooted in coastal management and hazard mitigation.

The 2018 comprehensive plan moves from laying the groundwork to meaningful action on climate change, including updating development ordinances and building codes to account for rising sea levels. As with policies in *Climate Ready Boston* to update zoning, these policies not only have a large geographic footprint but also have the potential to transform the built environment. Policies in the 2018 plan to protect coastal ecosystems that echo policies from the 2008 plan are also now directly tied to climate change adaptation. In addition to greater action on climate change, the updated comprehensive plan also has greater emphasis on capital improvements. Policies like deprioritizing public infrastructure investments in high flood risk areas and "evaluate the capital costs with considerations for life cycle cost and benefits of adaptation alternatives in the location and design of new infrastructure" (City of Boston, 2018, 5) suggest that the city is increasingly aware and acting on the fiscal risk that climate change poses to the city. Both the 2008 and 2018 comprehensive plan concentrate vulnerability reduction policies in districts along the coast, with decreased emphasis moving further inland.

3.4. Spatial changes in policy attention in Fort Lauderdale

In Fort Lauderdale, the most significant spatial change is the reduced net scores. Fig. 4 illustrates the decrease in net scores across the city. As the total number of policies grew, district hazard scores dropped on average by 14.5 points. While including more recent chapters in the comprehensive plan would change these numbers, the dropping net scores indicate that policies have become more spatially focused. The new plans that account for the increase in the total policy count, namely the *Stormwater Master Plan* and *Capital Improvements* plan, focus on infrastructural projects that affect a limited number of district hazard zones. For example, in the Southeast

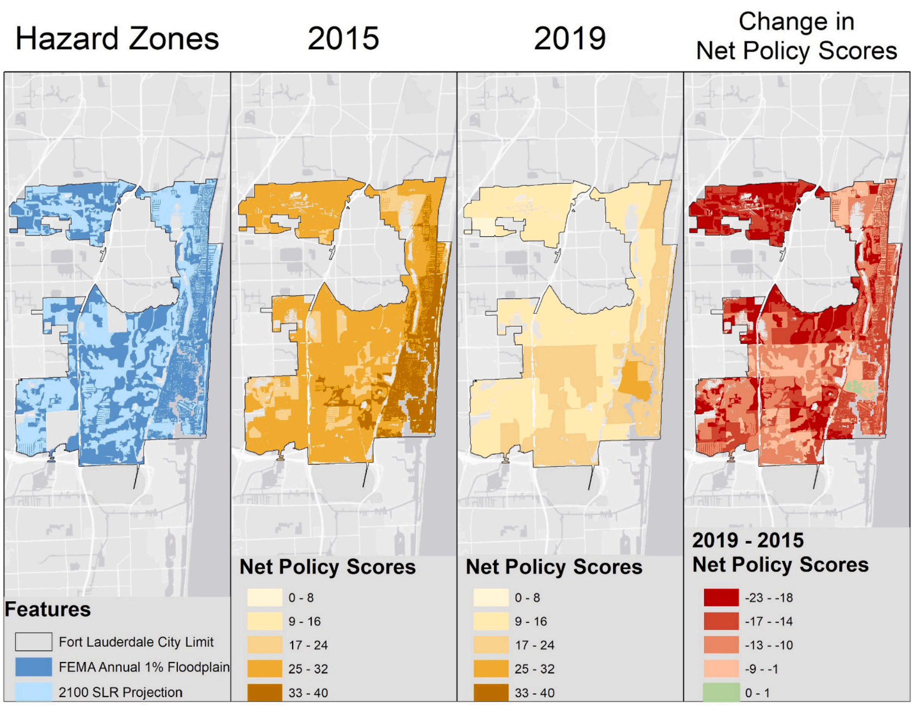

Fig. 4. Maps of hazard zones, net policy scores for the 2015 and 2019 plan integration for resilience scorecard (PIRS) analysis, and change in net scores between the two time points. Districts across Fort Lauderdale experienced a decrease in net policy scores.

Isles neighborhood, the *Stormwater Master Plan* proposes, “installing approximately 100 additional tidal valves to prevent backflow during high tide events and raising fourteen City-owned seawalls” (City of Boston, 2018, 52). The hazard mitigation plan also shifts from including a variety of policies that could affect large parts of the city to more targeted stormwater infrastructure interventions.

