EGU26 Short course: Compound Events and Multi-Hazard Analytics

The challenges of going from Single to Multi-hazard risk assessment and management

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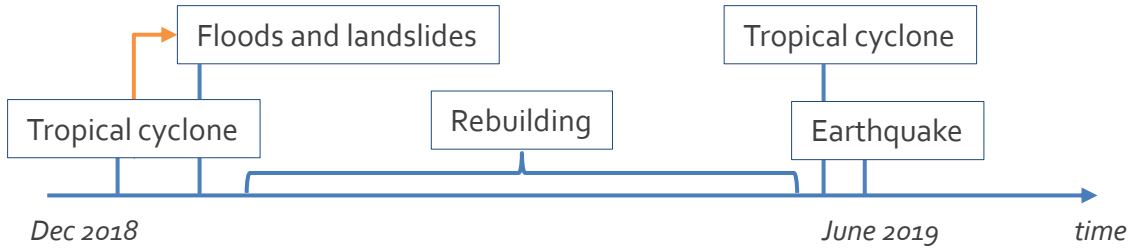
EGU 2026

An average of 20 typhoons and storms lash the Philippines each year, killing hundreds of people and leaving millions in near-perpetual poverty.

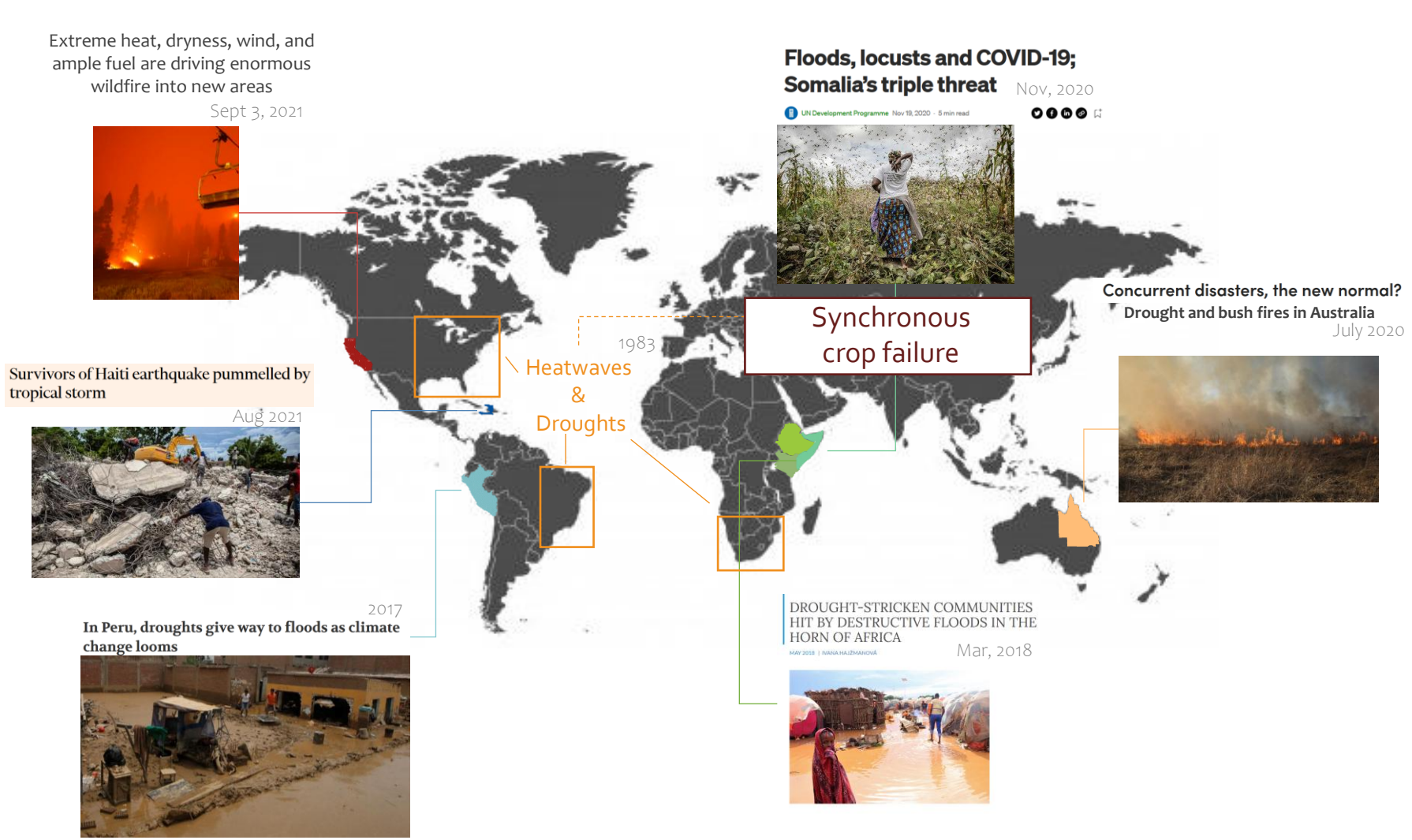
Fifty-seven people died in the mountainous Bicol region, southeast of Manila, while 11 were killed in the central island of Samar, mostly due to landslides and drownings, the officials said.

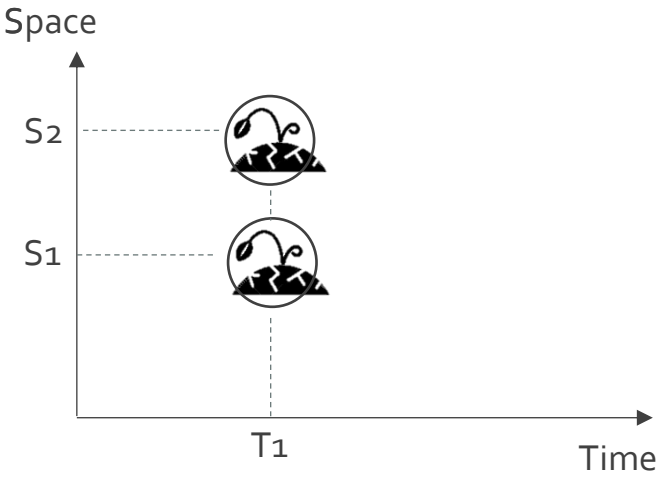
Batanes is pounded every year by tropical cyclones and typhoons that blast through the Philippines and homes are built of stone to survive the annual onslaught.

"We always experience typhoons so houses here are made to withstand strong winds," he said. "But we were not prepared for earthquakes such as this."



The complexity of disaster risk dynamics

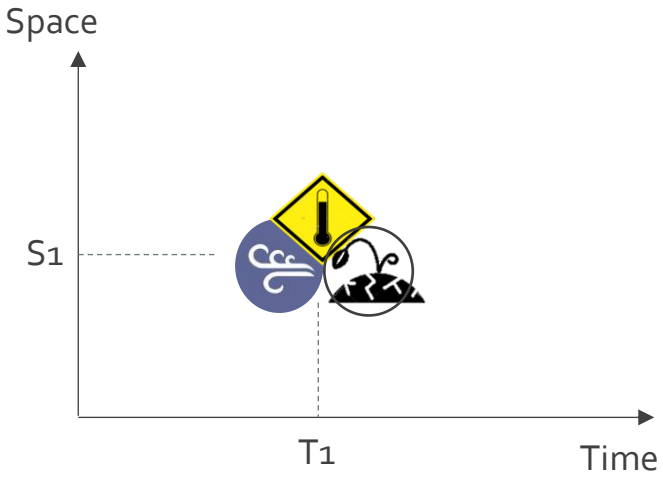




- Different combinations of related and unrelated hazards;
- Multiple interactions between risk components;
- Multiple physical & societal drivers;
- Spatiotemporal variability.

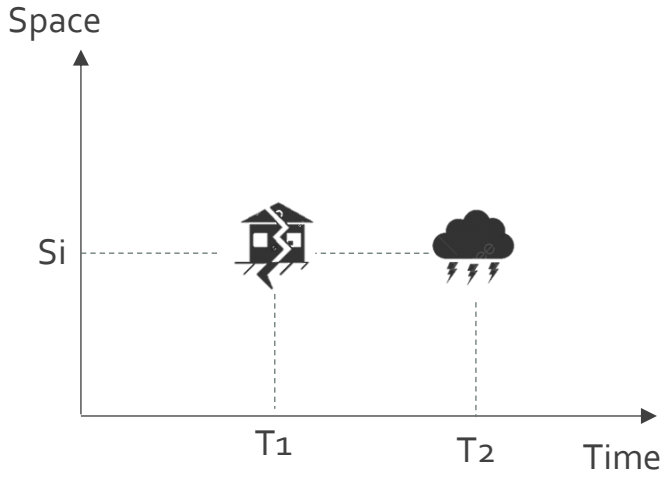
The dynamics of disaster risk

COMPOUND



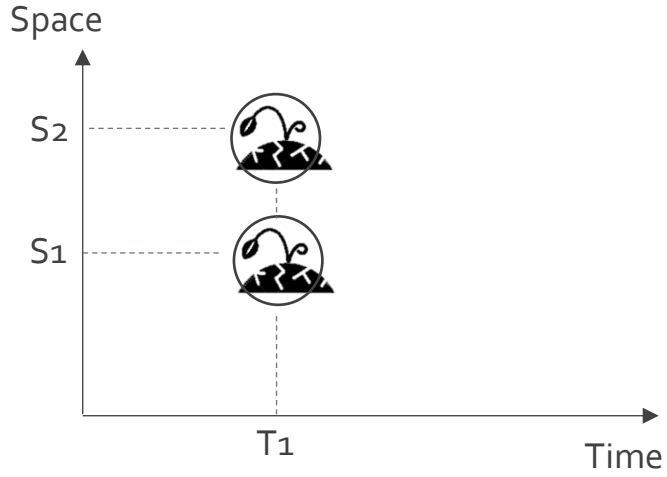
Two or more disasters that occur in succession, and whose impacts overlap spatially before recovery from a previous event is considered to be completed (De Ruiter et al. 2020).

CONSECUTIVE



The combination of multiple drivers and/or hazards that contributes to societal or environmental risk (Zscheischler et al., 2018).

SYSTEMIC



Systemic risk is associated with cascading impacts that spread within and across systems and sectors (UNDRR 2022).

Definition of Disaster Risk

The elements (e.g., buildings, humans, economic values) present in the area affected

The threatening event (including its probability and physical characteristics)

The resistance or lack of resistance of the exposed elements to the hazard

Risk: The expected impacts when a hazard of a particular intensity affects people or assets that have a certain level of vulnerability towards that hazard (UNDRR 2019).

UNDRR (2019)

Moving away from hazard-silo thinking

"Whilst the last decades have seen a clear shift in emphasis from managing natural hazards to managing risk, the majority of natural-hazard risk research still focuses on single hazards." (Ward et al., 2022).

International call for multi-hazard or comprehensive risk approaches

- Sendai Framework for Disaster Risk Reduction
- GFDRR (2016): "Omitting time dependency can underestimate the frequency and compound impacts of severe events".
- UNDRR Global Assessment Report (GAR 2019): "Risk must not be departmentalized."

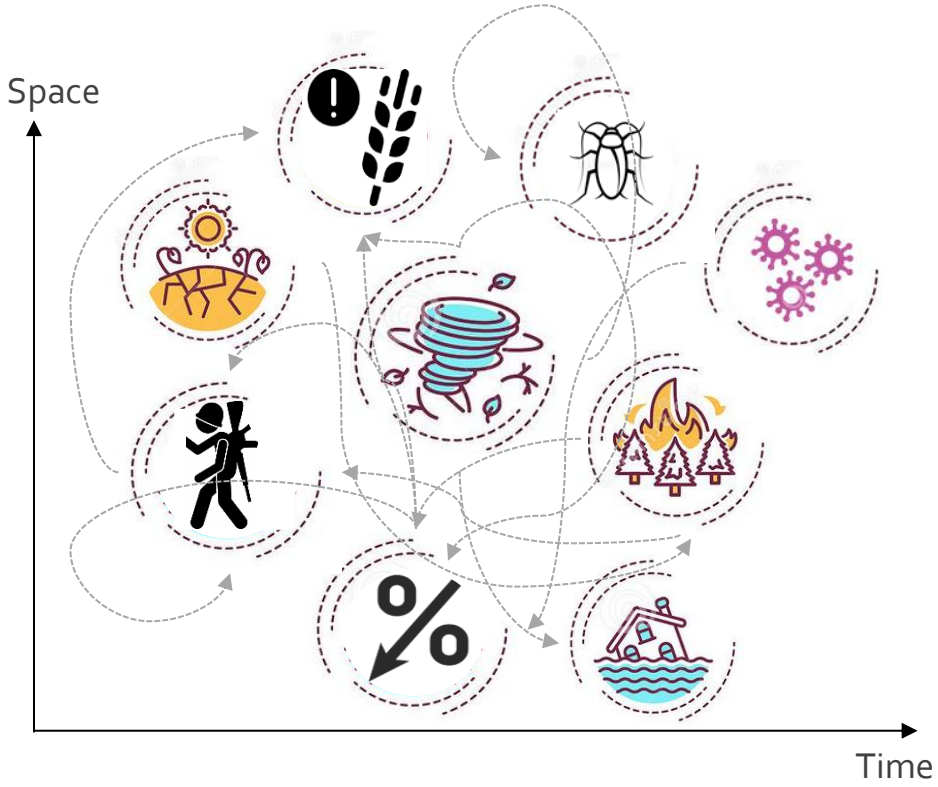
Who needs multi-risk assessments?

