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Integrated Assessment of Risk and Vulnerability. The Use of Online Decision-Support Tools to Communicate Coastal Vulnerability and Promote Adaptation Planning

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Abstract

The hazards posed by both accelerating rates of sea level rise and intensifying coastal storms have fostered a call for increased resiliency of coastal human communities and natural ecosystems. While sea level rise is a world-wide phenomenon, mitigating its impacts is a local decision-making challenge that requires site-specific remedies. To inform coastal communities in the state of New Jersey, USA of the risks posed by coastal flooding and to aid in adaptation planning, we undertook a series of integrated assessments to map and characterize various aspects of exposure and vulnerability. The resulting assessments have been incorporated into a suite of online decision-support tools as an outreach mechanism to aid coastal decision-makers. The tools have been incorporated under one umbrella, www.NJAdapt.org, allowing users to visualize flood hazards and sea level rise (NJ FloodMapper), to create maps (Coastal Hazard Profiler), to assess communities' vulnerabilities, and to increase preparedness (Getting to Resilience). However well intentioned, for these online tools to be truly effective, they must be integrated into a broader decision-support system that includes substantive professional outreach and person-to-person interaction.

Keywords:

place-based decision-making, sea level rise, coastal storms, flood exposure, NJAdapt

1 Introduction

Sea level rise is a physical reality that is impacting the coastline of the entire Mid-Atlantic United States (New Jersey, Delaware, Pennsylvania and New York). The hazards posed by both accelerating rates of sea level rise and intensifying coastal storms have fostered a call for increased resiliency of coastal human communities and natural ecosystems. While sea level

rise is a world-wide phenomenon, mitigating its impacts is a local decision-making challenge that requires site-specific remedies. Through land use planning, development and coastal management decisions, local decision-makers play a key role in influencing the resilience of coastal communities to climate-change related sea level rise and storm surge. As both the exposure to hazards and the underlying system vulnerability demonstrate spatial variability, any adaptation response will also be a locally-varying decision-making challenge. Faced with a variety of conflicting mandates and uncertainty as to the appropriate responses, local land use planners and managers are increasingly relying on place-based decision-support system tools that outline a range of geographically-targeted management options.

A necessary first step is a better understanding of the scope of potential hazards and of the exposure of key infrastructure and vulnerable populations to inundation, whether due to sea level rise alone or in combination with the effects of storm-related flooding. To help inform coastal resiliency planning in the state of New Jersey, we undertook an assessment of coastal areas most exposed to coastal flooding, storm surge and sea level rise. This assessment along with mapped information on the individual coastal hazards, the natural and built environments, and vulnerable human populations have been incorporated into a suite of online decision-support tools conceived as an outreach mechanism to aid coastal decision-makers. Designed to work in concert with what we term coastal community resiliency progression, the objective of these tools is to help coastal decision-makers identify vulnerabilities, with the goal of promoting community resiliency (Figure 1).

Figure 1: Coastal Community Resiliency Progression.

2 New Jersey Coastal Flood Exposure Assessment

To help inform coastal resiliency planning in the state of New Jersey, we undertook an assessment of coastal areas most exposed to coastal flooding, storm surge and sea level rise. In assessing the risks posed by sea level rise in combination with storm-related flooding, we adopted the following general framework:

Flooding Risk = Hazard x Exposure x Vulnerability

Step 1: Model hazards → Step 2: Map resulting exposure → Step 3: Assess vulnerability

As part of Step 1, the modelling of coastal hazards, we incorporated the Special Flood Hazard Areas (SFHA) identified by the Federal Emergency Management Agency (FEMA); the Sea, Lake and Overland Surges from Hurricanes (SLOSH) data of the National Weather Service (NWS), which model storm surge heights resulting from historical, hypothetical or predicted hurricanes (NOAA NWS, 1992; 2013), and National Oceanographic and Atmospheric Administration (NOAA) maps of Shallow Coastal Flooding (SCF). The FEMA SFHAs map the 1% base flood zone (i.e., a 1% chance of being equaled or exceeded in any given year) and the 0.2% (or 500-year flood) as well as V Zones (areas along the coast subject to additional hazards associated with storm-induced waves). SCF maps represent land areas along the coast that are periodically flooded by higher than average high tides (i.e. spring tides) combined with heavy rainfall and onshore winds (i.e., wind blowing landward from the ocean).

