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Multi-hazard interrelationships and dynamic risk scenarios in urban areas: a case of Nairobi and Istanbul

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We thank Bruce Malamud and Joel Gill for allowing us to use materials from their previous presentations on the topic.

NEEDS, University of Twente, November 2023

1. INTRODUCTION

1. WHAT ARE MULTI-HAZARDS?

UNDRR Terminology

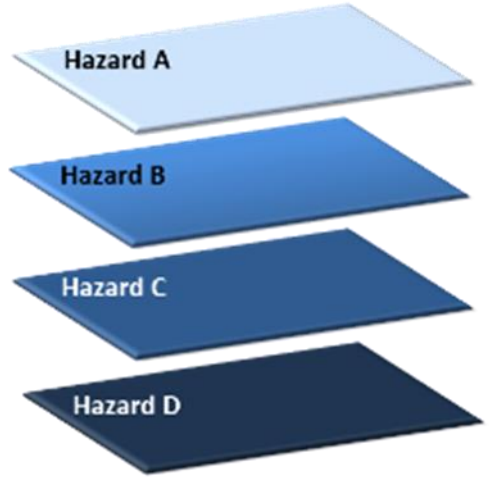
"**Multi-hazard** means:

(1) the selection of **multiple major hazards** that the country faces, and

(2) the specific contexts where hazardous events may occur **simultaneously, cascadingly or cumulatively over time**, and taking into account the potential **interrelated effects**."

More-than-one-hazards-in-a-place (**multi-layer single hazard**)

- Discrete
- Independent



Holistic approach (**multi-hazard**)

- Interconnected
- Interacting
- Interrelationships

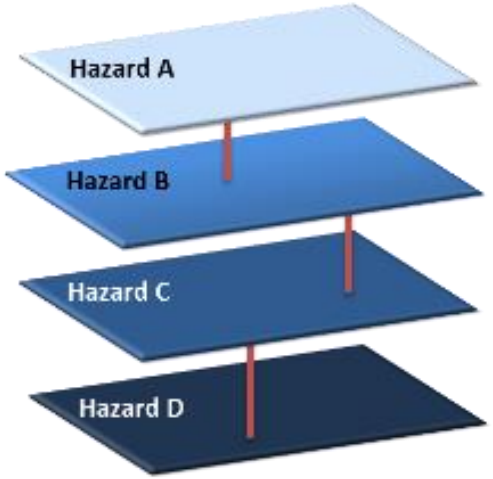


Figure from Gill and Malamud (2014) *Rev. of Geophysics*

1. MULTI-HAZARDS IN THE CONTEXT OF URBAN AREAS

- Urban areas as **hotspots of disaster risks** and resulting impacts
- **Increasing pressures** such as rapid urban expansion, increasing populations, poor urban planning, and the global impacts of climate change are **exacerbating both exposure and vulnerability** to an array of natural hazards
- **95% of future urban development** will happen in the context **of low- and middle-income countries** (UN-HABITAT, 2022): imperative for **risk-informed urban development** (Cremen et al., 2023)
- **Interrelationships** between hazards **rarely considered**

Istanbul, Turkey
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1. WHAT IS THIS WORK ABOUT?

- **Utilising Nairobi (Kenya) and Istanbul (Türkiye)** as case study examples, we **aim to present and apply an approach** to:

    - **Characterize the full breadth of multi-hazards and their interrelationships** in an urban setting.
    - **Co-develop multi-hazard scenarios of interest** for local stakeholders in urban areas.
    - Identify **potential uses, challenges and opportunities for mainstreaming multi-hazard thinking in DRR efforts** in urban areas in low- and middle-income countries.

