

Interactive comment on “Multi-hazards risks in New York City” by Yaella Depietri et al.

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Anonymous Referee #2

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General Comments:

The authors present a risk / hazard assessment of New York City from the perspective of multiple hazard sources. The authors utilized an interesting methodology to quantify hazards via historical records and New York Times articles. While the article presents a new viewpoint on the subject matter I found several primary areas in which the work could be improved. 1) The literature review is missing much of the seminal work on vulnerability based hazard and risk assessments, as well as several studies that were

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conducted specifically in this same study region, covering much of the same material as this work, and in some cases much more thoroughly. It is a bit problematic that the authors repeatedly state that studies considering multiple hazards are largely absent, when in fact there is a fairly large body of work on exactly this subject.

Thank you very much for your comment. As you pointed out, we improved the review of the state of the art about the literature it intends to address, namely vulnerability assessment and disaster risk reduction. We addressed this point by providing more context to the study in the introductory section 1.1. On the other hand, while there is indeed a large amount of studies that look at physical vulnerability in multi-hazard risk or look at how multiple hazards overlap spatially or temporally in specific locations, we found that the social dimension in multi-hazards vulnerability and risk is generally less explored in the literature related to multi-hazard risk.

I would rework the language a bit from the perspective of the papers I mention below. 2) I believe the risk modeling based on expert deterministic approach by averaging the vulnerability and exposure estimates by a group of experts. While interesting and important to include local opinion, this neglects the variance within the population interviewed. I believe a more probabilistic assessment would lend more information.

Thank you for your comments. In our list of stakeholders, the clear majority of the experts were actually belonging to one of the relevant local authorities, those daily tasks related to one or more aspects of disaster risk in NYC. The sampling respondents is quite homogenous which supports our choice of method. We did not collect more detailed information about the identity of the respondents to insure their anonymity, which limits other analyses of respondents we might have done.

3) The level of abstraction posed on the hazards seems a bit arbitrary, which could potentially be problematic. For example, the authors cluster all rainfall as one hazard, but include storm surge as another and note that these hazards could overlap. It would potentially be more meaningful then to disaggregate rainfall by mechanism as well to

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pull out the effect of tropical moisture sourced rainfall from local convective rainfall.

Thank for pointing this out. When we elaborate the data about inland flooding (the 311 calls of street or basement flooding) we excluded all events caused by coastal hazards (i.e. all hazards described as coastal by NOAA and that occurred in the period of availability of the data). This to avoid double counting in the coastal areas potentially affected by storm surges.

4) Finally, the writing could be improved. From the introduction it's not entirely clear what the purpose of the paper is (a new methodology, a case study of New York, a review of existing decision analysis approaches). The methodology is lacking important details. The discussion is a bit brief and doesn't really circle back to address issues raised in the introduction.

Regarding this point, we addressed it by adding additional text about how we intend this study to be an application of the multi-hazard approach to NYC. We intend to show how social multi-hazards risk analysis is important for resilience and adaptation planning in NYC. The study intends to provide a base of discussion for future planning in the city itself as well as recommendations for real world implementation of multi-hazard assessments in other similar urban contexts. We have also edited text to directly address the point here about clarity of the main purpose and further, to enhance readability and the quality of the writing.

Specific Comments: Introduction - line 80: Why are you discussing CSOs? This is not a hazard that you revisit in the paper, so I would recommend shortening this section up by removing this.

Thank you, correct, we addressed this comment by reducing our discussion on CSOs

Line 84: Point to an example of a hazard that overlaps spatially and temporally. You could even shorten the intro further by connecting these lines to the above discussion of Hurricane Sandy (rainfall & surge).

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Thank you, we have addressed this with specific edits to this section of the paper, tightening the discussion and example of spatial and temporal overlap.

Line 89: You don't deal with policy-related risk in this paper, so you should avoid discussing it here. Focus the discussion on the aspects of risk analysis that you are covering with your research.

We agree about this point and have limited this discussion to keep the main points on track.