- Support risk managers to address the different complexities of risk (Scolobig et al., 2017).
- Urban Planners (e.g., Scolobig et al., 2017; Peduzzi 2019)
  - Adaptation measures
- First Aid Responders
  - Determining evacuation or temporary shelter locations

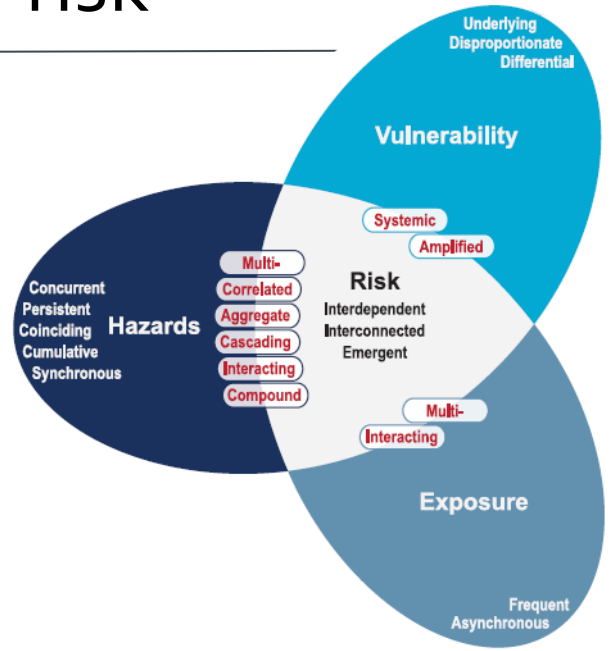
Need to improve modelling capabilities and institutional arrangements

- Institutional fragmentation (e.g., Cutter et al., 2015; Peduzzi 2019)

The complexities of multi-hazard disaster risk



Can we disentangle the complexity of disaster risk?



Simpson et al., (2021)

Terminology

Methodology

Multi-(hazard) risk assessment:

*"A multi-hazard risk assessment should identify **all possible and relevant hazards** and the valid comparison of **their contributions to hazard potential**, including the contribution to hazard potential from **hazard interactions** and **spatial/temporal coincidence of hazards**, while also taking into account the **dynamic nature of vulnerability** to multiple stresses."* (Gill & Malamud 2014).

- Different combinations of related and unrelated hazards;
- Multiple interactions between risk components;
- Multiple physical & societal drivers;
- Spatiotemporal variability.

What is Multi-(Hazard) Risk?

The selection of multiple major hazards that a location faces, and the specific contexts where hazardous events may occur simultaneously, cascadingly or cumulatively over time, and taking into account the potential interrelated effects (UNDRR, 2017).

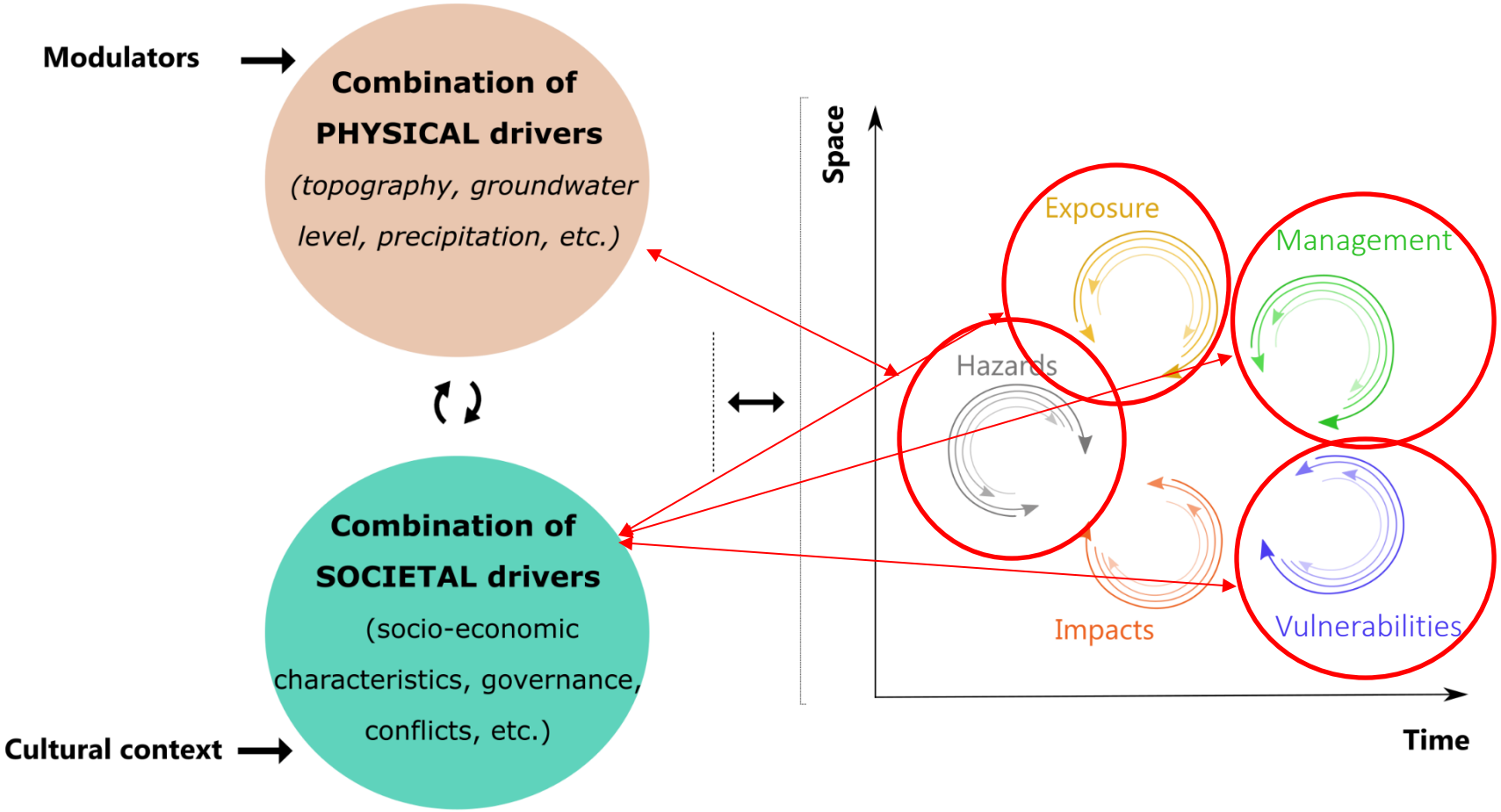
Risk generated from multiple hazards and the interrelationships between these hazards *(but not considering interreplationships on the vulnerability level)* (Zschau, 2017).

Risk generated from multiple hazards and the interrelationship between these hazards (and **considering interrelationships on the vulnerability level**) (Zschau, 2017).

How to go from single to multi-risk?

Recently developed frameworks

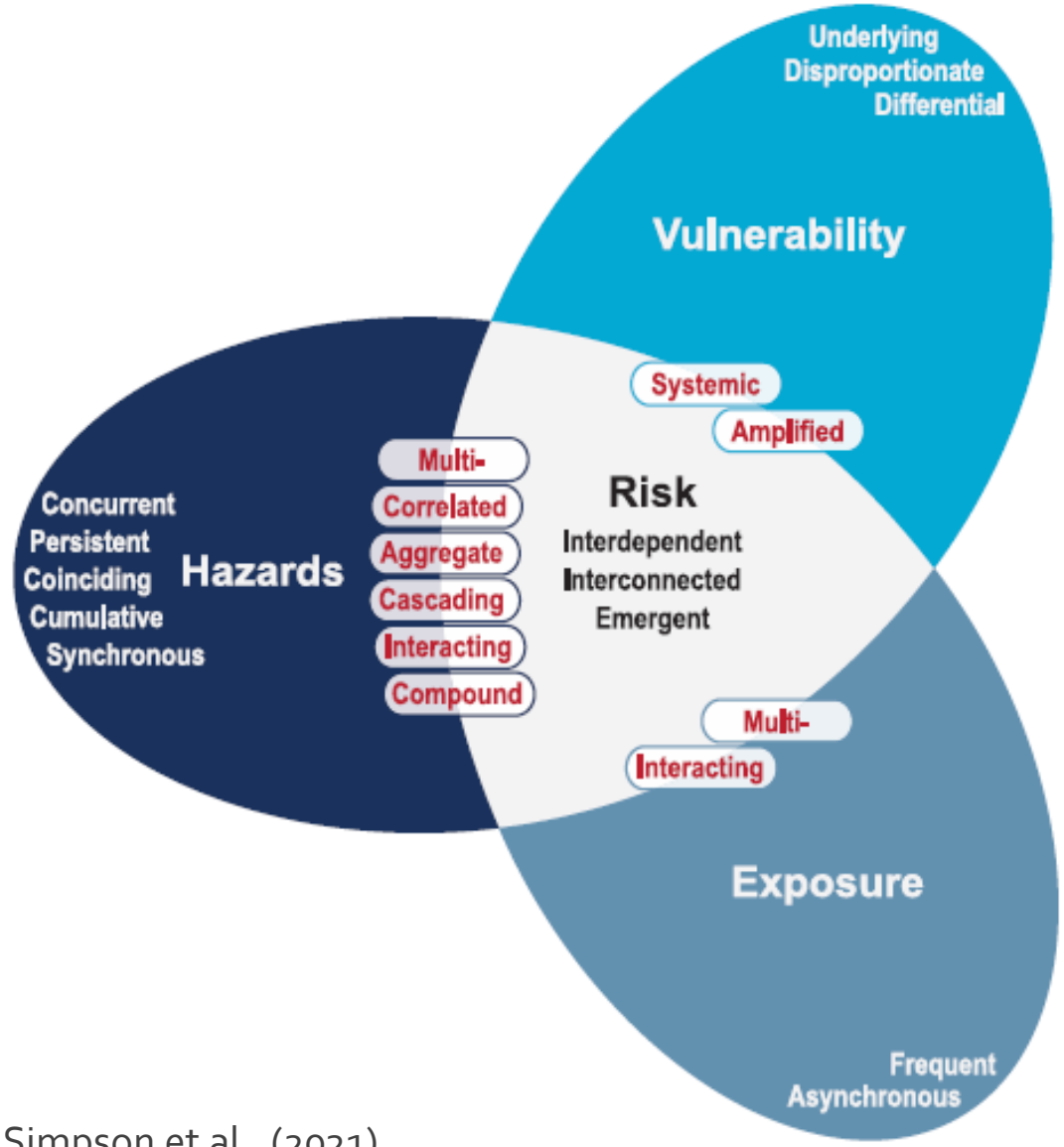
The dynamics of multi-hazard risk



Ir. Alessia Matano

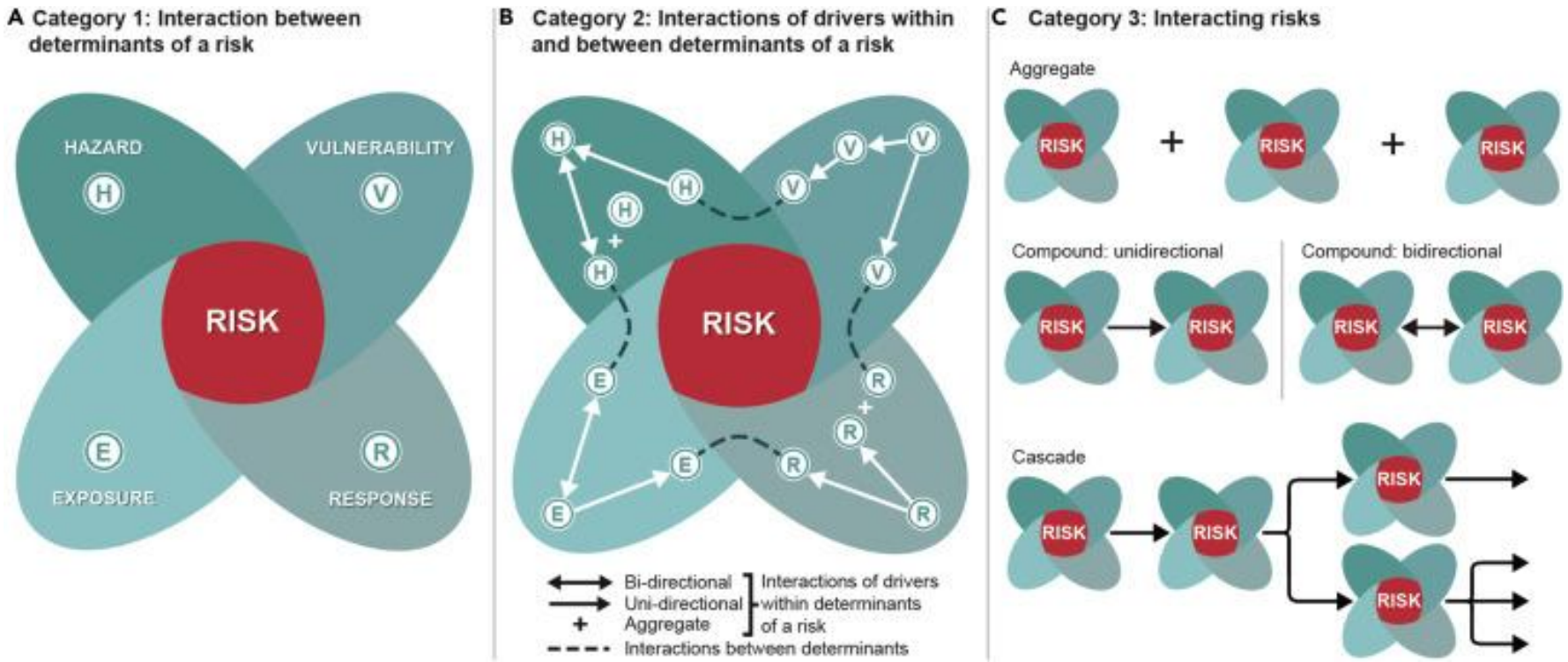
Matanó et al., (2022), *building on Zscheischler et al., (2020) and Raymond et al., (2020)*