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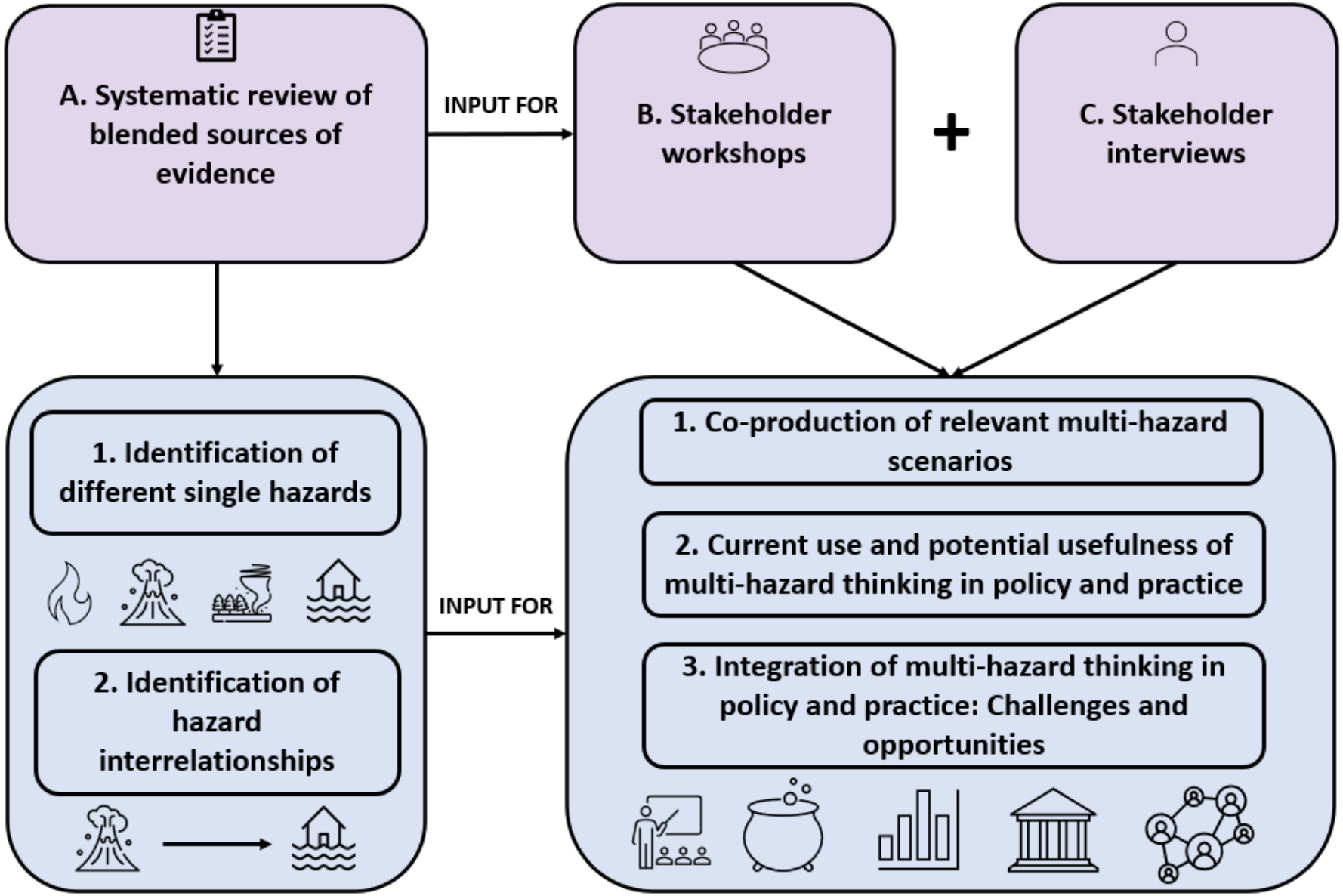
2. OUR APPROACH

