NICHES

Nature's integration in cities' hydrologies, ecologies and societies

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ADVANCING URBAN RESILIENCE

Policy brief

Pablo Herreros Cantis[*], **BC3 Basque Centre for Climate Change**, Svetlana Khromova, **Institute of Environmental Science and Technology (ICTA), Universitat Autónoma de Barcelona**

INTRODUCTION

Cities are at the forefront of climate change adaptation due to their higher exposure and vulnerability to extreme weather events, such as extreme precipitation. Risk approaches can be used to assess the impacts anticipated from extreme precipitation by breaking risk down into hazard, exposure, and vulnerability (IPCC, 2022). While extreme weather events are known to impact vulnerable communities unevenly, adaptation policies overlook the role of social vulnerability in developing equitable adaptation policies.

The impacts of extreme weather events can be very diverse because cities are extremely complex systems characterised by the interaction of social, political, economic, natural, and infrastructural components. This complexity must be taken into account in adaptation planning efforts so that they address the challenge in a holistic manner that minimises the chances of overlooking critical factors (McPhearson et al., 2021). A Social-Ecological-Technological Systems (SETS) lens can support adaptation by leveraging multiple dimensions of the urban environment. SETS approaches have been used in novel applications to holistically assess vulnerability to extreme weather events in cities (Chang et al., 2021). However, SETS vulnerability assessments have not previously fitted in urban risk analyses. This approach is important because it helps to see how social, ecological, and technological factors all combine to influence the risks of stormwater hazards, making it easier to identify the best solutions for protecting urban communities.

EVIDENCE AND ANALYSIS

A SETS Vulnerability Approach for Assessing Urban Stormwater-Related Risks

Research from the Biodiversa-funded NICHES project highlights the uneven spatial distribution of risks associated with extreme precipitation, including pluvial flooding and combined sewer overflows. Case studies from Barcelona, Boston, and Rotterdam provide valuable insights, with this policy brief focusing on findings from the Barcelona case study.

To assess stormwater-related risks at a neighbourhood scale, the study applies a comprehensive methodology based on the IPCC (2012) risk framework, which defines risk as a function of **hazard, exposure, and vulnerability**. Vulnerability is further analysed through the **social, ecological, and technological (SETS) dimensions** (Fig. 1):

- **Social vulnerability** considers factors such as age, income level, and language barriers that influence a community's ability to cope with flooding impacts.

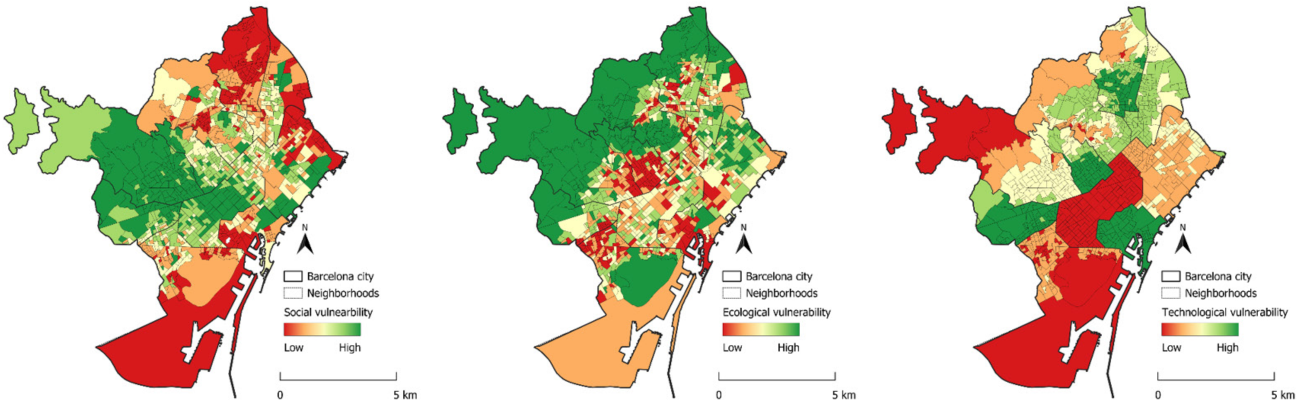

Fig 1. Single social, ecological and technological maps for Barcelona city (own elaboration).

- **Ecological vulnerability** assesses the capacity of natural systems to retain water and mitigate runoff.