Through consultation with a panel of coastal hazard experts, we identified criteria for a New Jersey coastal flooding exposure assessment protocol and ranking scheme. The assessment distinguishes three classes of geographic area based on variation in exposure to coastal hazards: Moderate, High and Extreme exposure. Areas exposed to flooding on a more frequent basis were given a higher ranking. Thus the ranking incorporates the probability or likelihood of the area being flooded. For example, even though a Category 3 storm surge has higher flooding elevations, the likelihood of occurrence is lower than a Category 1 storm surge, and therefore the Category 3 flood area was given a lower exposure ranking. Extreme exposure areas are those that are exposed to relatively frequent flooding. In addition, the Extreme exposure areas also include those areas subject to the most powerful wave impacts. Both current and future exposure were considered, the latter through the incorporation of projected sea level rises by 2050 and 2100. To inform the assessment, a panel of sea level rise (SLR) experts was convened to assist in developing the 'best available' values for the 2050 and 2100 sea level rise scenarios.

The results for the Present Day (baseline without future sea level rise) assessment suggest that areas of extreme exposure are limited to tidal marshes, low-lying areas exposed to shallow coastal flooding, and the most wave-exposed shorelines (Table 1, Figure 2). Many of New Jersey's heavily urbanized coastal communities are mapped as having Moderate to High levels of flooding exposure.

Table 1: NJ Coastal Flood Exposure: Areas by category (in acres and as % change from baseline year 2000).

Category	2000	2050		2100	
	Area (ac)	Area (ac)	% change	Area (ac)	% change
Moderate	197,433	183,329	-7.1	165,833	-16.0
High	148,060	165,272	+11.6	185,489	+25.3
Extreme	234,224	271,784	+16.6	310,608	+32.6
Total	579,717	620,385	+7.0	661,930	+14.2