Line 98: I disagree a bit with this paragraph. You perform a case study of New York City. How does this help us know more about risk analysis in other megacities? I would use more specific language, and again, just discuss what you are doing with this research. You could probably shorten this paragraph to just the first and last sentences.

Addressed. The length of the discussion has been reduced and revised to make clear that NYC is a case and similar approaches could be used in other coastal megacities to better understand combined risks to residents. It does not help us know about risk in other cities, but is intended as a potential replicable method.

Line 153: This sentence is awkwardly worded. Consider revising.

Thank you, addressed by revising the structure of the sentence. Intro general: I think the authors are missing some of the seminal work on decision analysis here. I would research decision scaling, multi-objective decision making, and robust decision making. These frameworks are being applied to very similar risk analysis problems as this one, and circumvent some of the issues the authors are discussing. As a starting point, see these papers:

Brown, C., Ghile, Y., Laverty, M., & Li, K. (2012). Decision scaling: Linking bottom-up vulnerability analysis with climate projections in the water sector. *Water Resources Research*, 48(9).

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Regan, H. M., Ben-Haim, Y., Langford, B., Wilson, W. G., Lundberg, P., Andelman, S. J., & Burgman, M. A. (2005). Robust decision-making under severe uncertainty for conservation management. *Ecological applications*, 15(4), 1471-1477.

Chankong, V., & Haimes, Y. Y. (2008). *Multiobjective decision making: theory and methodology*. Courier Dover Publications. Thank you for this suggestion. As you also noted above, we do not really discuss policy or decision making in the paper although we can certainly say that the research is policy relevant. We preferred to broaden the discussion on disaster risk and vulnerability without entering in the discussion of policy or decision making related to climate prediction with which we do not deal directly in this paper but which is covered partially in a companion paper.

Section 1.2: In general I think the authors are missing much important research on hazards in this region. These papers have done much to examine regional risk within the context of multi-hazards. Again, these papers are meant as a starting point for the authors to perform a more thorough literature review.

Though we are not attempting to be comprehensive in reviewing all hazard literature for the region, rather demonstrating a method for how multi-hazard risk can and should be assessed for advancing resilience and DRR policy. Still, we do include several suggested references and others in the revisions. Thank you for this. It's important for readability and to maintain the key points of the paper not to posit this as a comprehensive review of multiple literatures. We have stated this explicitly in the revisions.

Papers discussing storm surge: Lin, N., Emanuel, K. A., Smith, J. A., & Vanmarcke, E. (2010). Risk assessment of hurricane storm surge for New York City. *Journal of Geophysical Research: Atmospheres*, 115(D18). Added

Lin, N., Emanuel, K., Oppenheimer, M., & Vanmarcke, E. (2012). Physically based assessment of hurricane surge threat under climate change. *Nature Climate Change*, 2(6), 462. Added

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Aerts, J. C., Lin, N., Botzen, W., Emanuel, K., & de Moel, H. (2013). Low return period risk modeling for New York City. *Risk Analysis*, 33(5), 772-788. Included in the text

Orton, P., Georgas, N., Blumberg, A., & Pullen, J. (2012). Detailed modeling of recent-severe storm tides in estuaries of the New York City region. *Journal of Geophysical Research: Oceans*, 117(C9). Added

Papers discussing multiple extreme rainfall mechanisms in New York State: Knighton, J., Steinschneider, S., & Walter, M. T. (2017). A Vulnerability-Based, Bottom-Up Assessment of Future Riverine Flood Risk Using a Modified Peak-Over-Threshold Approach and a Physically Based Hydrologic Model. *Water Resources Research*, 53(12), 10043-10064. We thought that this reference may be beyond the scope of the paper, so we prefer not to include it.