Areas that had the lowest scores in 2015 also have the lowest scores in 2019, while areas with higher scores received even more policies to decrease vulnerability and retain high scores. This suggests that, while awareness of flood hazards is generally increasing across Fort Lauderdale’s network of plans, concentrations of high vulnerability remain (Berke et al., 2019b), and such issues have yet to be effectively addressed. For example, both the 2008 and 2018 comprehensive plans concentrate risk reduction policies along the coast with decreasing emphasis moving inland, and negative policy scores are concentrated in the coastal resort area and downtown. The 2007 *Downtown Master Plan* also promoted additional development downtown in the floodplain and sea level rise area. Removing this plan from the scorecard for the 2019 analysis due to its age increases net scores in the downtown districts.

A second notable change is the growing focus on sea level rise. In 2015, areas projected to be affected by sea level rise had an average net score of 25.7 compared to an average score of 31.0 in floodplains. By 2019, sea level rise zones had higher average net scores than floodplains, 14.1 and 13.7 respectively. In 2015, the difference between scores in the floodplain and sea level rise zone was driven by the hazard mitigation plan, which included fewer policies that affected sea level rise areas. While sea level rise zones had lower average scores in 2015, they had more consistent policy attention. In 2015, the minimum score in sea level rise areas was 20 compared to four in the floodplain. In 2019 the minimum score is 8 in sea level rise areas and zero in floodplain areas. The lower minimums in 2019 reflect not only the overall lower district-hazard scores but also the growing unevenness in policy attention. The 2019 scorecard reveals greater attention to some areas affected by sea level rise and reduced attention on others.

4. Discussion and conclusion

In the face of mounting flood risks and damages, coastal cities have an urgent need to enhance resilience. It is unclear whether major investments in resilience-building in cities, including the development of new climate change adaptation and resilience plans, are translating into an overall reduction in vulnerability to flooding. Longitudinal studies of resilience are urgently needed to answer this question, yet longitudinal studies of planning are few and far between. Moreover, any truly comprehensive assessment of planning in a community over time should consider the multitude of plans that shape development and ultimately vulnerability. A growing number of studies do assess how the policies in cities’ full networks of plans may affect resilience to flooding, yet to date, none have looked at how the network has changed over time. This paper begins to address this gap. In addition to this longitudinal analysis, a spatial evaluation of the policies in the networks of plans using the PIRS method enables an understanding of how these plans and policy changes manifest across the cities, and whether spatial patterns in policy attention change over time.

We posed two questions: (1) How has the network of plans’ combined potential effect on physical vulnerability to flooding changed over time? And, (2) what is the influence of new types of plans on policies that have the potential to impact vulnerability? In both Boston and Fort Lauderdale, we found that over time, plans dedicate greater attention to climate change and include more policies that have the potential to decrease physical vulnerability to flooding. In short, there is some evidence that plans are collectively better managing flood risk. However, the story is somewhat more complicated. In Fort Lauderdale, while the total number of policies increased, the average score per district dropped because newer policies had a limited spatial reach. In both cities, patterns of policy (in)attention persist over time, indicating that new plans do not necessarily address existing disparities. In Boston, the adoption of a climate change adaptation plan dramatically increased the number of policies to decrease physical vulnerability, suggesting that adaptation planning might be an effective way to increase policies with the potential to reduce risks (Woodruff and Stults, 2016).

Updates of plans provide strong evidence that plans are changing to mainstream climate change adaptation. For example, Boston’s 2008 *Open Space and Recreation* plan does not mention climate change, in the 2015 update resilience is a central theme. In this case, the emphasis on climate change resulted in a large increase in the number of policies to reduce physical vulnerability to flooding. However, many of the climate policies focus on capacity building, which are not included in our assessment. Thus, the growing emphasis on climate change may not be fully reflected in scorecard changes. For instance, the greater emphasis on climate change in Boston’s hazard mitigation plan update may have resulted in fewer policies that reduce physical vulnerability to flooding and more policies that build capacity. Indeed, early climate change adaptation plans were critiqued for emphasizing capacity building and failing to propose actions to reduce physical vulnerability (Biagini et al., 2014; Preston et al., 2011; Stults and Woodruff, 2016).