2. METHODOLOGICAL APPROACH



3. RESULTS

3A. SYSTEMATIC REVIEW OF BLENDED SOURCES OF EVIDENCE

3A. IDENTIFICATION OF SINGLE HAZARDS

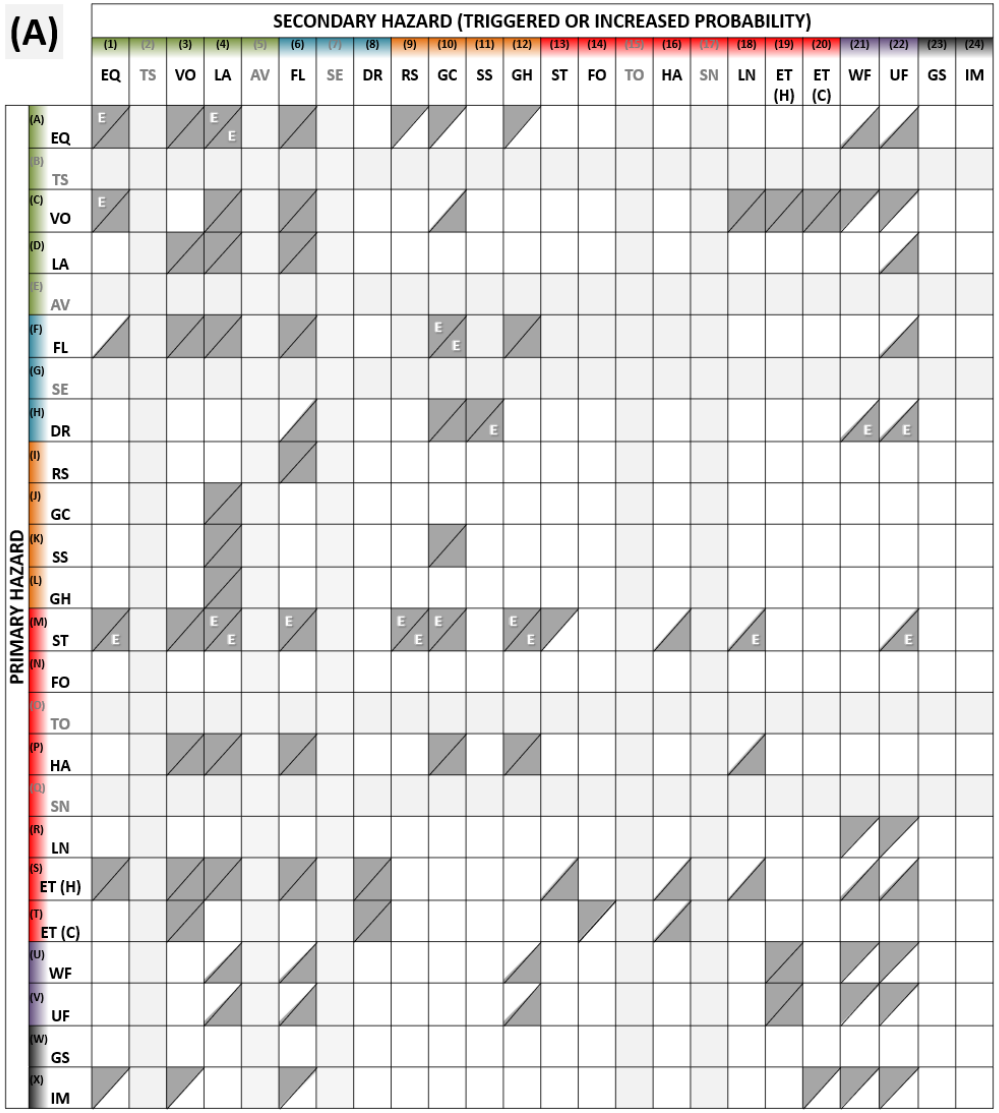
- We mapped **all single hazards that might impact Istanbul and Nairobi** (Classification amended from Gill & Malamud, 2014).
- Evidence for **case studies** and **what might be theoretically possible** using multiple sources using:
  - **Peer-reviewed literature**
  - **Grey literature**
  - **Newspapers**
  - **Social media**
  - **Databases (e.g., DesInventar)**
  - **Expert input**

- We found:
  - **Istanbul**: 23 natural hazards based on 57 sources of evidence
  - **Nairobi:** 19 natural hazards based on 69 sources of evidence
  - Detailed systematic databases of evidence available

KEY		
HAZARD GROUP	HAZARD	CODE
GEOPHYSICAL	Earthquake	EQ
	Tsunami	TS
	Volcanic Eruption	VO
	Landslide	LA
	Snow Avalanche	AV
HYDROLOGICAL	Flood	FL
	Seiche	SE
	Drought	DR
SHALLOW EARTH PROCESSES	Regional Subsidence	RS
	Ground Collapse	GC
	Soil (Local) Subsidence	SS
	Ground Heave	GH
ATMOSPHERIC	Storm	ST
	Fog	FO
	Tornado	TO
	Hailstorm	HA
	Snowstorm	SN
	Lightning	LN
	Extreme Temperature (Hot)	ET (H)
	Extreme Temperature (Cold)	ET (C)
BIOPHYSICAL	Wildfire	WF
	Urban Fire	UF
SPACE	Geomagnetic Storm	GS
	Impact Event	IM