Smith, J. A., Villarini, G., & Baeck, M. L. (2011). Mixture distributions and the hydroclimatology of extreme rainfall and flooding in the eastern United States. *Journal of Hydrometeorology*, 12(2), 294-309. Included

Towey, K. L., Booth, J. F., Frei, A., & Sinclair, M. R. (2018). Track and Circulation Analysis of Tropical and Extratropical Cyclones that Cause Strong Precipitation and Streamflow Events in the New York City Watershed. *Journal of Hydrometeorology*, (2018). Included

Agel, L., Barlow, M., Qian, J. H., Colby, F., Douglas, E., & Eichler, T. (2015). Climatology of daily precipitation and extreme precipitation events in the northeast United States. *Journal of Hydrometeorology*, 16(6), 2537-2557. Included

Talke, S. A., Orton, P., & Jay, D. A. (2014). Increasing storm tides in New York harbor, 1844–2013. *Geophysical Research Letters*, 41(9), 3149-3155. Included

Section 1.2.2: Throughout this section you refer to extreme precipitation as if it occurs by one single mechanism, when in fact extreme rainfall in this location occurs via by

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multiple distinct mechanisms. In a classic engineering analysis this isn't particularly problematic; however, you are claiming that this research presents a multi-hazard approach which successfully relates hazards in time and space. Wind driven surge does often correlate with rainfall, but probably only tropical moisture export sourced rainfall. At this point I'm a little lost as to how you will successfully overlay these two hazards without decomposing rainfall into at least tropical / non-tropical events.

From the database of 311 calls for street and basement flooding we excluded those events that were classified as coastal from the NOAA database to avoid double counting

Line 266: Again, here you're discussing CSOs when your paper does not cover CSOs. I would shorten this up.

Thank you for this second comment, we shorten the discussion on CSOs

Line 274: Are you suggesting that all precipitation events and mechanisms will increase uniformly based on trends observed at an annual time scale? I'm not sure that I agree. For example please see Knighton et al (2017).

Thank you for your comment. We are suggesting that this trend of increased precipitation may continue increasing in the future due to climate change based on other references we are citing. We do not suggest a uniform increase.

Knighton, J., Steinschneider, S., & Walter, M. T. (2017). A Vulnerability-Based, Bottom-Up Assessment of Future Riverine Flood Risk Using a Modified Peak-Over-Threshold Approach and a Physically Based Hydrologic Model. *Water Resources Research*, 53(12), 10043-10064.

Line 292: This sentence is confusing "most in the month of September, but generally lead to large damages." What is it about September that makes you think damage would be less? Thank you, we adjusted the sentence

Line 319: What data? NOAA has many rainfall products. Be more specific. We refer

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to daily meteorological data measured at Central Park continuously for the selected period. We added more information regarding these data in the manuscript

Line 322: What do you mean by cross-referenced. Be more specific here. Did you keyword search archived records? If so, what keywords? Did you filter out specific dates? Did you do this manually, or with a scripting language? Thank you for pointing this out. We addressed the comment expanding on it in the methods section. We meant that we looked at events of extreme heat immediately followed by high precipitation events and looked for those dates for relevant articles in the New York Times. We did not do a keyword search but investigated each New York Time edition published on the day of the multi-hazard event identified through the analysis of NOAA meteorological data. We had previously identified heat waves events (three consecutive days beyond 90 F) and heavy precipitation events (daily precipitation beyond 1.75 inches of rain) and then we looked for consecutive, multi-hazard events.

Line 339: I am not sure I agree that a deterministic averaging makes the most sense here. I would be interested to know the distribution of weights from all survey responses. This approach hides issues that can be embedded in decision making groups, such as disagreement on vulnerabilities.

We acknowledge your concern, however, as we mentioned above we reduced to the minimum the type of information to identify the respondents of the questionnaire to insure anonymity about an issue that is much of concern especially to local authorities. The respondents were asked to allocate 100 points amongst each set of indicators. We used the budget allocation participatory method to assign weights which leads us to adopt averaging. As we did not record more information about the identity of respondent to insure anonymity, we regret that we cannot address this comment because additional data is lacking. It is true of course, that one can come up with .

Line 361: I'm confused as to what these subjective definitions do to assist in decision making.

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Thanks. Generally, this is the type of values (ranging from 1 to 5) that one derives from risk and vulnerability studies. It helps prioritize areas and focus on these to address risk and then perhaps, according to the resources available deepen the assessment with place based studies. We have added detail to the text to make sure this is clearly expressed.