Plans in our analysis show cities are moving beyond capacity building to take action to reduce rising flood risks. Fort Lauderdale’s 2018 comprehensive plan update calls for sea level rise to be incorporated into development regulations, building codes, and capital improvement decisions. Similarly, Boston’s new comprehensive plan builds on *Climate Ready Boston* by proposing zoning that accounts for increasing flood risks. If enacted, these policies could have profound impacts on where development is located and how vulnerable it is to flooding. Our simplified coding approach (+1 for policies that decrease vulnerability, −1 for policies that increase vulnerability) does not account for the impact of different policies. A policy to replace a storm drain receives the same score as these transformational policies. Future research could seek to evaluate the relative potential impact of policies, although this is likely to be quite subjective.

The explosion of new plans in Boston further demonstrates how planning is changing to better address increasing flood risks. The adoption of new plans resulted in a major increase in policies with the potential to reduce vulnerability, lifting scores for every hazard-district across the city. With an average score of 11.76 per district, *Climate Ready Boston*, in particular, had a large influence. Policies from *Climate Ready Boston* were also included in other city-wide and neighborhood plans, illustrating how dedicated climate change adaptation plans can set a policy agenda to reduce risks (Lyles et al., 2017). Based on our analysis of policies that could affect physical vulnerability to flooding, the city’s resilience plan has a smaller impact. The resilience plan echoes policies from *Climate Ready Boston*, but it largely focuses on addressing underlying drivers of social vulnerability such as systematic racism, poverty, and income and wealth inequality. These actions are critical for just adaptation (Meerow et al., 2019; Shi et al., 2016), but not well captured using our methods. Future research should look at a broader range of policies and how they relate to different aspects of vulnerability (e.g., social) across a city's plan network, although they would probably not be as amenable to spatial analysis. It would also be helpful to interview planners about why plans focus on different policy types and whether this is inadvertent and due to lack of coordination or purposefully designed to be complementary.

Rather than adopt new types of plans, Fort Lauderdale has taken a mainstreaming approach by integrating climate change into their comprehensive and infrastructure plans. While these plans do include some wide-reaching policies, many of the policies focus on spatially specific infrastructure measures like sea walls and drainage improvements. As a result, the total number of policies increases over time, but the average district score drops. The trend towards more spatially specific policies also results in more unevenness in scores across the city. Clear, strongly worded, spatially specific policies are generally considered a component of strong plans (Berke and Godschalk, 2009). Spatially specific policies indicate greater neighborhood acceptance and political support for implementation (Neuman, 1998). Our finding that spatially specific policies are reducing district net scores raises new questions about what scale of policies are most effective in the face of climate change. The small-scale infrastructure policies that dominate Fort Lauderdale's plans may be most effective when they are combined with additional land use policies that seek to minimize or avoid the "safe development" paradox, whereby protective infrastructure facilitates development in flood-prone areas increasing the risk of future catastrophic losses (Burby, 2006).

The spatial distribution of policies in both cities shows that current policies tend to perpetuate spatial disparities in policy attention. In Fort Lauderdale, risk reduction measures tend to be more concentrated in the coastal area in both 2015 and 2019. Similarly, policies continue to encourage development in the city's downtown and coastal resort areas. In Boston, areas with low policy scores in 2015 also tend to have low scores in 2019. While it is natural to encourage investment in existing areas and target protection measures in those same areas, it may be unsustainable in the long-run if these areas are constantly flooding (Hino et al., 2017; Woodruff et al., 2018a). Moreover, it likely perpetuates existing disparities in investment (Anguelovski et al., 2016; Berke et al., 2019a; Howell and Elliott, 2019). Previous PIRS studies have found that policies tend to support mitigation in areas of low social vulnerability, rather than targeting communities with the highest social vulnerability (Berke et al., 2019b). Our analysis suggests that plans are likely perpetuating these inequities, since spatial patterns in policy attention remain fairly consistent, although future research should explicitly assess this by comparing social vulnerability indicators with PIRS results. Using the PIRS as a diagnostic tool and emphasizing social vulnerability may help communities better steer future policies to areas that have historically received less policy attention and been underserved. Resilience plans may help achieve these goals by linking flood mitigation to broader social issues and underlying drivers of vulnerability (Chakraborty et al., 2018; Woodruff et al., 2018b).