- **Technological vulnerability** examines built environment characteristics, including impervious surface coverage, sewer system capacity, and terrain slope, which impact the effectiveness of stormwater management solutions.

These SETS vulnerability dimensions are then integrated with hazard and exposure data to develop a composite risk index (Fig. 2), providing a holistic understanding of flood-related risks. The findings underscore the critical role of social vulnerability in determining overall risk, with the greatest impacts on socially vulnerable communities. Meanwhile, insights from ecological and technological domains offer guidance for future risk reduction strategies, such as upgrading outdated sewer infrastructure and expanding green spaces to enhance urban flood resilience.

Adopting a SETS approach enhances the conceptualisation of vulnerability by capturing the evolving dynamics of flood risk management. This perspective moves beyond the traditional reliance on technological solutions, acknowledging the interconnected role of social and ecological factors in shaping urban resilience. This gap in understanding restricts our ability to anticipate how climate change will impact water management systems and, in turn, urban communities. For policymakers, the Barcelona case demonstrates the value of combining green infrastructure development, social equity considerations, and technological upgrades to build urban resilience effectively. Cities facing similar challenges can benefit from this comprehensive framework to create adaptive and inclusive strategies for mitigating stormwater-related hazards like pluvial flooding and combined sewer overflows.

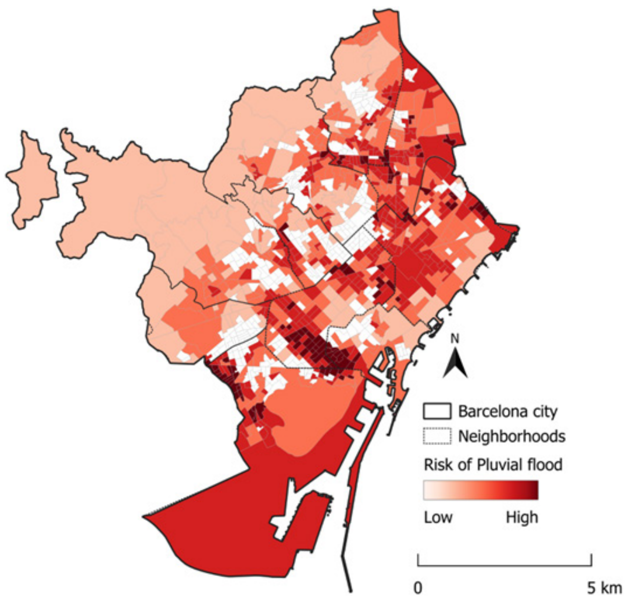

Fig 2. Risk Index for Pluvial Flooding at the Census Block Group Level in Barcelona (own elaboration).

CO-PRODUCING ACTIONABLE KNOWLEDGE FOR CLIMATE RISK MANAGEMENT

Additionally, the process of mapping risk requires making decisions about what impacts to consider, what data to utilise, and how to communicate it. This calls for co-production processes through which potential end-users and research beneficiaries are included in the research process. The involvement of non-academic actors allows for the integration of end-user needs and expectations, consequently contributing to the generation of actionable knowledge. In a recent co-production exercise, NICHES collaborator Pablo Herreros-Cantis led the development of a flood-health vulnerability visualisation tool in collaboration with environmental justice organisations and healthcare practitioners of the city of Milwaukee, WI, USA. The process, published in the journal cities (Herreros-Cantis et al., 2024), consisted of a co-production approach that spanned from the identification of relevant research questions to the dissemination of the results in the form of an interactive story map. The tool, publicly available, allows users to visualise the uneven distribution of risk and vulnerability to flooding, providing local advocacy organisations with usable and useful information for their work.

POLICY IMPLICATIONS AND RECOMMENDATIONS

To reduce the risks posed by stormwater-related hazards, climate adaptation strategies should focus on the following key measures:

- **Advancing Social Equity in Climate Adaptation.** Adaptation policies must address social disparities by prioritising support for vulnerable communities. Strengthening social capital in economically disadvantaged areas through targeted green space development and financial assistance for climate-resilient infrastructure will help reduce the disproportionate risks faced by these communities.

- **Scaling Up Green Infrastructure Solutions.** Nature-based solutions (NBS) such as rain gardens, green roofs, and urban wetlands should be integrated into urban planning to enhance stormwater management capacity and reduce flood risks. These strategies provide a cost-effective alternative to large-scale infrastructure expansion while ensuring long-term climate resilience.