Eq1 and 2: What are the units of all variables? These are levels of hazard intensity expressed between 1 to 5

Line 382: This is an interesting approach, but floodplain maps exist for the region. Why not use them? For example, see the Hudson River floodplain mapper produced by Columbia (<http://www.ciesin.columbia.edu/hudson-river-flood-map/>)

Thank you for pointing out to these alternative data. We use the floodplain maps we used in response to discussion with city officials as to best source at the time of the analysis.

Line 389: I would check this against a NOAA tide gage at the Battery in NYC. The NCEI Storm event catalog is definitely missing some records over the period you are interested in. The continuously recorded water surface elevation on the Hudson could be a more reliable source of hazard information for surge.

Thank you for this comment. We will pursue for sure in subsequent research we are doing on integrate stormwater and storm surge scenarios and resilience in the NYC region. We also make note following reviewer suggestion of this information being available for others who may be interested as well in tracking hazard information.

All remaining equations: Again, what are the units of all variables? This is all presented in a confusing way. This paper could use a text description of these equations, and an annotation section to better explain how you are mixing units like this.

For the equations we used levels of hazard intensity and levels of vulnerability. We added further information to method section about the use of levels of hazards, vulner-

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ability and risk to conduct to the operations among the variables and explanation of the variables to make this more transparent.

Equation 6: Why equal weighting? Was this a subjective choice by the authors? vulnerability is generally expressed by these three components which might contribute in different ways to the final vulnerability depending on the indicators chosen to describe them, however and estimation of how exposure, susceptibility and coping capacity differently contribute to vulnerability is not estimated in the literature. This is the reason why the authors followed the general approach to assign equal weights to these composite indicators.

We added a note referring to the standard approach and also to make clear that many other weighting procedures are possible which may influence outcomes. However, as we point out in the text, the unweighted analysis is not very different from the weighted version.

Line 501: Instead of providing several anecdotal accounts, I would be interested in knowing how many events occurred over the n-years reviewed. What were the coincident mechanisms and frequencies? Are the pdfs of hazard the same for co-occurrences of two hazards?

We provided additional information in the text about the type number of events identified, thank you for this comment. We also note that this might be an underestimation.

Line 515: Hurricane Sandy hit in October, not the winter. The snowfall occurred in the midwest when the tropical moisture encountered another atmospheric event. You make it sound like this impacted NYC.

This was an error in the text and has been corrected.

Tables 3 and 4: What are the columns? I'm lost as to what this table is showing.

We changed the format of the Tables which hopefully clarifies that we are listing past and future types of multi-hazards events affecting NYC.

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Line 612: I'm not sure that I'm convinced that you've really shown this in an objective way. Thanks for this note.

We agree to focus discussion to the point that we started collecting important information about multi-hazard risk in NYC but that was only a smaller part of the work carried out in this paper.

You presented several anecdotes about multiple events occurring at once, but I'm left without a good understanding of which mechanisms co-occur for the region, and at what frequency and intensity.

Thank you for your comment. We understand that further analysis can be made to better define the nature of the frequency and intensity of multi-hazard risk in NYC. With our analysis we intended to provide context to the main part of the study which is the multi-hazard risk spatial assessment. We thus carried out a preliminary inquiry amongst the respondent of the survey and based on the meteorological data we analyzed. We greatly appreciate your comment and will reserve to deepen the analysis in the follow up studies we are carrying out in NYC. It is beyond the scope of this study however to analyze historical spatial or temporal overlap in past events, rather we focus on potential in the future as additional context for why multi-hazard risk is important to consider, as pointed out also in many other papers.

Line 641 "higher impacts": Here I disagree. Your survey asked people about vulnerability. As you say throughout your paper, the risk is exposure * vulnerability * hazard. Just because the surveyed population reports higher potential for vulnerability does not imply that there are larger impacts.

Thanks for this comment. Throughout the paper we define risk as the product of hazard and vulnerability (we consider exposure as a component of vulnerability). In our weighting exercise with local stakeholders we asked to weight the hazards too and not only vulnerability. In this sense we included information about potential impacts as well.