In addition to providing valuable research insights, PIRS has been used as a diagnostic tool in practice (Berke et al., 2021). Where practitioners have used PIRS, it helped improve knowledge and awareness of hazard risks, develop spatial understanding of policies, and begin conversations about the impacts of specific policies. In Norfolk, VA PIRS was the basis for projects to reduce flood risk in vulnerable neighborhoods. In Rockport, TX PIRS was used to develop their comprehensive plan and identify techniques to reduce flood vulnerability (City of Rockport, 2019). Assessing how policies in plans spatially overlap can help identify areas in need of additional policy interventions and hopefully move towards stronger plans that collectively work to reduce flood risks.

Over time, we also see a shift in policy attention from the current floodplain towards future sea level rise areas. In particular, in Fort Lauderdale the plans in the original scorecard had more policies to reduce risk to current than future flooding. Four years later, this appears to have shifted, with greater policy attention on sea level rise areas. It is encouraging that plans are proactively considering long-term risks. Today's land use and investment decisions will determine the risk of tomorrow.

Disclosure statements

Any opinions and conclusions expressed herein are those of the authors and do not necessarily reflect the views of the U.S. Census Bureau. This work was mostly or entirely completed while Dr. Bryce Hannibal was at Texas A&M University.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This work was funded by the National Science Foundation award #1825123 & 1825367. The article is also based on work supported by the U.S. Department of Homeland Security Science and Technology Directorate (grant 0031369). We would also like to thank Madison Moore and Elizabeth Van Horn for assistance in coding plans in this study.

References

Aerts, J.C.J.H., Wouter Botzen, W.J., Emanuel, K., Lin, N., de Moel, H., Michel-Kerjan, E.O., 2014. Evaluating Flood Resilience Strategies for Coastal Megacities. Science 344 (6183), 473–475. https://doi.org/10.1126/science.1248222.