Complex disaster risk: frameworks



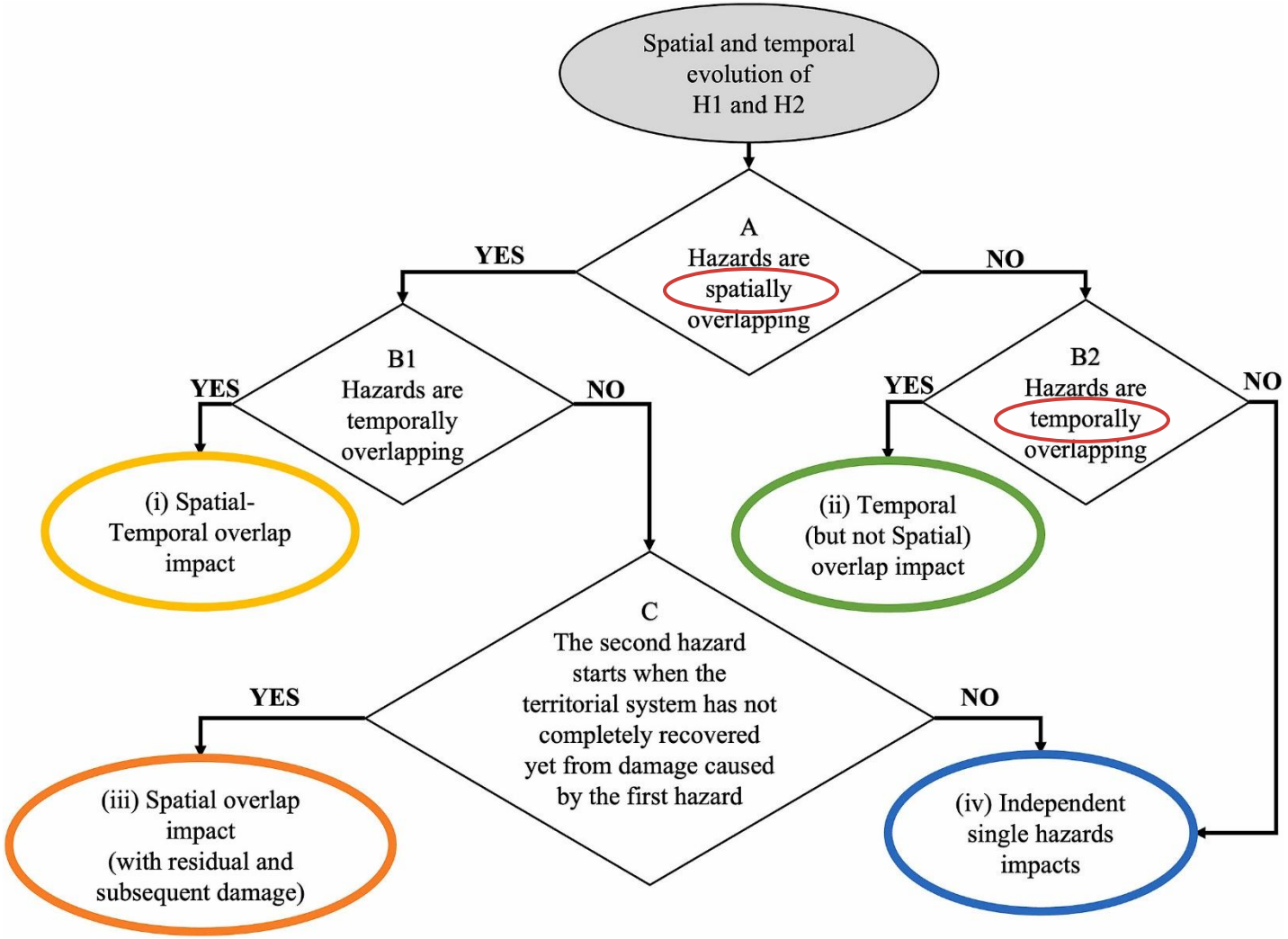
Simpson et al., (2021)

Complex disaster risk: frameworks



Simpson et al., (2021)

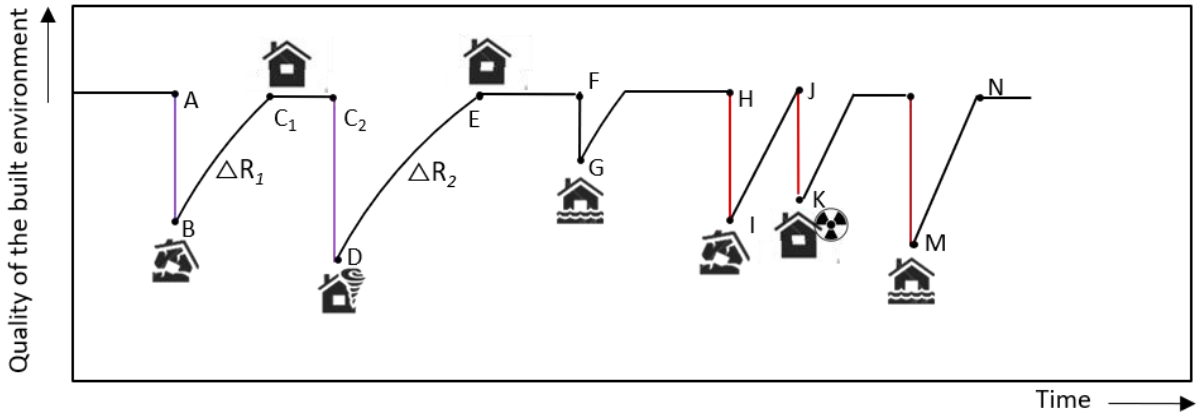
Complex disaster risk: frameworks



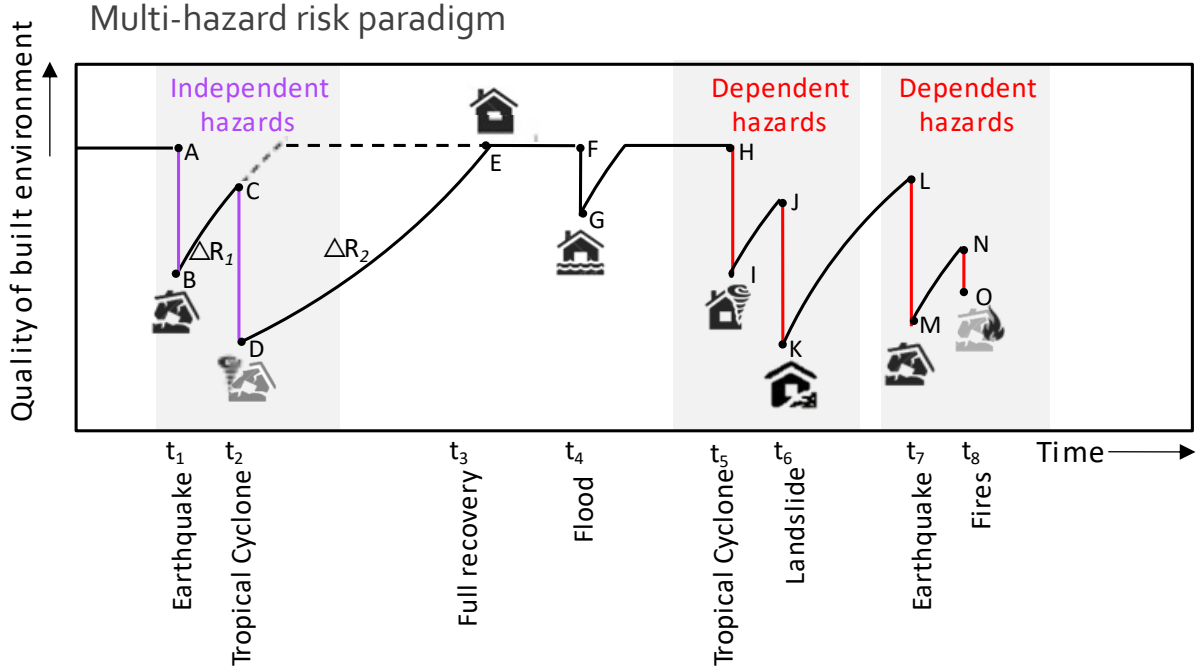
De Angeli et al., (2022)