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Please also note the supplement to this comment:

<https://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2018-193/nhess-2018-193-AC3-supplement.pdf>

Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., <https://doi.org/10.5194/nhess-2018-193>, 2018.

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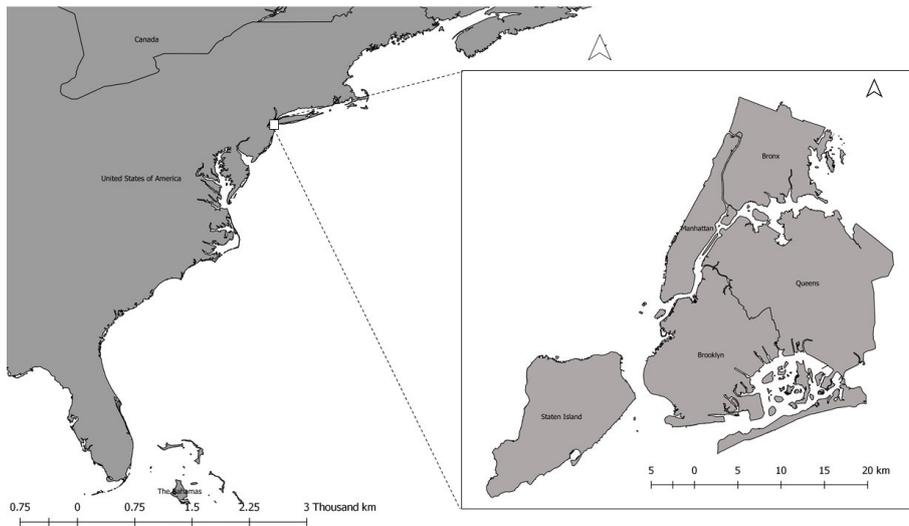


Fig. 1. Figure 1

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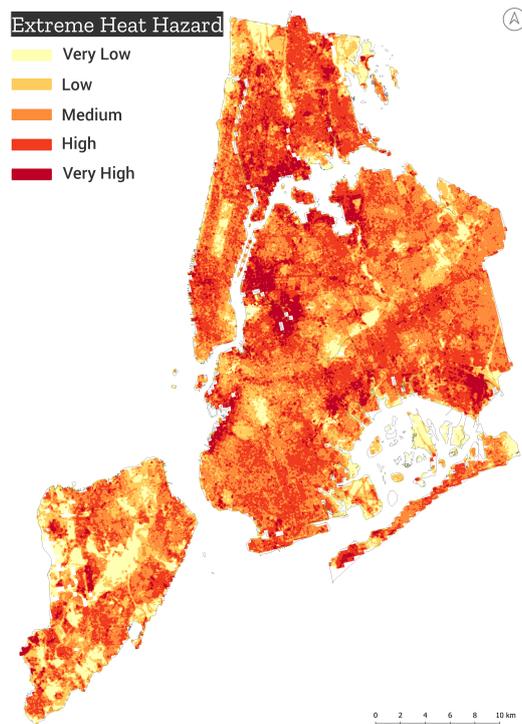