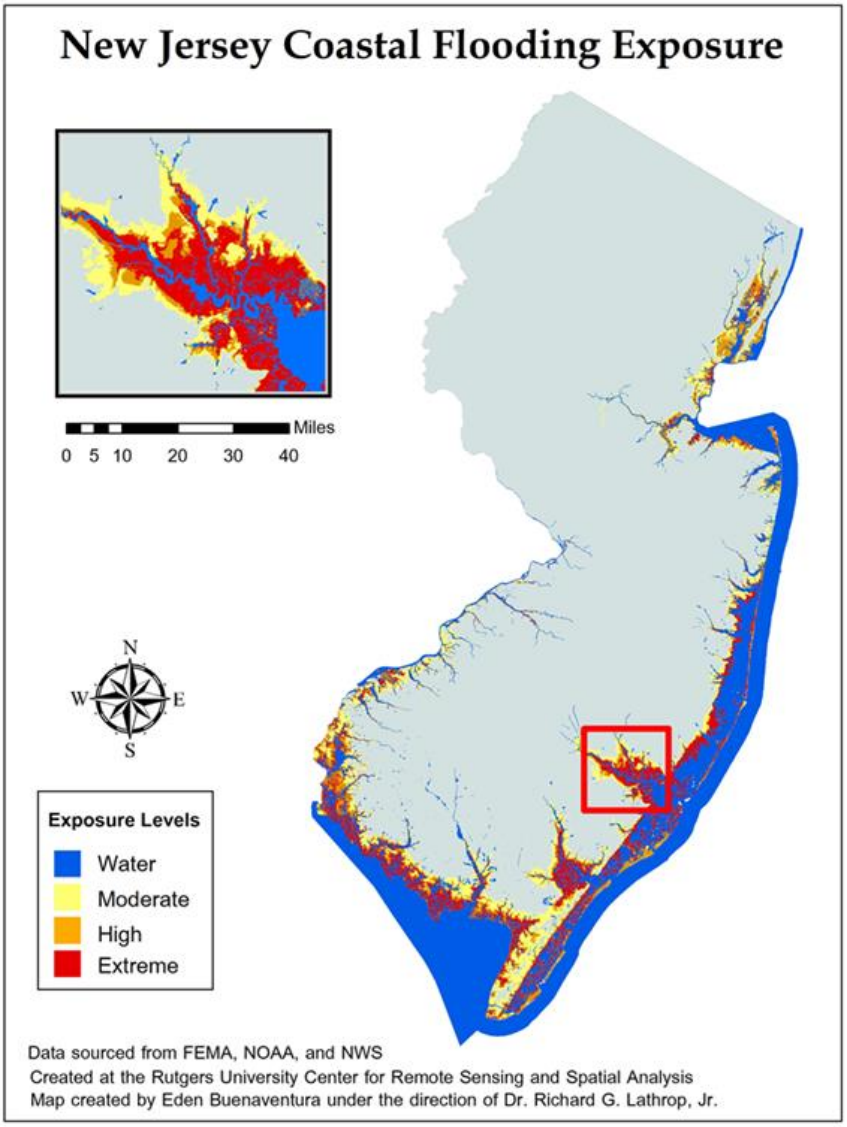

Figure 2: Map of coastal flooding exposure under present-day conditions.

In planning for enhanced coastal resiliency, it is vital to consider the populations, facilities and resources at risk of exposure, which can be evaluated for possible adaptation measures that include flood-proofing, elevation, relocation and property buy-outs. To undertake a limited assessment of the vulnerability of human populations and built infrastructure (Step 3 above), the composite flood exposure maps were cross-tabulated with several other geographic information system (GIS) data sets (Table 2).

Table 2: Summary of the geographic information systems (GIS) data

Data Type	Source
Coastal evacuation routes	NJ Department of Transportation
Critical facilities	FEMA HAZUS and NJOIT
List of known contaminated sites	NJ Department of Environmental Protection
Population	US Census Factfinder2
Parcel and land value	NJOIT and Department of Treasury

Within these areas exposed to coastal flooding, there is a noteworthy amount of infrastructure in terms of major roads/evacuation routes, critical facilities (such as Hospitals, Schools, Power stations, …), contaminated sites and property. Also affected are segments of society that may have limited capacity to prepare for or recover from extreme flooding events. As sea level is expected to continue to rise, if not accelerate, over the coming decades, we projected the increase in exposure for existing critical facilities and populations that might be expected in 2050 and 2100. The miles of major roads exposed to flooding increases nearly 13% by 2100. The number of existing critical facilities exposed increases from 692 (present day) to 781 (or by 13%) by 2050, and to 879 (or by 27%) by 2100. The overall population potentially directly exposed to flooding increases from 913,651 (present day) to 1,012,174 (11%) by 2050, and to 1,116,294 (22%) by 2100. The socially vulnerable population, the number of affected parcels, and properties exposed to coastal flooding are also expected to increase. For more information on New Jersey Coastal Flood Exposure Assessment, go to http://www.njadapt.org/about.html.

3 Online Decision-Support Tools

The coastal hazards and exposure assessment outlined above has been incorporated into a suite of online decision-support tools to aid coastal decision-makers. As our target audiences of coastal emergency management personnel and land use decision-makers are often non-expert GIS users without ready access to GIS software and data, we opted for a web-based GIS or WebGIS approach. WebGIS (sometimes referred to as the Geo Web) uses web technology to communicate between the web application server and the end user client (Haklay et al., 2008; Fu and Sun, 2010). A suite of tools were developed and incorporated under one umbrella, www.NJAdapt.org. The web-based tools allow users to visualize flood hazards and sea level rise (NJ FloodMapper), create maps (Coastal Hazard Profiler), assess communities' vulnerabilities, and increase preparedness (Getting to Resilience). NJAdapt was

developed as a collaboration between the Rutgers University Climate Institute, the Rutgers University Center for Remote Sensing & Spatial Analysis (CRSSA), the Jacques Cousteau National Estuarine Research Reserve (JCNERR) and NOAA's Coastal Services Center.