Complex disaster risk: frameworks

Single-hazard paradigm

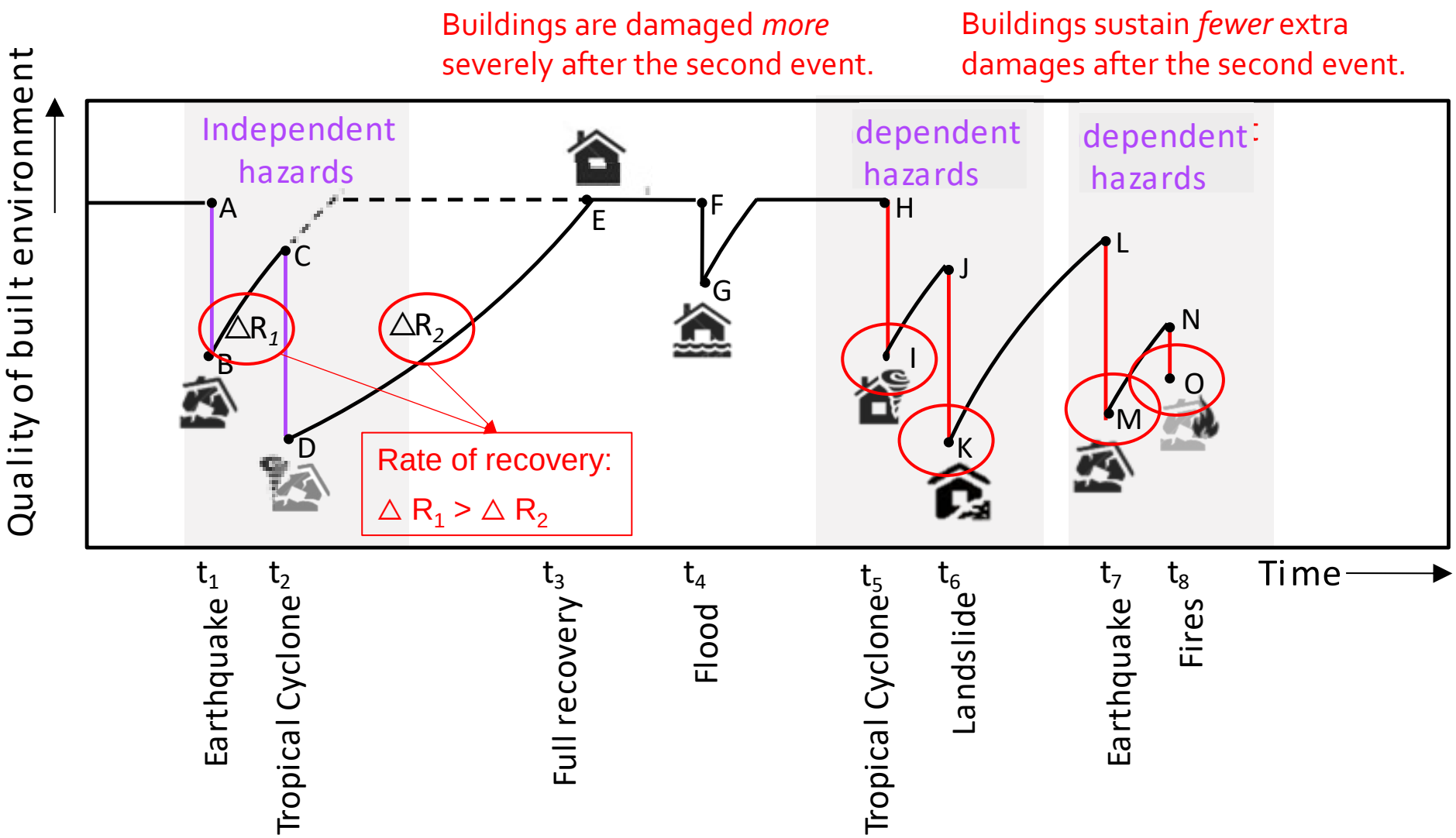


Multi-hazard risk paradigm



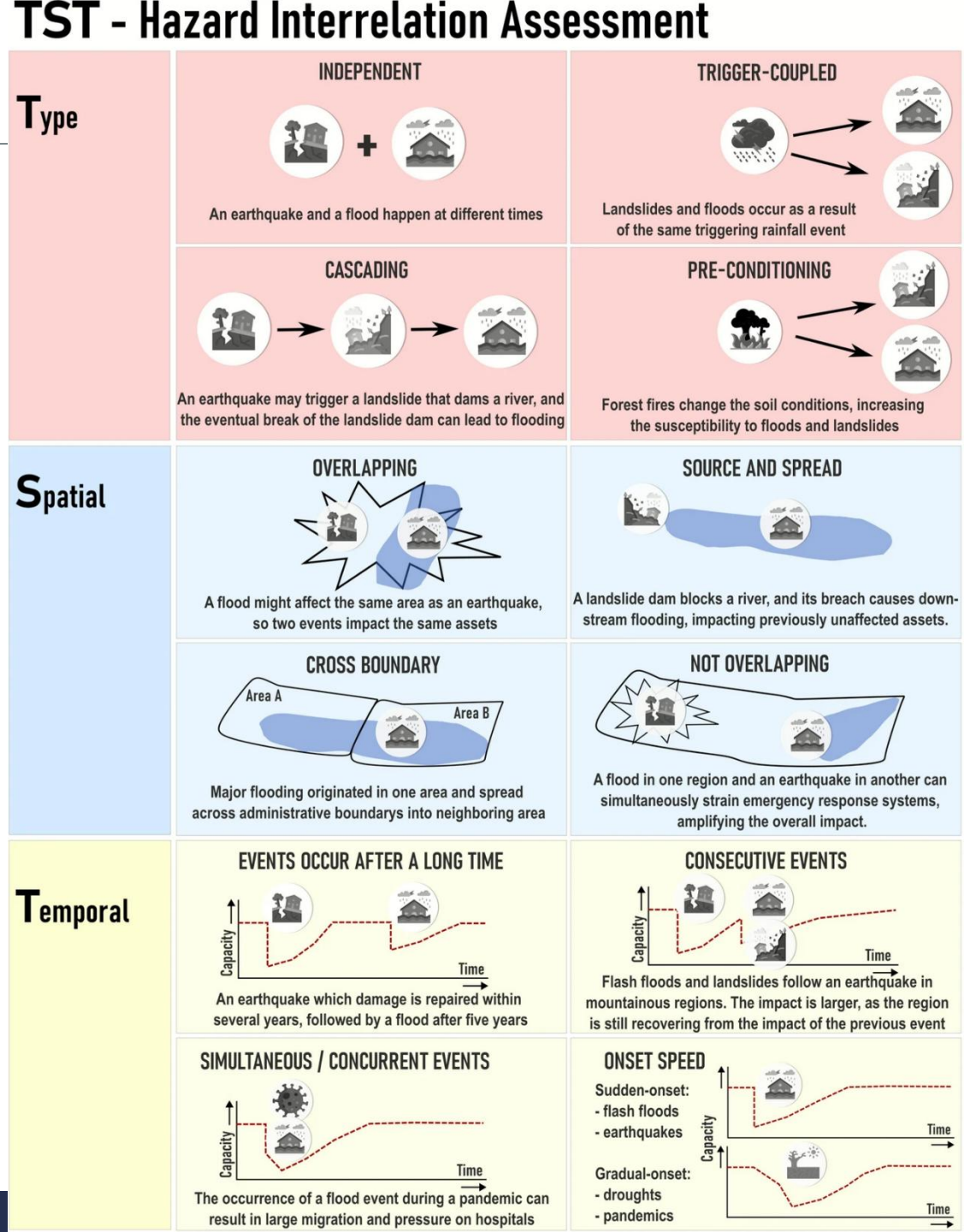
De Ruiter et al., (2020)

Complex disaster risk: frameworks



De Ruiter et al., (2020)

The dynamics of disaster risk

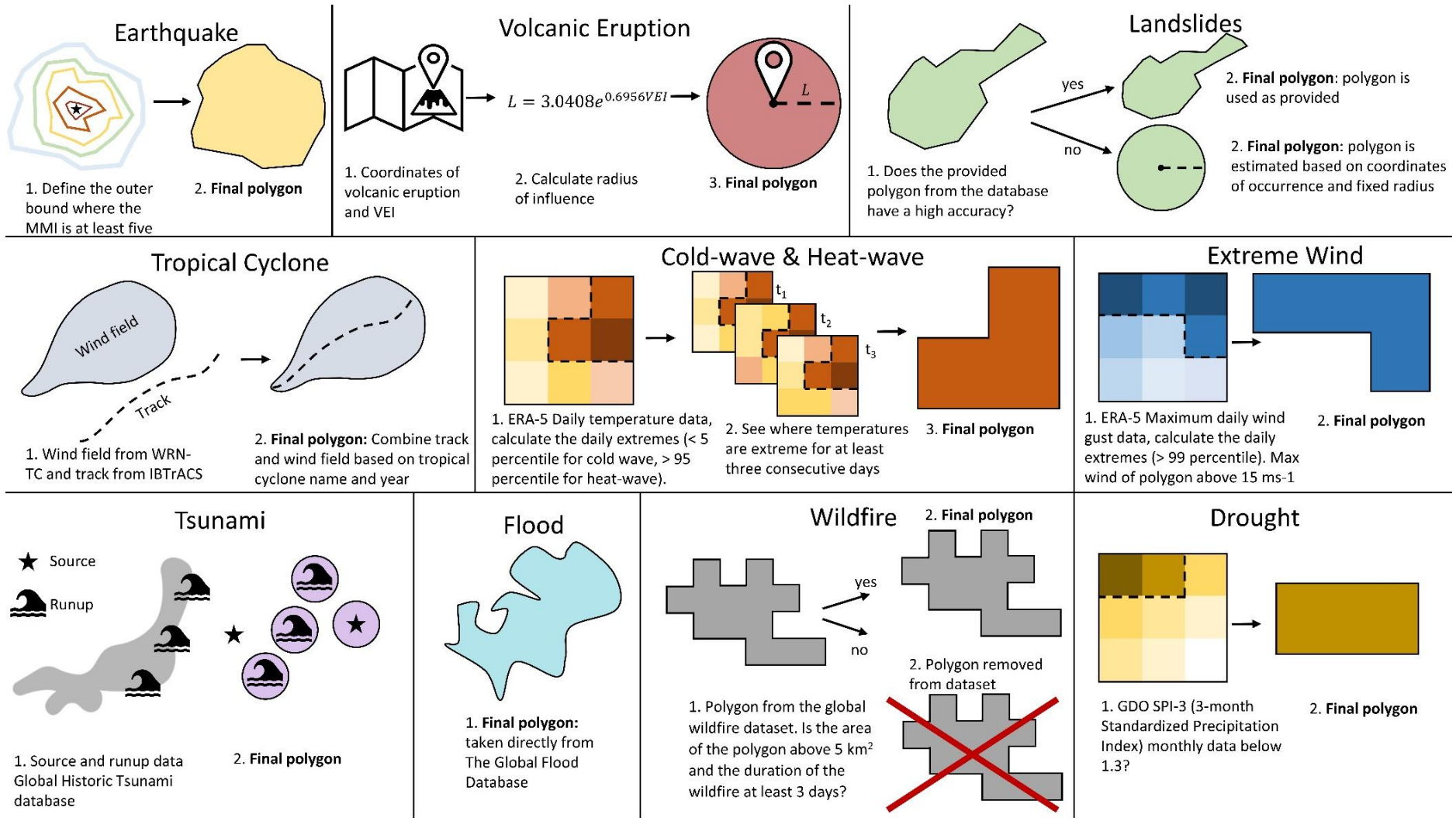


(Wenzel et al. 2026)

How to go from single to multi-risk?

Data and methodological advances

MYRIAD-HESA: a new method to generate global multi-hazard event sets



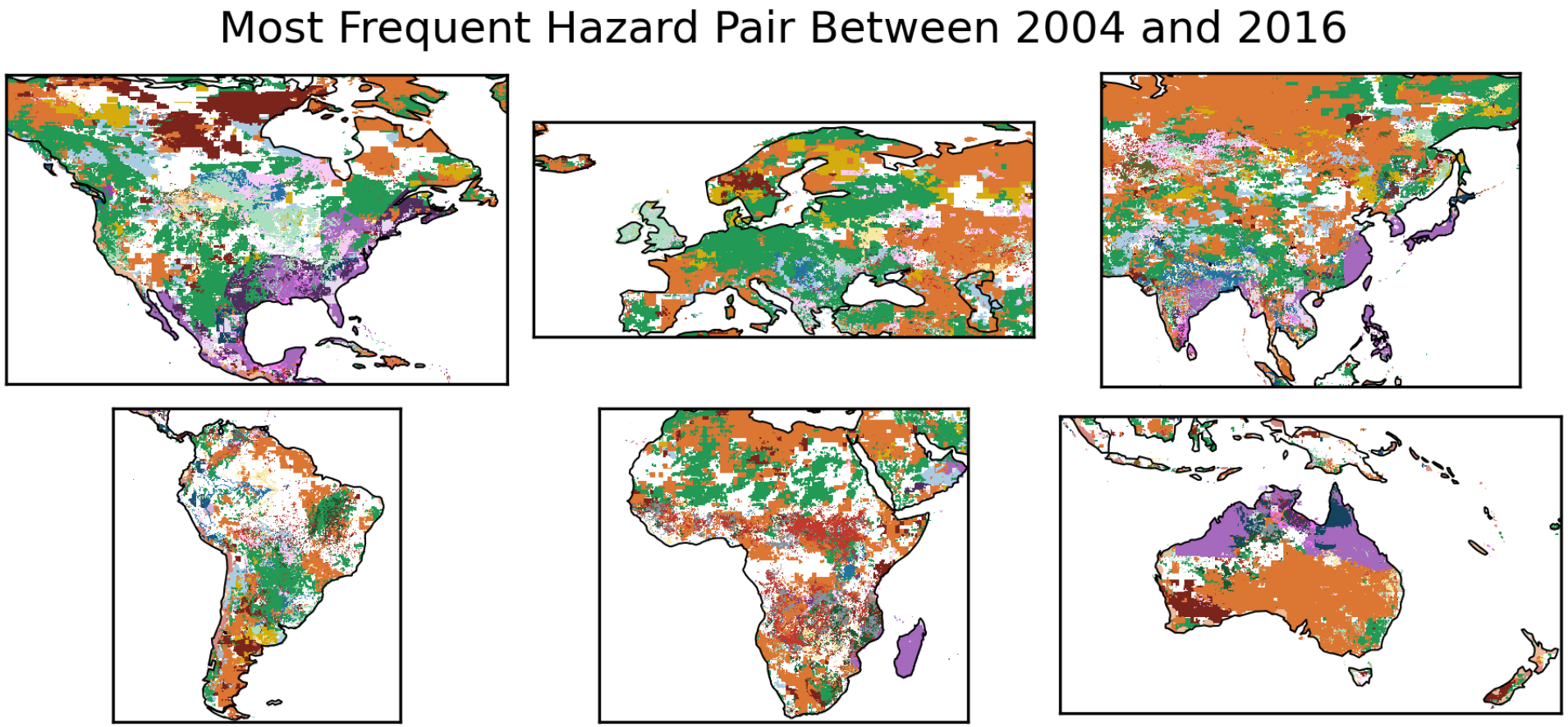
Claassen et al. (2023)

Judith Claassen
j.n.Claassen@vu.nl

MYRIAD-HESA: a new method to generate global multi-hazard event sets

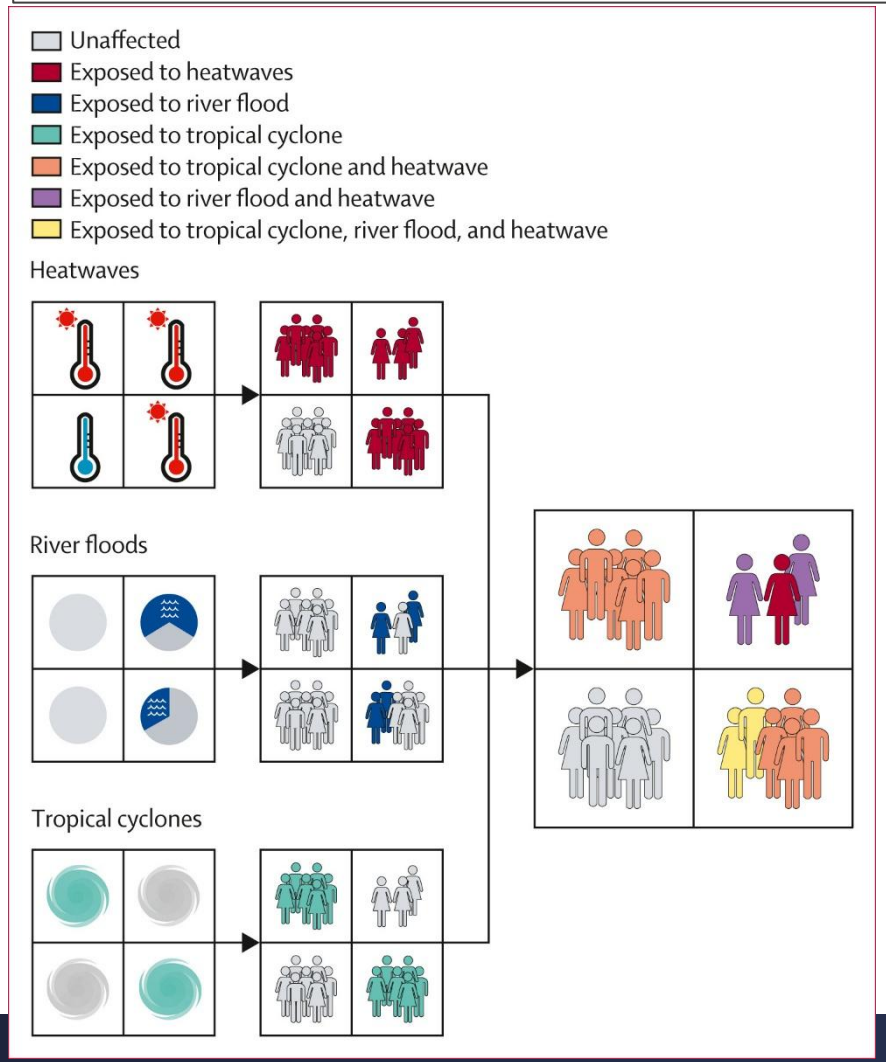
Claassen et al. (2023)

Judith Claassen
j.n.Claassen@vu.nl



Global exposure to multi-hazard risk

Map historical population exposure to multiple interacting climate-related hazards and identify regions that have been most affected.