Fig. 2. Figure 2a

C14

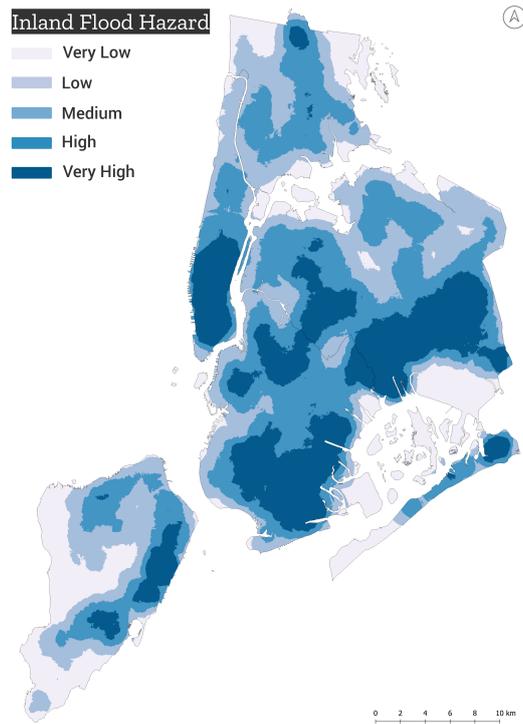


Fig. 3. Figure 2b

C15

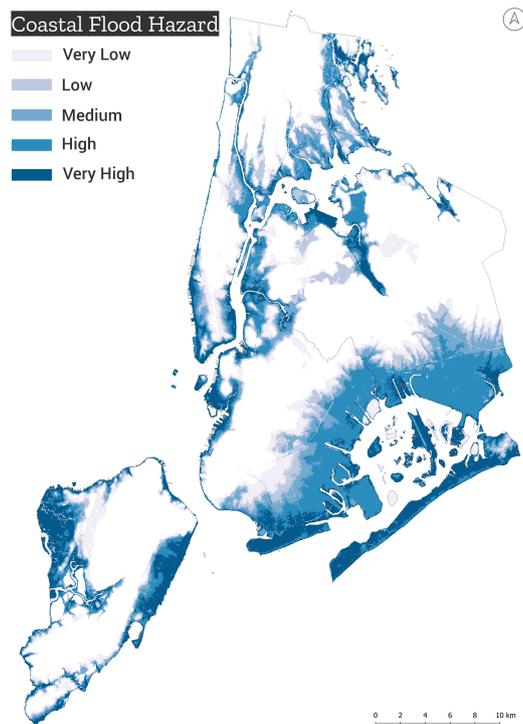


Fig. 4. Figure 2c

C16

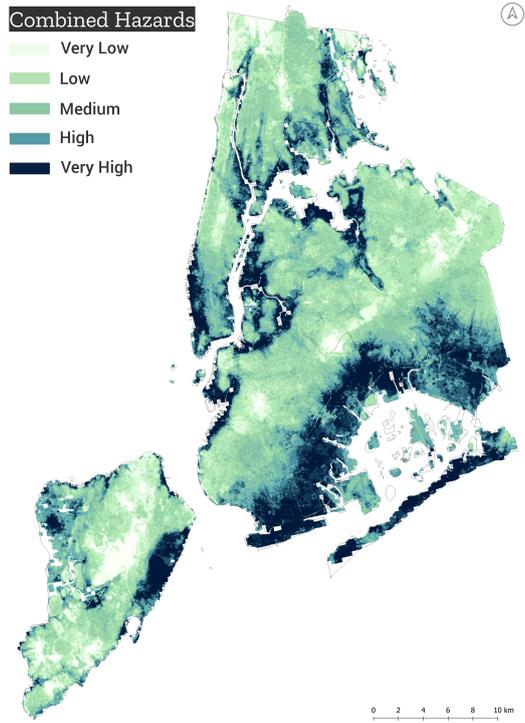


Fig. 5. Figure 3

C17