Albright, E.A., Crow, D.A., 2019. Capacity Building toward Resilience: How Communities Recover, Learn, and Change in the Aftermath of Extreme Events. Policy Stud. J. September, psj.12364. https://doi.org/10.1111/psj.12364.
Anguelovski, I., Shi, L., Chu, E., Gallagher, D., Goh, K., Lamb, Z., Reeve, K., Teicher, H., May 2016. Equity Impacts of Urban Land Use Planning for Climate Adaptation: Critical Perspectives from the Global North and South. J. Plann. Educ. Res. https://doi.org/10.1177/0739456X16645166.
Berke, P., Godschalk, D., 2009. Searching for the Good Plan: A Meta-Analysis of Plan Quality Studies. J. Plann. Literature 23 (3), 227–240. https://doi.org/10.1177/0885412208327014.
Berke, P., Newman, G., Lee, J., Combs, T., Kolosna, C., Salvesen, D., 2015. Evaluation of Networks of Plans and Vulnerability to Hazards and Climate Change: A Resilience Scorecard. J. Am. Plann. Assoc. 81 (4), 287–302. https://doi.org/10.1080/01944363.2015.1093954.
Berke, P.R., Malecha, M.L., Siyu, Y.u., Lee, J., Masterson, J.H., 2019a. Plan Integration for Resilience Scorecard: Evaluating Networks of Plans in Six US Coastal Cities. J. Environ. Plann. Manage. 62 (5), 901–920. https://doi.org/10.1080/09640568.2018.1453354.
Berke, Philip, Siyu Yu, Matt Malecha, John Cooper, 2019. Plans That Disrupt Development: Equity Policies and Social Vulnerability in Six Coastal Cities. J. Plann. Educ. Res., July, 0739456X19861144. 10.1177/0739456X19861144.
Philip Berke, Justin Kates, Matt Malecha, Jaimie Masterson, Paula Shea, Siyu Yu, Using a resilience scorecard to improve local planning for vulnerability to hazards and climate change: An application in two cities, Cities, Volume 119, 2021, https://doi.org/10.1016/j.cities.2021.103408.
Biagini, B., Bierbaum, R., Stults, M., Dobardzic, S., McNeeley, S.M., 2014. A Typology of Adaptation Actions: A Global Look at Climate Adaptation Actions Financed through the Global Environment Facility. Global Environ. Change 25 (March), 97–108. https://doi.org/10.1016/j.gloenvcha.2014.01.003.
Boston Planning & Development Agency. 2021. "BPDA Owned Land." 2021. http://www.bostonplans.org/work-with-us/bpda-owned-land.
Birchall, S. Jeff, Nicole Bonnett, 2021. Climate Change Adaptation Policy and Practice: The Role of Agents, Institutions and Systems." Cities 108 (January 1, 2021): 103001. 10.1016/j.cities.2020.103001.
Boston Redevelopment Authority, 2017. Downtown Waterfront District Municipal Harbor Plan & Public Realm Activation Plan. Retrieved from. http://www.bostonplans.org/getattachment/027c2240-38ba-474f-aac3-122e4b7f0012.
Brody, S.D., 2003. Are We Learning to Make Better Plans?: A Longitudinal Analysis of Plan Quality Associated with Natural Hazards. J. Plann. Educ. Res. 23 (2), 191–201. https://doi.org/10.1177/0739456X03258635.
Brody, S.D., Highfield, W.E., 2013. Open Space Protection and Flood Mitigation: A National Study. Land Use Policy 32 (May), 89–95. https://doi.org/10.1016/j.landusepol.2012.10.017.
Brody, S.D., Zahran, S., Maghelal, P., Grover, H., Highfield, W.E., 2007. The Rising Costs of Floods: Examining the Impact of Planning and Development Decisions on Property Damage in Florida. J. Am. Plann. Assoc. 73 (3), 330–345.
Buchanan, M.K., Kulp, S., Cushing, L., Morello-Frosch, R., Nedwick, T., Strauss, B., 2020. Sea Level Rise and Coastal Flooding Threaten Affordable Housing. Environ. Res. Lett. 15 (12), 124020 https://doi.org/10.1088/1748-9326/abb266.
Burby, R.J., 2006. Hurricane Katrina and the Paradoxes of Government Disaster Policy: Bringing About Wise Governmental Decisions for Hazardous Areas. Ann. Am. Acad. Political Social Sci. 604 (1), 171–191. https://doi.org/10.1177/0002716205284676.
Burby, Raymond J., ed. 1998. Cooperating with Nature: Confronting Natural Hazards with Land Use Planning for Sustainable Communities. Natural Hazards and Disasters. Washington, D.C: Joseph Henry Press.
Burby, R.J., Beatley, T., Berke, P.R., Deyle, R.E., French, S.P., Godschalk, D.R., Kaiser, E.J., Kartez, J.D., May, P.J., Olshansky, R., Paterson, R.G., Platt, R.H., 1999. Unleashing the Power of Planning to Create Disaster-Resistant Communities. J. Am. Plann. Assoc. 65 (3), 247–258. https://doi.org/10.1080/01944369908976055.
Chakraborty, J., Collins, T.W., Grineski, S.E., 2018. Exploring the Environmental Justice Implications of Hurricane Harvey Flooding in Greater Houston, Texas. Am. J. Public Health 109 (2), 244–250. https://doi.org/10.2105/AJPH.2018.304846.