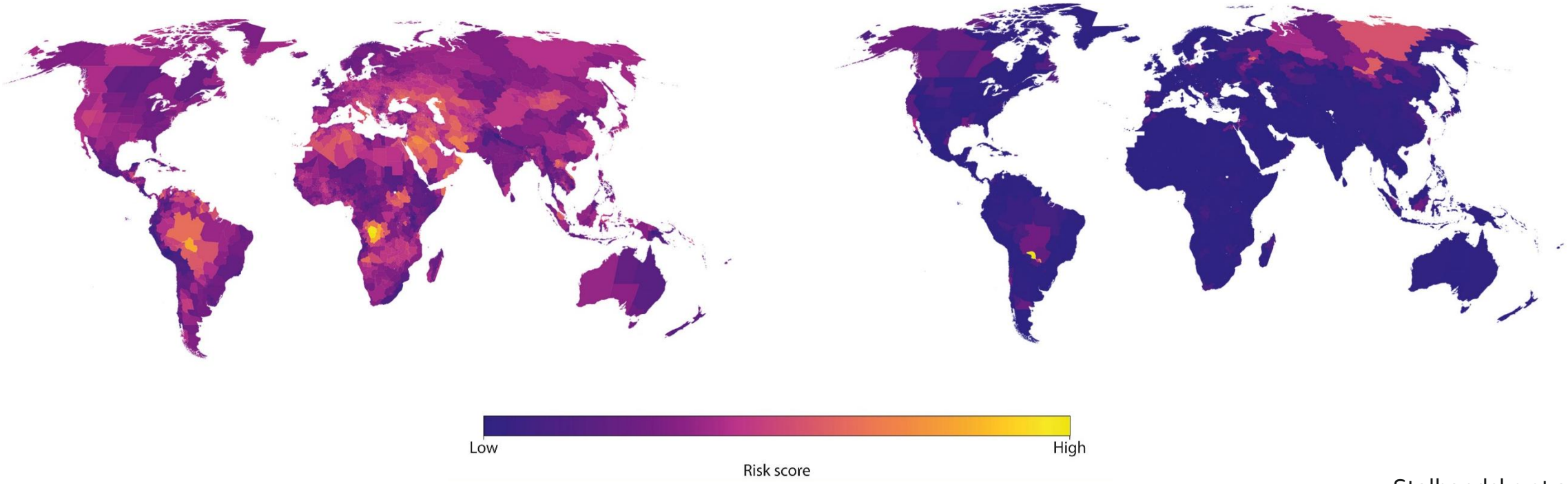


Stalhandske et al. (2025)

Global exposure to multi-hazard risk

Between 2003–2012 and 2012–2021, per-person exposure to at least three hazards increased by 69%.

Regions with the highest burden of exposure to single (left) vs 3-or more (right) hazards highlighted, relative to the total population.



Stalhandske et al. (2025)

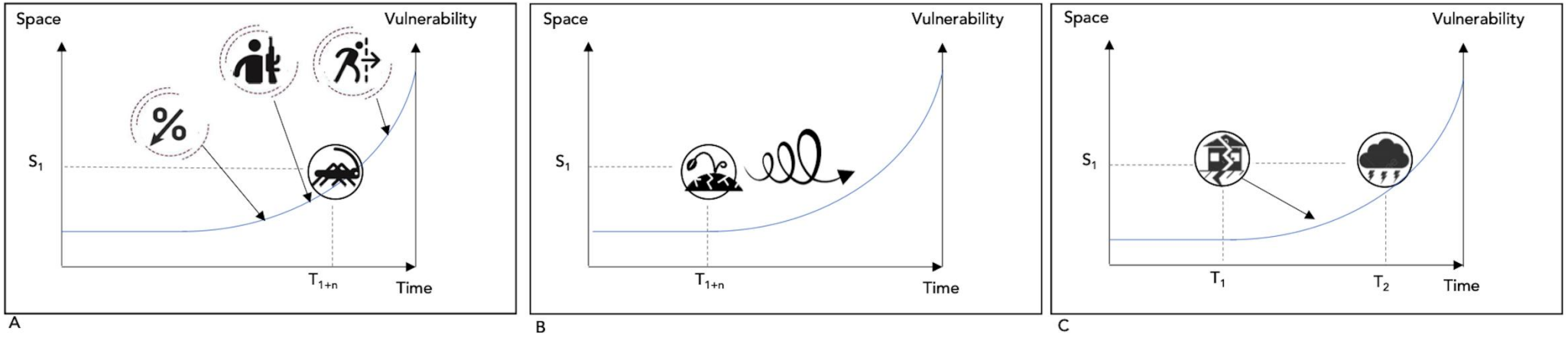
The challenges of dynamic vulnerability

Three types of dynamics of vulnerability:

A. Changes in vulnerability during compounding disasters and societal shocks

B. Changes in vulnerability during long-lasting disasters

C. The underlying dynamics of vulnerability

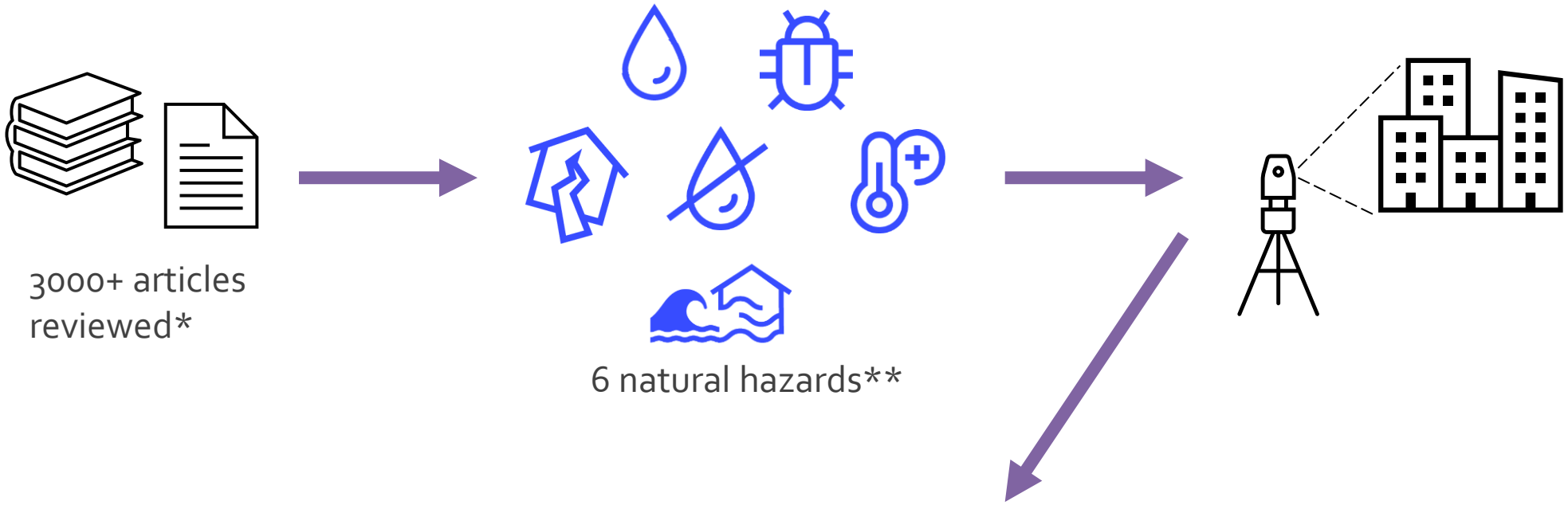


Capture vulnerability dynamics using methods commonly applied in the fields of compound & multi-hazards, and socio-hydrology.

De Ruiter & Van Loon (2022)

Evidence-based Vulnerability Drivers

VulneraCity



3000+ articles reviewed*

6 natural hazards**

VulneraCity - The urban vulnerability drivers database

Stolte, Tristian; Koks, Elco; de Moel, Hans; Reimann, Lena; van Vliet, Jasper; de Ruiter, Marleen; Ward, Philip

*Based on a systematic literature review of peer-reviewed scientific articles

**Pluvial flooding, waterborne diseases, earthquakes, drought, heatwaves, coastal flooding

Stolte et al. (2024)

Tristian Stolte
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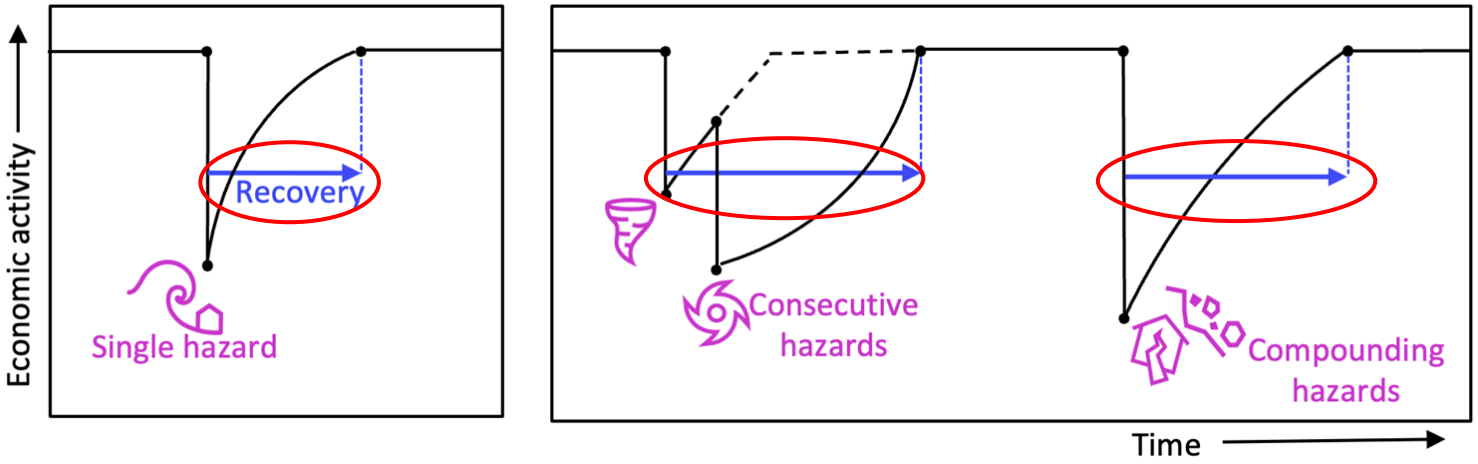
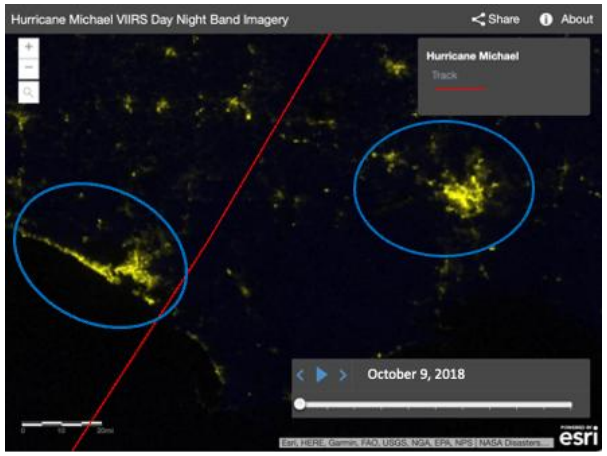
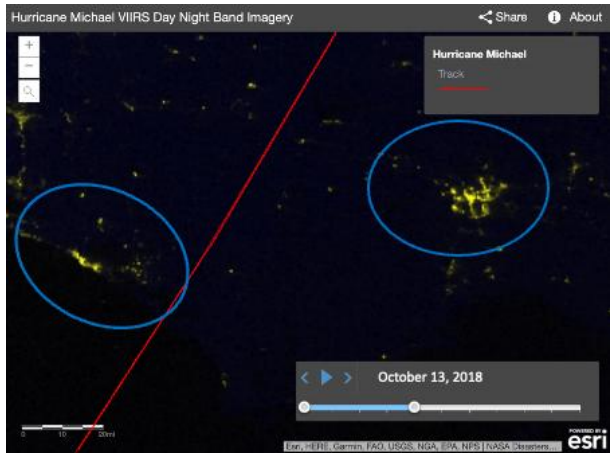
Recovery under consecutive disasters