- **Modernising Urban Water Systems.** Upgrading ageing sewer infrastructure is essential to overcoming technological constraints that limit effective climate adaptation. Investments should focus on smart water management technologies, such as decentralised rainwater harvesting systems and real-time monitoring of rainfall events, to optimise existing infrastructure and mitigate future risks.

- **Integrate Multiple Sources of Knowledge for Holistic Urban Adaptation.** Recognise urban environments as complex, interconnected systems where climate risks stem from multiple interdependent factors. Incorporate diverse knowledge sources, including scientific research, local expertise, traditional ecological knowledge, and citizen observations, to develop context-specific adaptation solutions. Strengthen interdisciplinary research and cross-sector collaboration to ensure a comprehensive understanding of urban risks and vulnerabilities.

- **Co-Produce Knowledge and Develop Actionable Tools.** Foster co-production approaches that bring together policymakers, researchers, local communities, and industry stakeholders to develop practical, user-driven solutions for climate adaptation. Ensure that research findings are translated into accessible and actionable tools. Promote participatory processes that empower communities by integrating their lived experiences and priorities into adaptation strategies. Support long-term engagement platforms and partnerships to facilitate continuous learning and adaptation in response to evolving climate risks.

SUSTAINABILITY AND LEGACY

- SETS framework building upon Chang 2021 [This study extends the work of Chang et al. 202 by demonstrating how the SETS framework bridges gaps in understanding the fragmented nature of stormwater-related hazards across disciplines. By integrating SETS with a risk-based approach, we provide a more dynamic and comprehensive view of urban vulnerabilities and risks];

- Milwaukee FHVA Storymap [indicate it being developed by "NICHES collaborator Pablo Herreros et al?"];

- Khromova, S., Herreros Cantis, P. and Langemeyer, J. (2023). Inland flooding and water quality community vulnerability maps. NICHES Deliverable D3.1. [This report provides an overview of the methodology and theoretical framework for assessing vulnerability in the communities of the three NICHES core cities: Barcelona, Boston, and Rotterdam. It offers a common knowledge basis for mapping social-hydrological vulnerabilities within SETS.].

FURTHER READING

Khromova, S., Méndez, G., Eckelman, M., Herreros-Cantis, P. and Langemeyer, J. (2025). A Social-Ecological-Technological Vulnerability Approach for Assessing Urban Hydrological Risks. Ecological Indicators.

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McPhearson, Timon, Christopher M. Raymond, Natalie Gulsrud, Christian Albert, Neil Coles, Nora Fagerholm, Michiru Nagatsu, Anton Stahl Olafsson, Niko Soininen, and Kati Vierikko. "Radical changes are needed for transformations to a good Anthropocene." *Npj urban sustainability* 1, no. 1 (2021): 5.

PROJECT OBJECTIVES AND METHODOLOGY

NICHES aims to explore the potential for mitigating the impacts of extreme precipitation through Nature-Based Solutions (NBS). Working together with stakeholders in 5 case studies (e.g. policymakers, practitioners, NGOs and community groups and the wider public, sectoral actors and the private sector), the project examines the ecological, social, infrastructural, and economic impacts of extreme precipitation on society and aquatic ecosystems. An integrated assessment framework will be developed to understand the potential of NBS for urban runoff mitigation and to explore trade-offs in meeting the needs of populations in different parts of the urban system. Finally, the project aims to co-conceive transition pathways for integrating restorative NBS into urban policies. The pathway development will build on i) a governance and policy analysis related to the management of urban waters and ii) an integrated assessment framework to assess stakeholders' needs and values against political and economic feasibility. A co-design approach across all activities will engage relevant stakeholders and ensure the relevance and wider applicability of results for increased uptake.


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NICHES

PROJECT IDENTITY

PROJECT NAME

Nature's **I**ntegration in **C**ities' **H**ydrologies, **E**cologies and **S**ocieties

COORDINATOR

Ulf Stein
Ecologic Institute
Berlin, Germany, ulf.stein@ecologic.eu

CONSORTIUM

eco logic
UAB Universitat Autònoma de Barcelona
NIOO
University of Sheffield
PENSOFT
Northeastern University

FUNDING SCHEME

Call: Food and Natural Resources (H2020-FNR-2020)
Topic title and ID: FNR-12-2020 - Industrial microbiomes – learning from nature

DURATION

April 2022 – March 2025 (36 months)

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Water JPI

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