City of Boston. 2008. "Open Space Plan." file:///Users/sierra/Dropbox/RPN%20Project/Boston/plans/2008-OpenSpacePlan.htm.
City of Boston. 2014a. "City of Boston Natural Hazard Mitigation Plan." https://www.cityofboston.gov/images_documents/Boston%20Revised%20Draft%20Hazard%20Mitigation%20Plan%202014%20Update%20%2003-31-15_tcm3-51167.pdf.
City of Boston. 2014b. "Housing a Changing City: Boston 2030." https://www.boston.gov/finance/housing-changing-city-boston-2030.
City of Boston. 2015. "Open Space & Recreation Plan 2015-2021." https://www.boston.gov/environment-and-energy/open-space-and-recreation-plan-2015-2021.
City of Boston. 2016. "Climate Ready Boston." https://www.boston.gov/departments/environment/preparing-climate-change.
City of Boston. 2017. "Imagine Boston 2030." https://imagine.boston.gov/imagine-boston-plan/.
City of Boston. 2018. "Coastal Resilience Solutions for South Boston." https://www.boston.gov/departments/environment/climate-ready-south-boston.
City of Fort Lauderdale. 2008. "City of Fort Lauderdale 2008 Comprehensive Plan." https://www.fortlauderdale.gov/departments/sustainable-development/urban-design-and-planning/comprehensive-plan.
City of Fort Lauderdale. 2018. "2020 Advance Fort Lauderdale Comprehensive Plan." https://www.fortlauderdale.gov/departments/sustainable-development/urban-design-and-planning/comprehensive-plan.
City of Rockport. "Rockport Strong: City of Rockport Comprehensive Plan 2020–2040", 2019. City of Fort Lauderdale. "2020 Advance Fort Lauderdale Comprehensive Plan", 2018. https://www.fortlauderdale.gov/departments/sustainable-development/urban-design-and-planning/comprehensive-plan.
Climate Central. "Ocean at the Door: New Homes and the Rising Sea," 2019. https://www.climatecentral.org/news/ocean-at-the-door-new-homes-in-harms-way-zillow-analysis-21953.
Cutter, Susan L., Boruff, Bryan J., Shirley, Lynn W., 2003. Social Vulnerability to Environmental Hazards. Soc. Sci. Q. 84 (2), 242–261.
DeAngelis, Joseph, Johamary Pena, Alexsandra Gomez, Jaimie Masterson, and Philip Berke. "Building Resilience Through Plan Integration." American Planning Association, 2021. https://www.planning.org/pas/memo/2021/jan/.
Fastiggi, Mary, Sara Meerow, Thaddeus R. Miller, 2020. Governing Urban Resilience: Organisational Structures and Coordination Strategies in 20 North American City Governments. Urban Studies, March, 004209802090727. 10.1177/0042098020907277.
Finn, Donovan, Divya Chandrasekhar, Yu Xiao, 2019. A Region Recovers: Planning for Resilience after Superstorm Sandy. J. Plann. Educ. Res., July, 0739456X19864145. 10.1177/0739456X19864145.
Finn, D., Hopkins, L.D., Wempe, M., May 2007. The Information System of Plans Approach: Using and Making Plans for Landscape Protection. Landscape Urban Plann. 81 (1–2), 132–145. https://doi.org/10.1016/j.landurbplan.2006.11.006.
Fitzgibbons, J., Mitchell, C.L., 2019. Just Urban Futures? Exploring Equity in '100 Resilient Cities'. Wsorld Dev. 122 (October), 648–659. https://doi.org/10.1016/j.worlddev.2019.06.021.
Godschalk, D., Beatley, T., Berke, P., Brower, D., Kaiser, E.J., 1998. Natural Hazard Mitigation: Recasting Disaster Policy And Planning. Island Press.
Hallegatte, S., Green, C., Nicholls, R.J., Corfee-Morlot, J., 2013. Future Flood Losses in Major Coastal Cities. Nat. Clim. Change 3 (9), 802–806. https://doi.org/10.1038/nclimate1979.
Highfield, W.E., Brody, S.D., Blessing, R., 2014. Measuring the Impact of Mitigation Activities on Flood Loss Reduction at the Parcel Level: The Case of the Clear Creek Watershed on the Upper Texas Coast. Nat. Hazards 74 (2), 687–704. https://doi.org/10.1007/s11069-014-1209-1.
Hino, M., Field, C.B., Mach, Katharine J., 2017. Managed Retreat as a Response to Natural Hazard Risk. Nat. Clim. Change 7 (5), 364–370. https://doi.org/10.1038/nclimate3252.
Howell, Junia, Elliott, James R, 2019. Damages Done: The Longitudinal Impacts of Natural Hazards on Wealth Inequality in the United States. Soc. Probl. 66 (3), 448–467. https://doi.org/10.1093/socpro/spy016.
IPCC, 2014. Adaptation Planning and Implementation. In: Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M. (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, pp. 869–898.
Kousky, Carolyn, 2014. Informing Climate Adaptation: A Review of the Economic Costs of Natural Disasters. Energy Econ. 46 (November), 576–592. https://doi.org/10.1016/j.eneco.2013.09.029.