Comparison of recovery between single and multi-hazards



Nighttime light satellite data as a proxy for economic activity





Sophie Buijs

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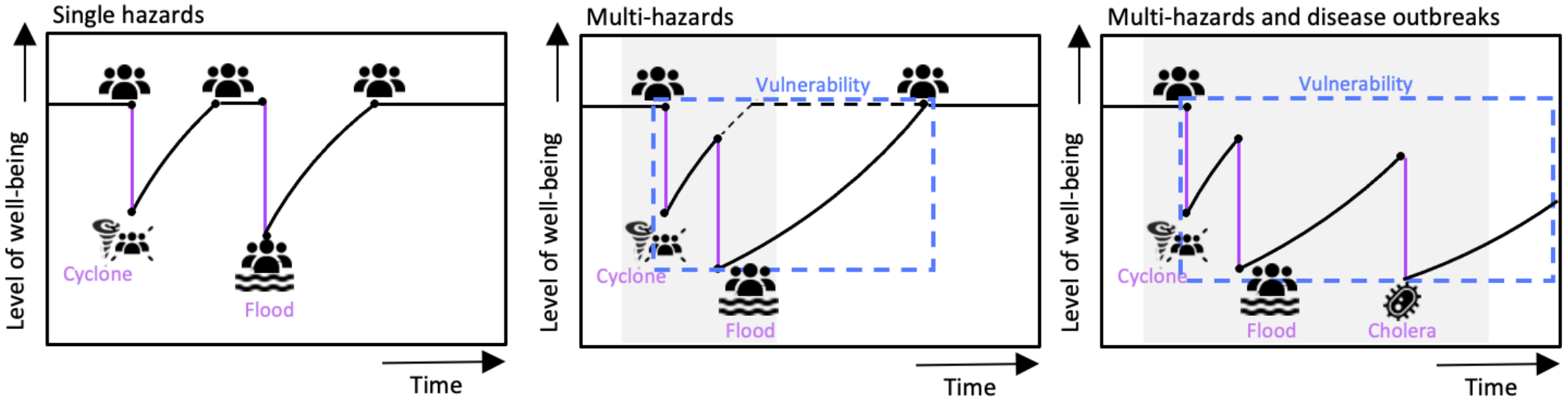
Buijs et al. (in review)

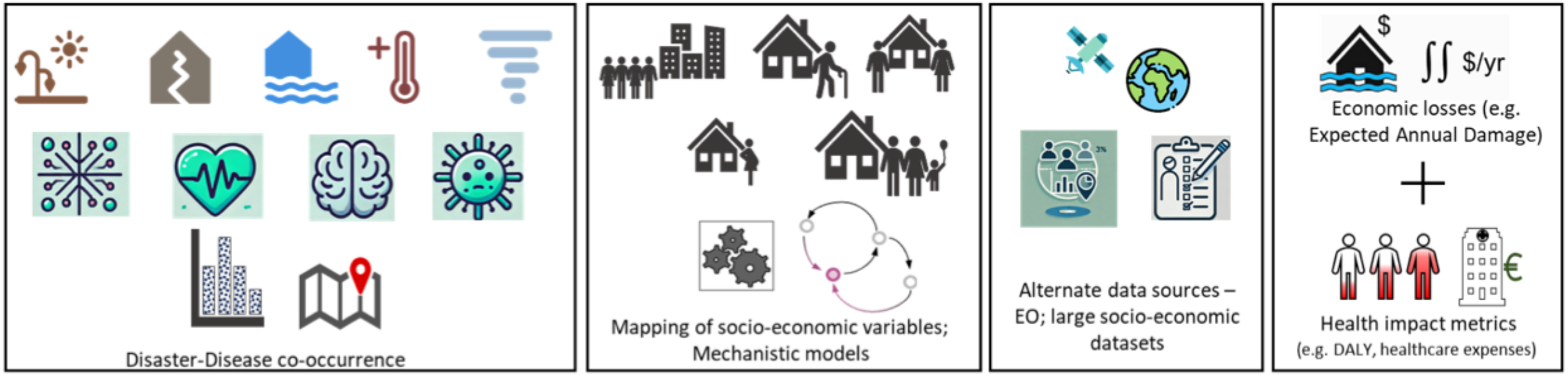
Considering disease outbreaks and health



Sairam & De Ruiter (2026)

- The UNDRR (2022) and WHO (2019) underscore that disease outbreaks that follow hazards must be considered an additional hazard within disaster risk, as they prolong recovery and make societies more vulnerable to subsequent hazards.
- 58% of infectious diseases faced by humanity worldwide have been at some point aggravated by climatic hazards (Mora et al. 2022).

Considering disease outbreaks and health



Sairam & De Ruiter (2026)

Interested in this topic? Join our RiskKAN working group online group meetings, once every 2 months.

Nivedita Sairam

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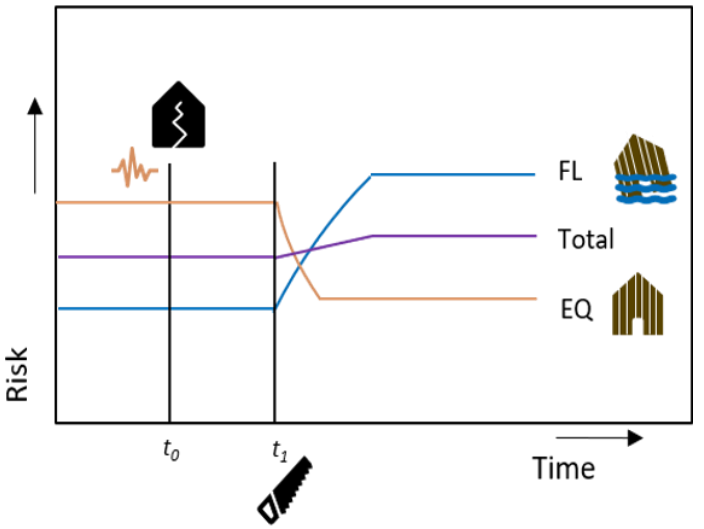
How to go from single to multi-risk?

Challenges for risk management

Complexities of Risk Management

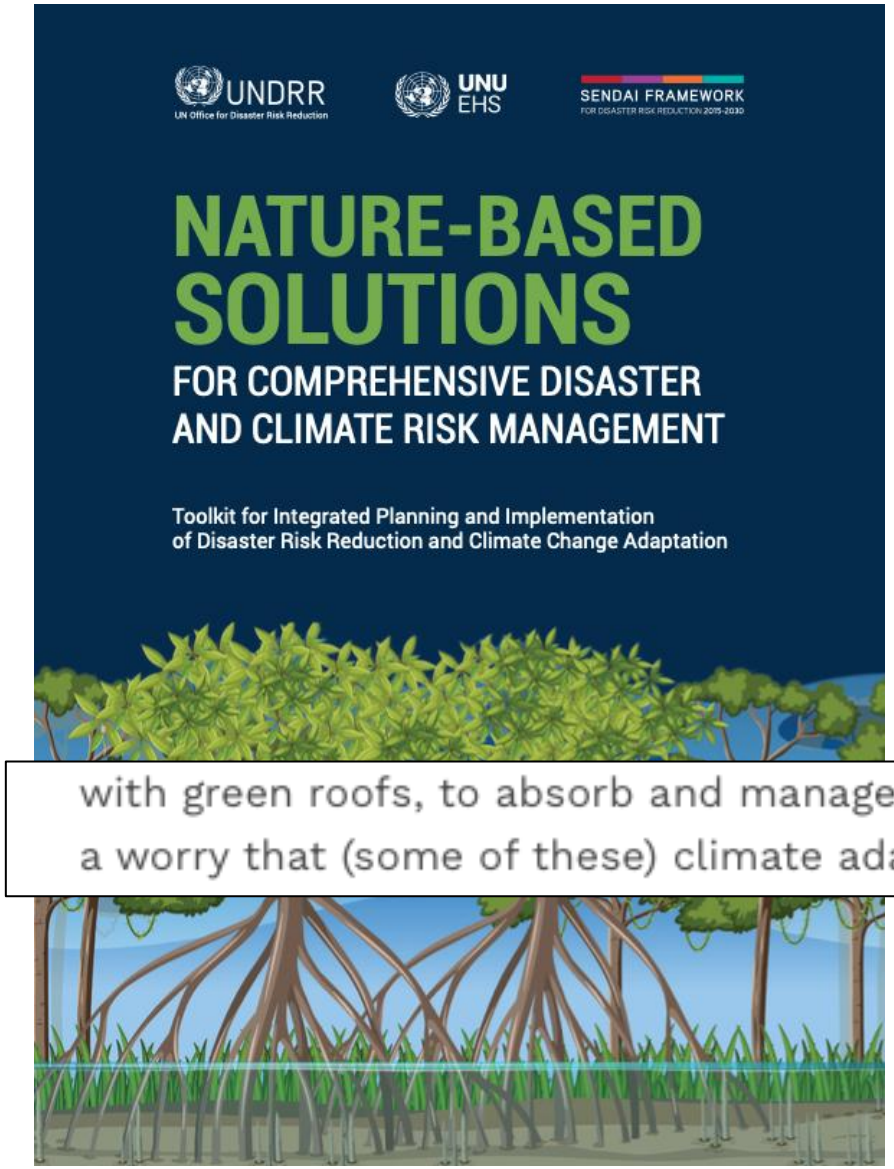
(A)SYNERGIES



- **Asynergies** between risk reduction measures that are aimed at reducing the risk of one hazard, can have opposing or conflicting effects on the risk of another hazard (De Ruiter et al., 2021).

De Ruiter et al., (2021)

Complexities of Risk Management



"The era of hazard-by-hazard risk reduction is over. We need to reflect the systemic nature of risk in how we deal with it." (GAR 2019)

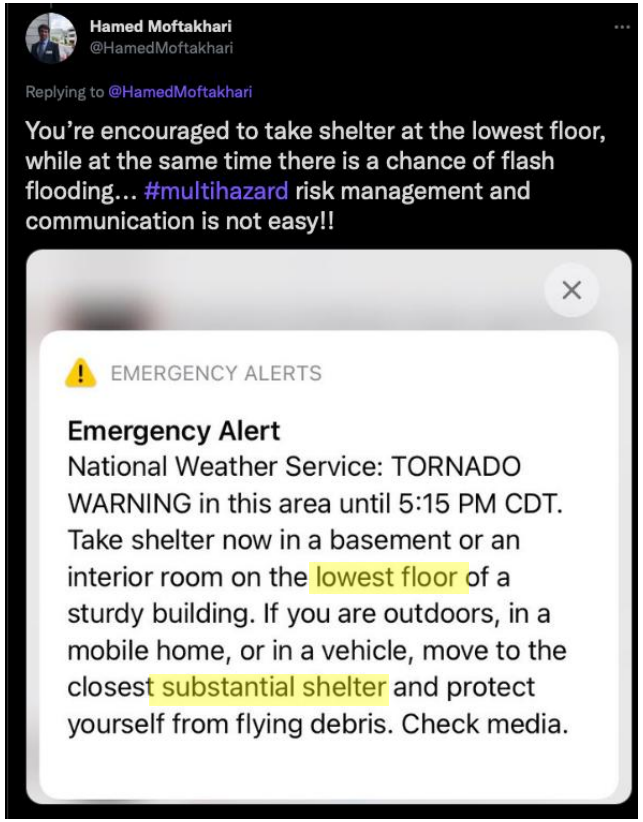
with green roofs, to absorb and manage stormwater and mitigate the urban heat island effect. Currently, there is a worry that (some of these) climate adaptation strategies will affect mosquito-borne disease risk

Krol et al., (2024)

Taking into account the complexity of disaster risk in EWS

March 2021: severe tornadoes forecasted in the Mississippi Valley

Source: USA Today, March 25th, 2021



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RISKKAN
Knowledge Action Network

Taking into account the complexity of disaster risk in EWS

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RISKKAN
Knowledge Action Network

Maui official defends not using sirens during deadly wildfires

At least 111 people have been confirmed dead in the disaster.