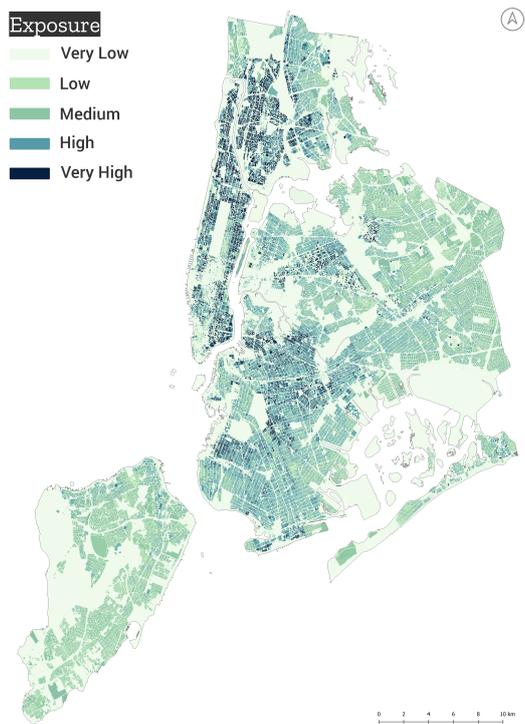


Fig. 6. Figure 4a

C18

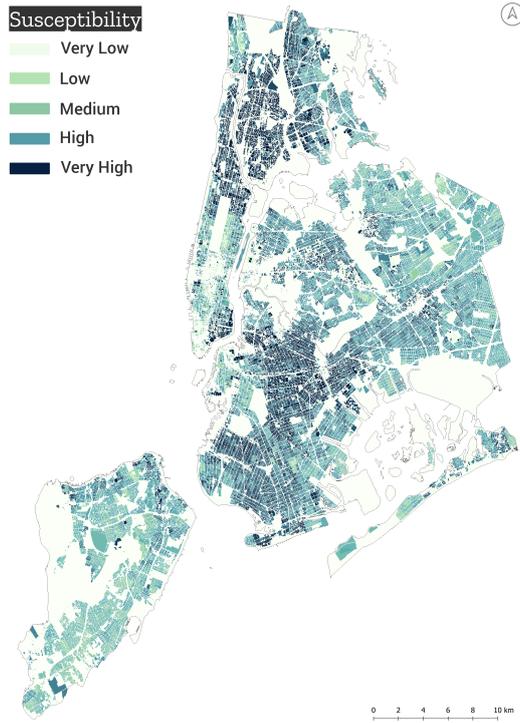


Fig. 7. Figure 4b

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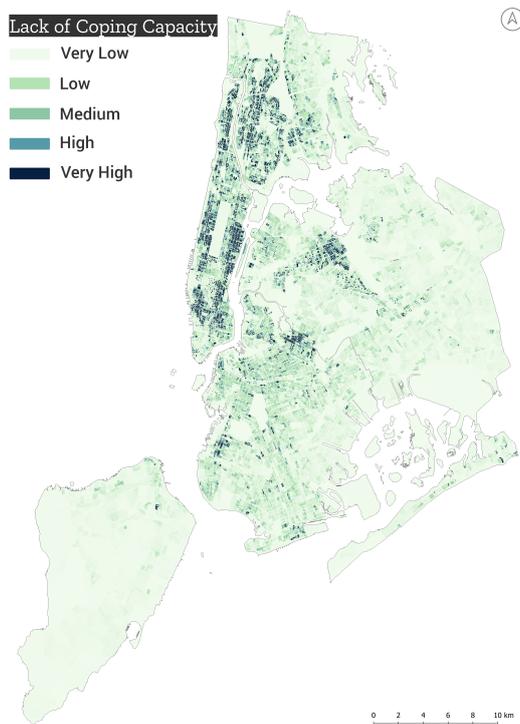