Liao, Lu., Warner, Mildred E., Homsy, George C., 2020. When Do Plans Matter?: Tracking Changes in Local Government Sustainability Actions From 2010 to 2015. J. Am. Plann. Assoc. 86 (1), 60–74. https://doi.org/10.1080/01944363.2019.1667262.

Lyles, W., Stevens, M., 2014. Plan Quality Evaluation 1994–2012: Growth and Contributions, Limitations, and New Directions. J. Plann. Educ. Res. 34 (4), 433–450. https://doi.org/10.1177/0739456X14549752.

Lyles, Ward, Berke, Philip, Overstreet, Kelly Heiman, 2017. Where to Begin Municipal Climate Adaptation Planning? Evaluating Two Local Choices. J. Environ. Plann. Manage. October, 1–21. https://doi.org/10.1080/09640568.2017.1379958.

Lyles, Ward, Berke, Philip, Smith, Gavin, 2014. A Comparison of Local Hazard Mitigation Plan Quality in Six States, USA. Landscape Urban Plann. 122 (February), 89–99. https://doi.org/10.1016/j.landurbplan.2013.11.010.

Maccallum, Diana, Hopkins, Diane, 2011. The Changing Discourse of City Plans: Rationalities of Planning in Perth, 1955–2010. Plann. Theor. Pract. 12 (4), 485–510. https://doi.org/10.1080/14649357.2011.626313.

Malecha, M., Masterson, J.H., Yu, S., Berke, P. (2019). Plan Integration for Resilience Scorecard Guidebook: Spatially evaluating networks of plans to reduce hazard vulnerability – Version 2.0. College Station, Texas: Institute for Sustainable Communities, College of Architecture, Texas A&M University. Retrieved from: http://mitigationguide.org/wp-content/uploads/2018/03/Guidebook-2020.05-v5.pdf.

Malecha, Matthew L., Sierra C. Woodruff, and Philip R. Berke. "Planning to Exacerbate Flooding: Evaluating a Houston, Texas, Network of Plans in Place during Hurricane Harvey Using a Plan Integration for Resilience Scorecard." Natural Hazards Review 22, no. 4 (November 1, 2021): 04021030. https://doi.org/10.1061/(ASCE)NH.1527-6996.0000470.

Malecha, M., S. Woodruff, P. Berke, forthcoming. "Planning to Mitigate, or Exacerbate, Flooding Hazards? Evaluating a Houston, Texas, Network of Plans in Place during Hurricane Harvey Using a Plan Integration for Resilience Scorecard".

Malecha, Matthew L., Brand, A.D., Berke, Philip R., 2018. Spatially Evaluating a Network of Plans and Flood Vulnerability Using a Plan Integration for Resilience Scorecard: A Case Study in Feijenoord District, Rotterdam, the Netherlands. Land Use Policy 78 (November), 147–157. https://doi.org/10.1016/j.landusepol.2018.06.029.

Meerow, Sara, Pajouhesh, Pani, Miller, Thaddeus R., 2019. Social Equity in Urban Resilience Planning. Local Environ. 24 (9), 793–808. https://doi.org/10.1080/13549839.2019.1645103.

Meerow, Sara, Woodruff, Sierra C., 2020. Seven Principles of Strong Climate Change Planning. J. Am. Plann. Assoc. 86 (1), 39–46. https://doi.org/10.1080/01944363.2019.1652108.

Moser, Susanne C., 2012. Adaptation, Mitigation, and Their Disharmonious Discontents: An Essay. Clim. Change 111 (2), 165–175. https://doi.org/10.1007/s10584-012-0398-4.

National Academies of Sciences, Engineering, and Medicine, 2019. Building and Measuring Community Resilience: Actions for Communities and the Gulf Research Program. The National Academies Press, Washington, D.C.