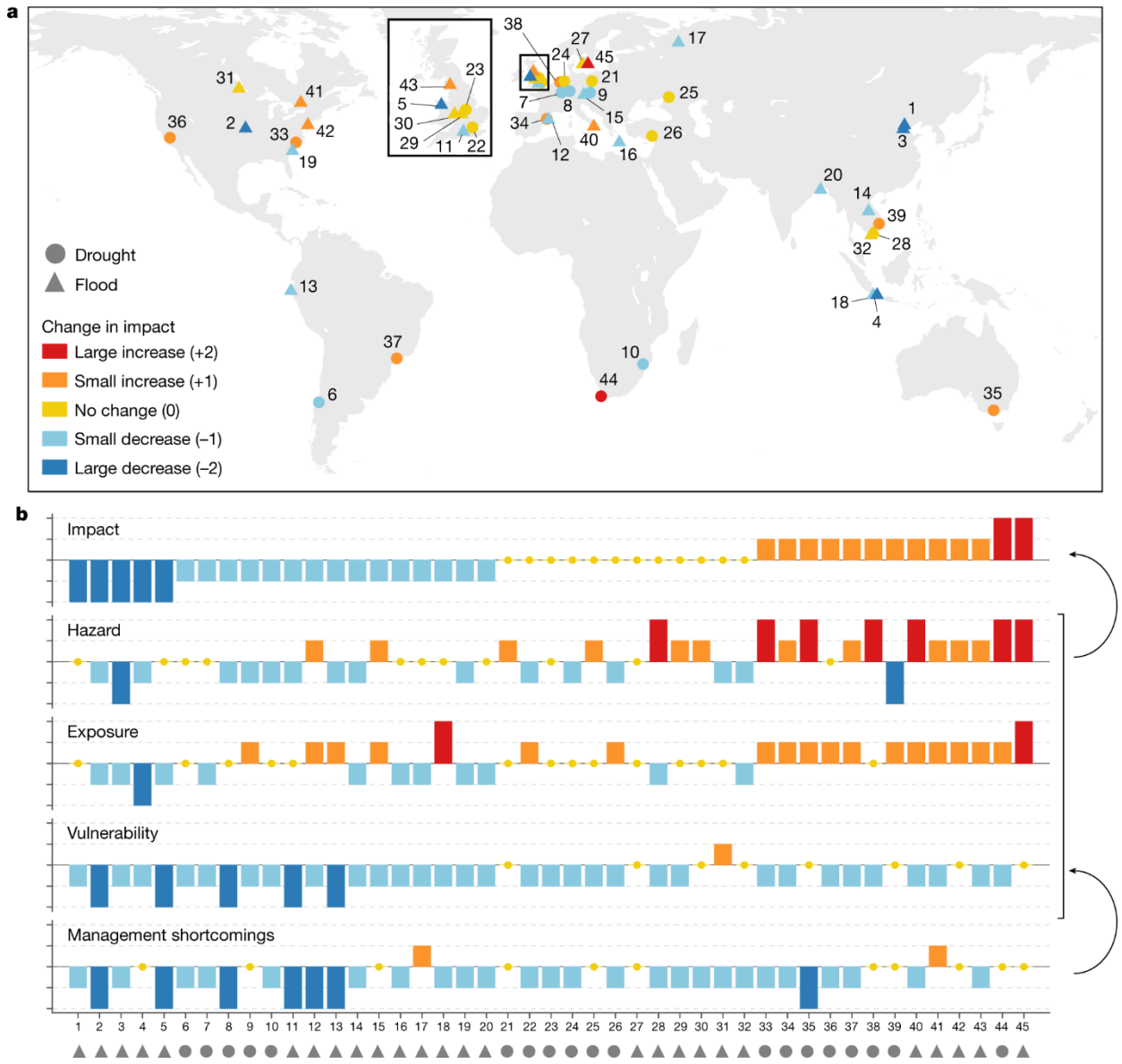
By Meredith Deliso
Video by Julian Kim and Emmanuelle Saliba
August 17, 2023, 6:23 PM

How the deadly wildfires took over Maui hour by hour Our new visual timeline offers a forensic look at the origin of the Maui fires, how they spread hour by hour across the island and the struggle of residents to survive.

A Maui official defended not activating sirens during last week's deadly wildfires, as the county's emergency response has come under scrutiny over what more could have been done to possibly save lives.

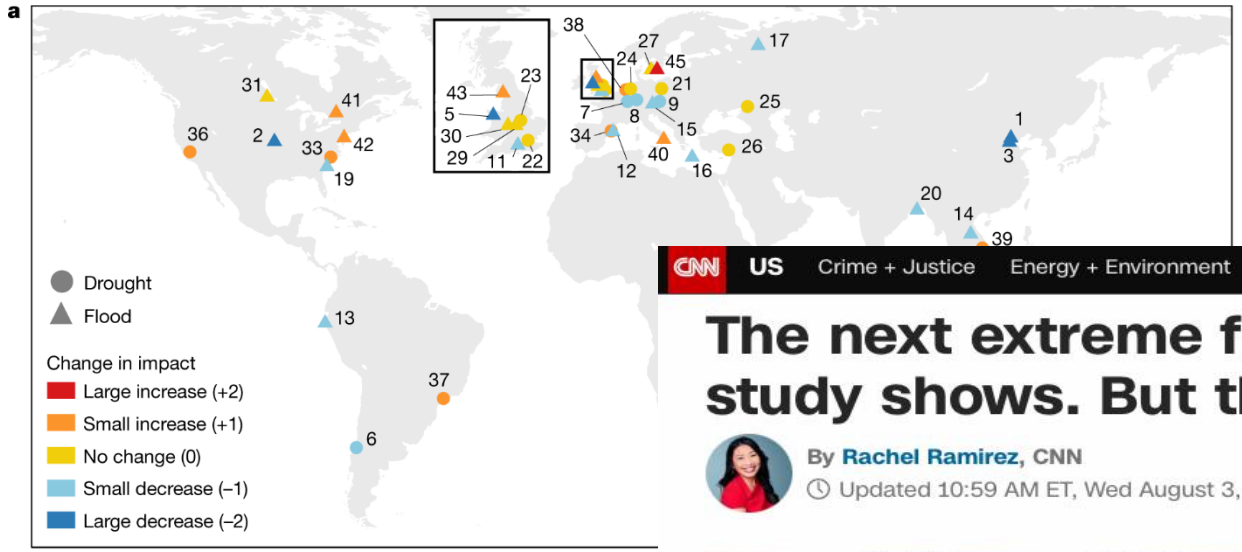
Maui Emergency Management Agency Administrator Herman Andaya said the protocol is to use the coastal sirens only during tsunami warnings, and not during wildfires.

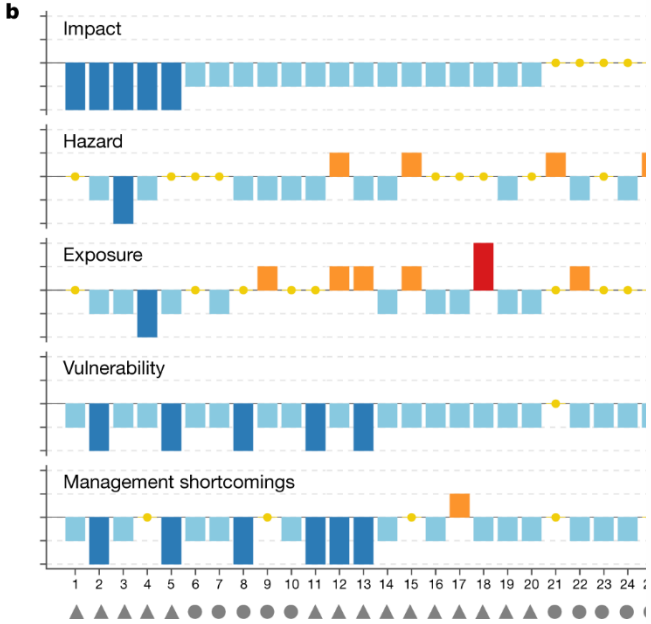
What can we learn from past events?



Kreibich et al., (2022)

What can we learn from past events?





Risk management generally reduces the impacts of floods and droughts but faces difficulties in reducing the impacts of unprecedented events.

CNN US Crime + Justice Energy + Environment More Audio

The next extreme floods could be even worse, a new study shows. But there's a way to prevent that

By Rachel Ramirez, CNN
Updated 10:59 AM ET, Wed August 3, 2022

Photos: Catastrophic flooding in Kentucky

Kreibich et al., (2022)

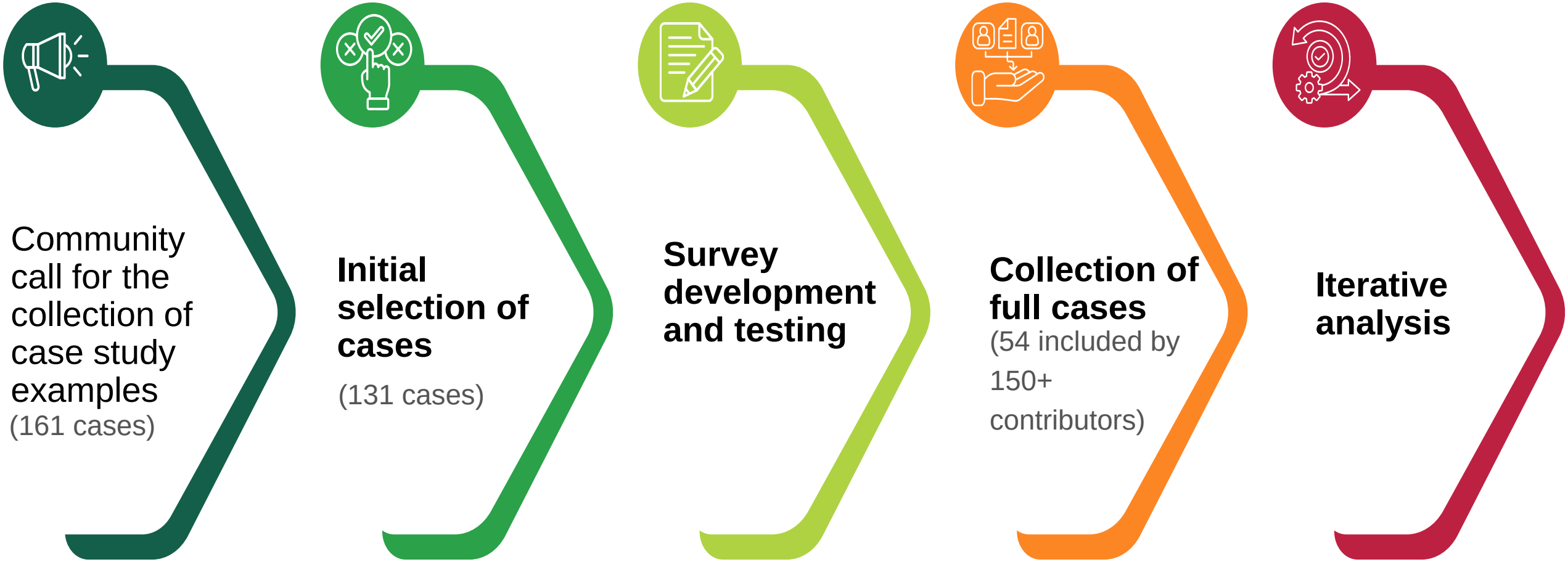
Disaster Forensics

The systematic, multi-disciplinary investigation of past disaster events to identify their root causes, risk drivers, and direct/indirect impacts (UNDRR 2024).

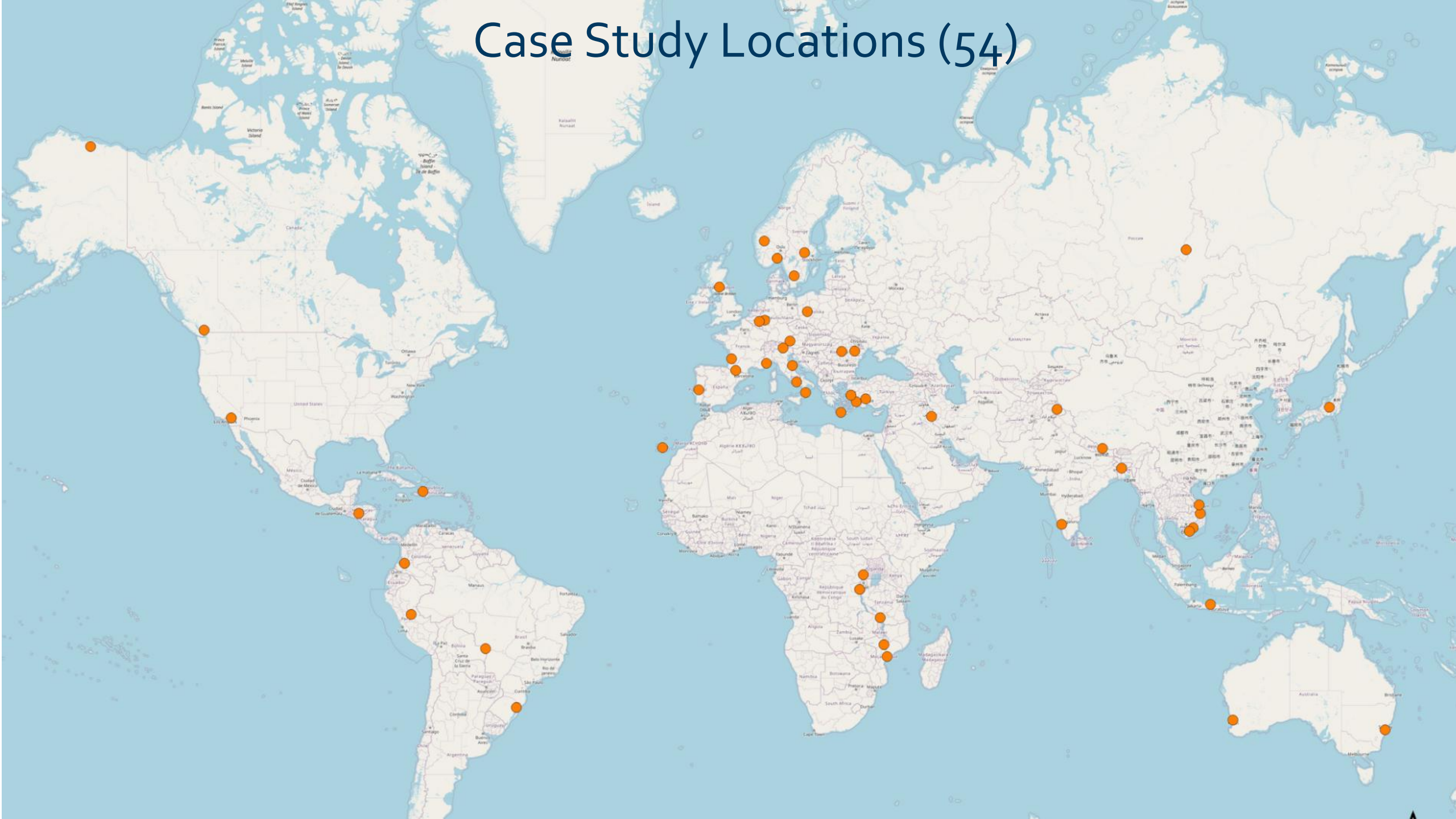
Can we learn more by forensically examining past multi-hazard events globally?