Fig. 8. Figure 4c

C20

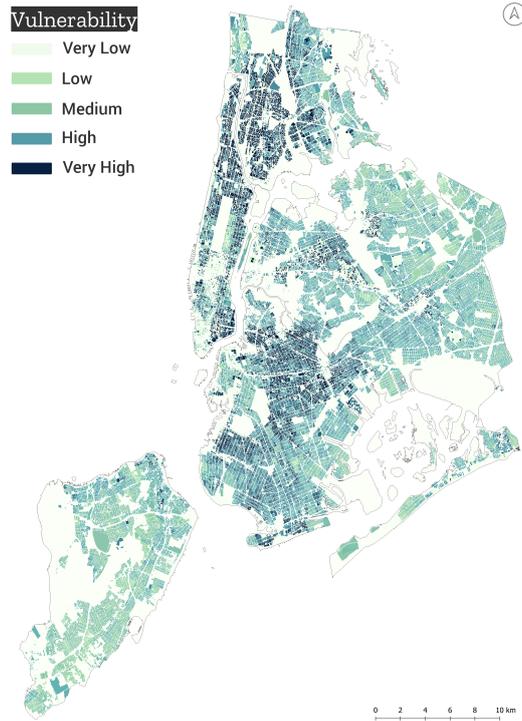


Fig. 9. Figure 5

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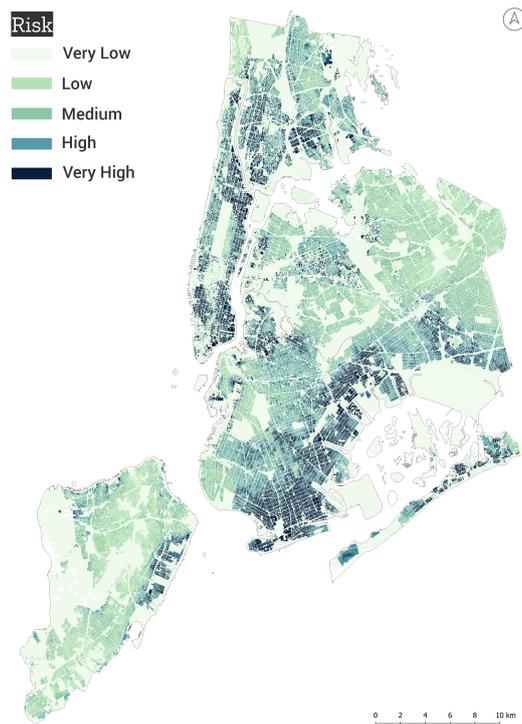


Fig. 10. Figure 6a

C22

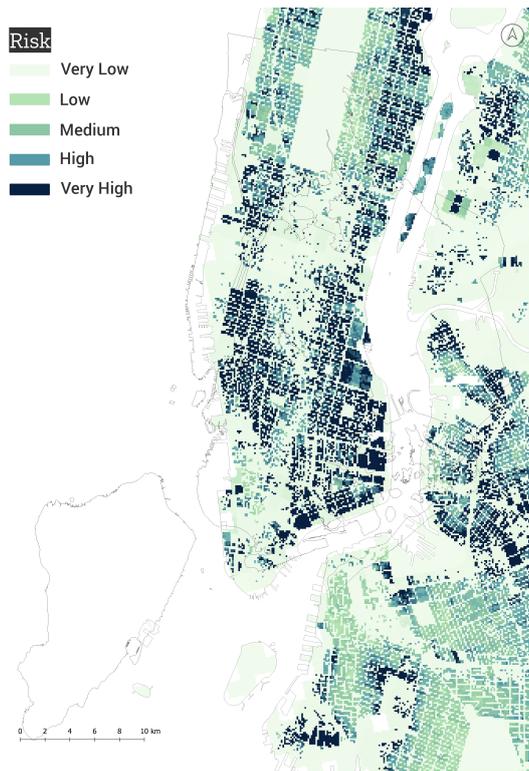


Fig. 11. Figure 6b

C23

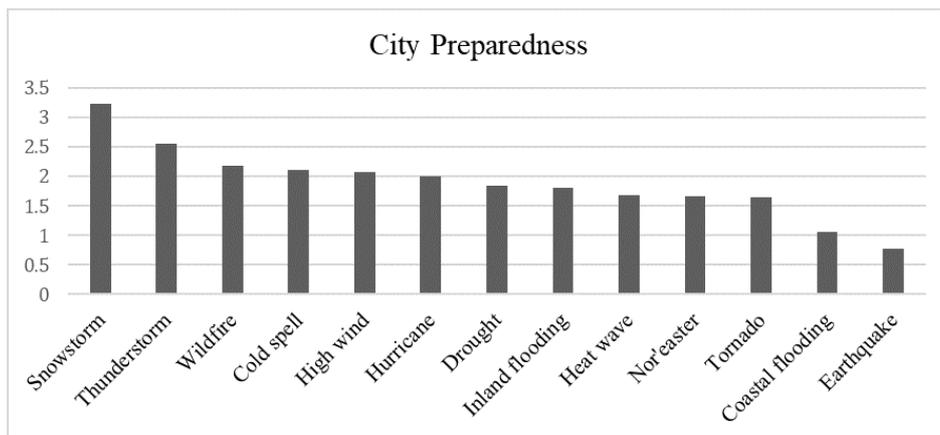


Fig. 12. Figure 7

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