National Research Council (Ed.), 2014. Reducing Coastal Risk on the East and Gulf Coasts. National Academies Press, Washington, D.C.

Neuman, Michael, 1998. Does Planning Need the Plan? J. Am. Plann. Assoc. 64 (2), 208–220. https://doi.org/10.1080/01944369808975976.

Olazabal, Marta, Gopegui, Maria Ruiz De, 2021. Adaptation Planning in Large Cities Is Unlikely to Be Effective. Landscape Urban Plann. 206 (February), 103974 https://doi.org/10.1016/j.landurbplan.2020.103974.

Preston, Benjamin L., Westaway, Richard M., Yuen, Emma J., 2011. Climate Adaptation Planning in Practice: An Evaluation of Adaptation Plans from Three Developed Nations. Mitig. Adapt. Strat. Glob. Change 16 (4), 407–438. https://doi.org/10.1007/s11027-010-9270-x.

Runhaar, Hens, Wilk, Bettina, Persson, Åsa, Uittenbroek, Caroline, Wamsler, Christine, 2018. Mainstreaming Climate Adaptation: Taking Stock about 'What Works' from Empirical Research Worldwide. Reg. Environ. Change 18 (4), 1201–1210. https://doi.org/10.1007/s10113-017-1259-5.

Shi, Linda, Chu, Eric, Anguelovski, Isabelle, Aylett, Alexander, Debats, Jessica, Goh, Kian, Schenk, Todd, Seto, Karen C., Dodman, David, Roberts, Debra, Roberts, J. Timmons, VanDeveer, Stacy D., 2016. Roadmap towards Justice in Urban Climate Adaptation Research. Nat. Clim. Change 6 (2), 131–137. https://doi.org/10.1038/nclimate2841.

Stults, Missy, Woodruff, Sierra C., 2016. Looking under the Hood of Local Adaptation Plans: Shedding Light on the Actions Prioritized to Build Local Resilience to Climate Change. Mitig. Adapt. Strat. Glob. Change, November. https://doi.org/10.1007/s11027-016-9725-9.

Sweet, William V, Kopp, Robert, Weaver, Christopher, Obeysekera, Jayantha, Radley Horton, E., Thieler, Robert, Zervas, Chris, 2017. "Global and Regional Sea Level Rise Scenarios for the United States". NOS CO-OPS 083. National Oceanic and Atmospheric Administration, Silver Spring, Maryland.

Vella, K., W. H. Butler, N. Sipe, T. Chapin, and J. Murley. "Voluntary Collaboration for Adaptive Governance: The Southeast Florida Regional Climate Change Compact." Journal of Planning Education and Research 36, no. 3 (September 1, 2016): 363–76. 10.1177/0739456X16659700.

Wilkinson, Cathy, Saarne, Toomas, Peterson, Garry D., Colding, Johan, 2013. Strategic Spatial Planning and the Ecosystem Services Concept - an Historical Exploration. Ecol. Soc. 18, no. 1 https://doi.org/10.5751/ES-05368-180137.

Woodruff, Sierra, BenDor, Todd K., Strong, Aaron L., 2018a. Fighting the Inevitable: Infrastructure Investment and Coastal Community Adaptation to Sea Level Rise. Syst. Dyn. Rev. https://doi.org/10.1002/sdr.1597.

Woodruff, Sierra C. 2018. "Coordinating Plans for Climate Adaptation." Journal of Planning Education and Research, November, 0739456X1881013. 10.1177/0739456X18810131.

Woodruff, Sierra C., Sara Meerow, Missy Stults, and Chandler Wilkins, 2018. Adaptation to Resilience Planning: Alternative Pathways to Prepare for Climate Change. J. Plann. Educ. Res., October, 0739456X18801057. 10.1177/0739456X18801057.

Woodruff, Sierra C., Stults, Missy, 2016. Numerous Strategies but Limited Implementation Guidance in US Local Adaptation Plans. Nat. Clim. Change, May. https://doi.org/10.1038/nclimate3012.

Yu, Siyu, Brand, A.D., Berke, Philip, 2020. Making Room for the River. J. Am. Plann. Assoc. 1–14. https://doi.org/10.1080/01944363.2020.1752776.