A necessary first step is a better understanding of the scope of future sea level rise and the exposure of key infrastructure and vulnerable populations to inundation, whether due to sea level rise alone or in combination with storm surge-related flooding. The NJFloodMapper WebGIS tool (www.NJFloodMapper.org) was launched in 2012 (Lathrop et al., 2014). As part of our user-centred design process, we employed an instructional systems design (ISD) model (Gagne, 1987) to address the identified needs of our target audience of coastal decision-makers. A summative evaluation was conducted six months post-launch to allow adequate time for the target audience to evaluate and use the application for operational planning purposes. Based on this summative evaluation as well as additional follow-up interviews with a focus group of users, NJFloodMapper Version 2 was released in 2016. In addition to refining the user interface based on the focus group's suggestions, Version 2 included new functionality that illustrates graphically the probable timing of when sea level rise will surpass various elevations on the New Jersey coast.

As many critical land use planning decisions in New Jersey are made at the municipal level, the Coastal Hazard Profiler was designed to provide users with ready access to municipal-level information. The Coastal Hazard Profiler supplements interactive geospatial visualization with municipal summary reports which combine text, data and graphics. Mapped information on human population, and the natural and built environments provide spatial context. Overlay maps of various coastal hazards such as sea level rise, storm surge and flood zones along with the coastal flooding exposure assessment (described in Section 2 above) were incorporated to facilitate the identification of current and future hazards and vulnerabilities.

The Getting to Reliance (GTR) online assessment tool (http://www.prepareyourcommunitynj.org) includes a questionnaire that was developed to assist communities to reduce vulnerability and increase preparedness. Outputs provided at the completion of the questionnaire can strengthen local/county plans for all hazards and emergency operations, as well as be worth valuable points through FEMA's Community Rating System, thereby helping to lower municipal homeowners' flood insurance premiums. GTR was designed to be a one-on-one process where JCNERR Coastal Resiliency Specialists work alongside municipal staff to increase their preparedness by linking planning, mitigation and on-the-ground adaptation efforts.

4 Conclusion

The NJDAPT platform (http://www.njadapt.org/) and the underlying exposure and vulnerability assessments were developed to help jump-start local community discussions about hazard impacts, providing municipal-scale maps that show people, places and natural resources exposed to coastal flooding. In working one-on-one with coastal decision-makers, we have found that the mapped data and the discussions generated by the maps are valuable and applicable to a variety of community planning processes—from comprehensive land-use

to hazard mitigation and conservation planning. However, accessibility to geospatial information is not simply a question of making information available online. We concur with Niles and Hanson (2003) in that 'Virtual accessibility requires that people be able to find, make sense of, and apply information on the Internet: considering access to information as good in its own right overlooks the importance of the context within which that information is received and the reason for which it is sought.'

While visualization of flood exposure is a critical first step, it became clear through our experience working with coastal decision-makers coping with the aftermath of SuperStorm Sandy (October 2012) that additional decision-support tools and local-level training were needed to help them translate the place-based information into concrete action plans. The Coastal Hazard Profiler, specifically designed to provide municipal-scale maps and information in a readily accessible format, was developed in response to this identified need. Additional JCNERR Coastal Resiliency Specialists were hired to serve as this critical intermediary, helping communities work through the Coastal Community Resiliency Progression process (Figure 1). Our experience suggests that for online decision-support tools to be truly effective, they must be integrated into a broader decision-support system that includes substantive professional outreach and person-to-person interaction.

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