What do we know about the real-life experiences of managing multi-hazard events?

The Process


Community call for the collection of case study examples
(161 cases)
Initial selection of cases
(131 cases)
Survey development and testing
Collection of full cases
(54 included by 150+ contributors)
Iterative analysis

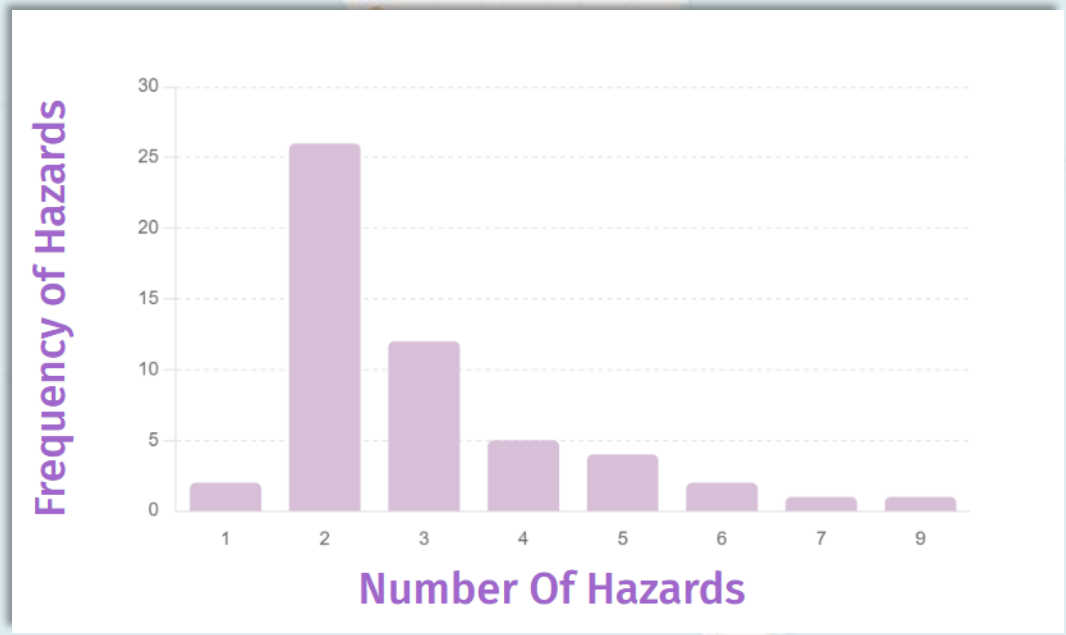
Case Study Locations (54)

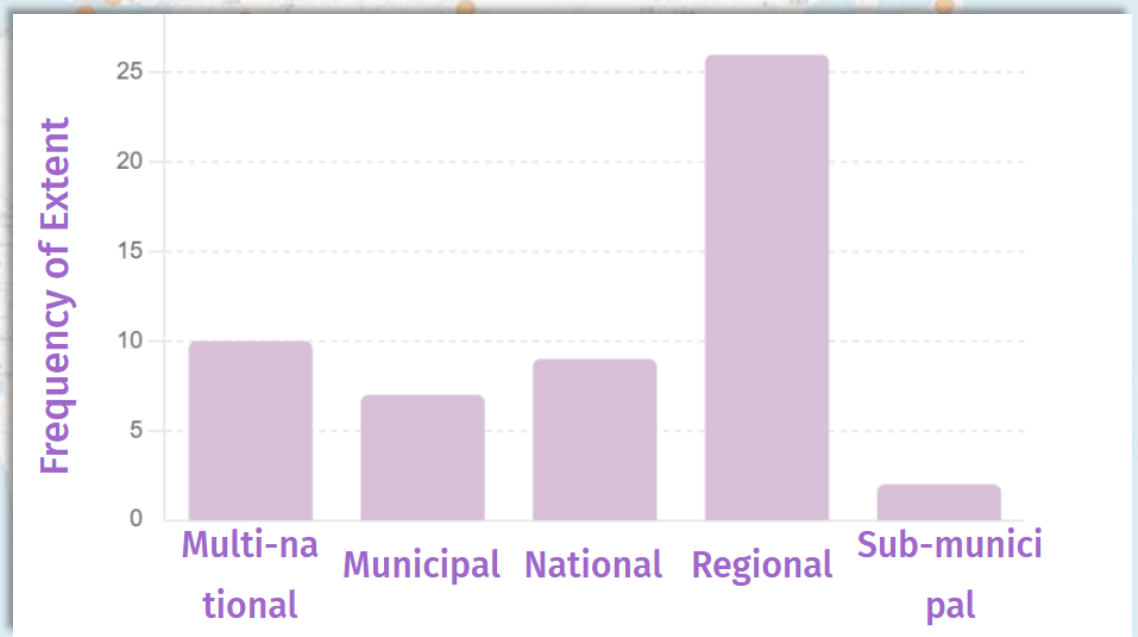


Case Study Stats

The three multi-hazard disaster typologies:

- Compound: 18
- Consecutive: 20
- Combined: 16



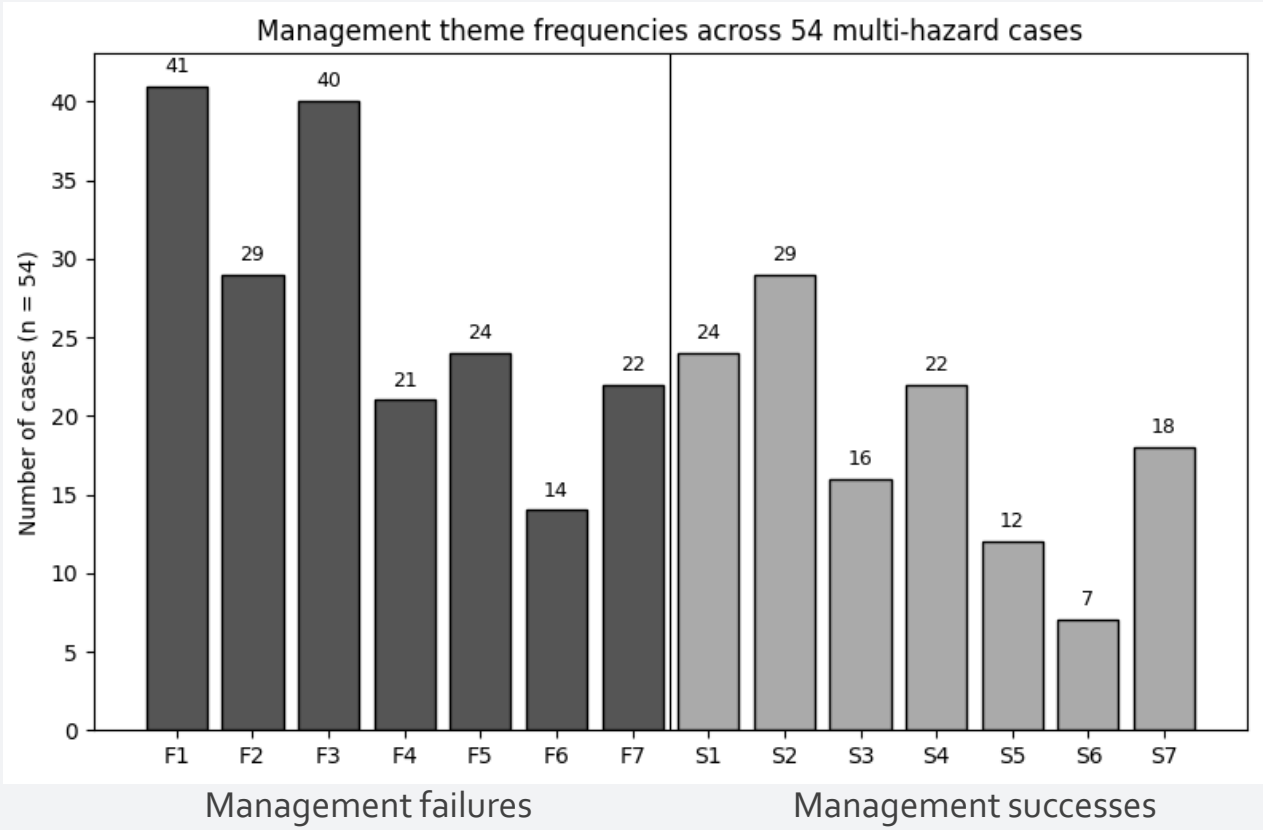


Initial Results: Management Lessons

Thematic coding reveals that failures substantially outnumber reported successes.

Management failures/bottlenecks:

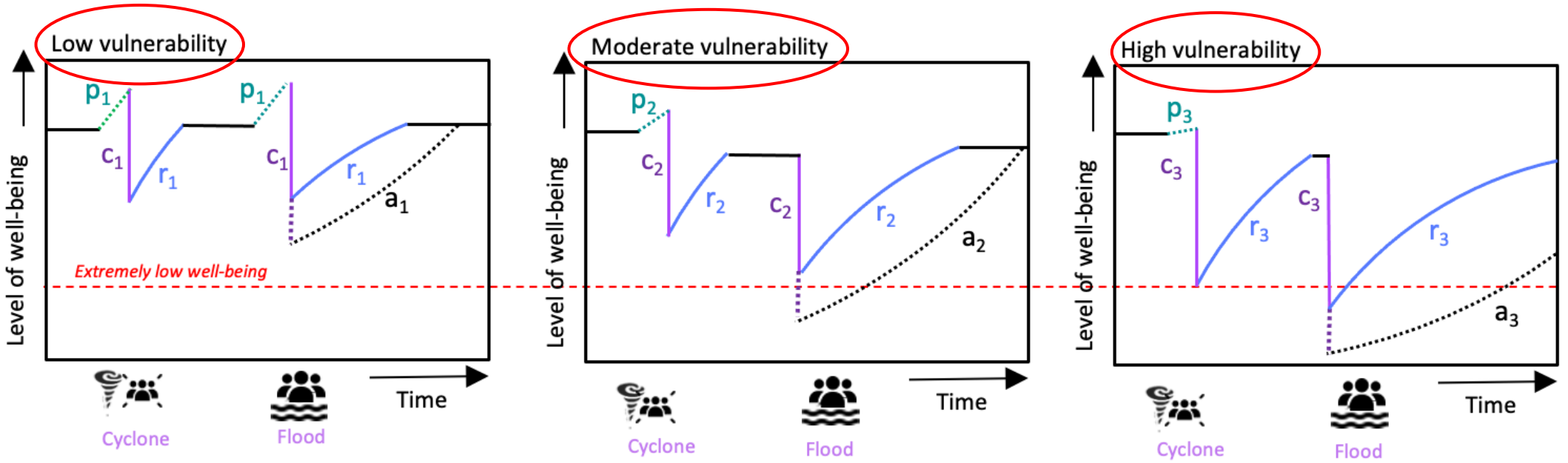
1. governance deficiencies (F1; 41/54 = 76%)
2. preparedness & early warning gaps (F3; 40/54 = 74%)
3. inadequate risk information (F2; 29/54 = 54%)
4. long-term planning deficits (F5; 24/54)
5. infrastructure failures (F7; 22/54)
6. inclusion gaps and root drivers of risk (F4; 21/54)
7. missed Build Back Better opportunities (F6; 14/54)



Management successes:

1. timely early warning and anticipatory action (S1; 24/54)
2. planning and preparedness (S2; 22/54)
3. inter-agency collaboration (S4; 22/54)
4. *These are more fragmented and less consistently reported than failures

The challenge of equitable adaptation



Haer & De Ruiter (2024)

- Accounting for different socio-economic groups;
- Representation in adaptation decision making process;
- Should identify who is most vulnerable to the impacts of disasters, and how adaptation can best serve their needs (Mohtat & Khirfan, 2022);
- Measures to address root causes of vulnerability. (Haer & De Ruiter 2024);
- A multi-hazard perspective on equitable adaptation is essential (Haer & De Ruiter 2024).

Dynamics of risk: the VU-IVM team

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