3A. IDENTIFICATION OF HAZARD INTERRELATIONSHIPS: NAIROBI

(A)



NAIROBI KEY			
HAZARD GROUP	HAZARD	CODE	ROW, COLUMN
GEOPHYSICAL	Earthquake	EQ	A, 1
	Tsunami	TS	B, 2
	Volcanic Eruption	VO	C, 3
	Landslide	LA	D, 4
	Snow Avalanche	AV	E, 5
HYDROLOGICAL	Flood	FL	F, 6
	Seiche	SE	G, 7
	Drought	DR	H, 8
SHALLOW EARTH PROCESSES	Regional Subsidence	RS	I, 9
	Ground Collapse	GC	J, 10
	Soil (Local) Subsidence	SS	K, 11
	Ground Heave	GH	L, 12
ATMOSPHERIC	Storm	ST	M, 13
	Fog	FO	N, 14
	Tornado	TO	O, 15
	Hailstorm	HA	P, 16
	Snowstorm	SN	Q, 17
	Lightning	LN	R, 18
	Extreme Temperature (Hot)	ET (H)	S, 19
	Extreme Temperature (Cold)	ET (C)	T, 20
BIOPHYSICAL	Wildfire	WF	U, 21
	Urban Fire	UF	V, 22
SPACE	Geomagnetic Storm	GS	W, 23
	Impact Event	IM	X, 24

SYMBOL	NAIROBI EXPLANATION
	Hazard **Triggers** Secondary Hazard (Influencing **Nairobi**)
	Hazard **Increases Probability** of Secondary Hazard (Influencing **Nairobi**)
	Hazard Both **Triggers and Increases the Probability** of Secondary Hazard (Influencing **Nairobi**)
E	**Evidence** for the Interrelationship Influencing **Nairobi** (see Supplementary Materials Excel Database)
	Single Hazard (TS, AV, SE, TO, SN) not found to Influence Nairobi (entire row and column greyed).

- **Examined each pair of hazards** from the single hazard databases **for potential interrelationships** (using blended evidence) and created a **matrix visualization**.
- For **Nairobi** we found**:**
  - **126** of potential hazard interrelationships.

3A. IDENTIFICATION OF HAZARD INTERRELATIONSHIPS: ISTANBUL

(B)

PRIMARY HAZARD	SECONDARY HAZARD (TRIGGERED OR PROBABILITY CHANGE)																							
	(1) EQ	(2) TS	(3) VO	(4) LA	(5) AV	(6) FL	(7) SE	(8) DR	(9) RS	(10) GC	(11) SS	(12) GH	(13) ST	(14) FO	(15) TO	(16) HA	(17) SN	(18) LN	(19) ET (H)	(20) ET (C)	(21) WF	(22) UF	(23) GS	(24) IM
(A) EQ	E E	E		E E																				
(B) TS						E	E																	
(C) VO																								
(D) LA		E																						
(E) AV																								
(F) FL	E					E																		
(G) SE																								
(H) DR											E E													
(I) RS						E																		
(J) GC																								
(K) SS										E E														
(L) GH																								
(M) ST				E		E				E			E		E E	E		E						
(N) FO																								
(O) TO																								
(P) HA																								
(Q) SN																				E				
(R) LN																					E			
(S) ET (H)						E							E			E		E			E			
(T) ET (C)																								
(U) WF																								
(V) UF																								
(W) GS																								
(X) IM																								

ISTANBUL KEY			
HAZARD GROUP	HAZARD	CODE	ROW, COLUMN
GEOPHYSICAL	Earthquake	EQ	A, 1
	Tsunami	TS	B, 2
	Volcanic Eruption	VO	C, 3
	Landslide	LA	D, 4
	Snow Avalanche	AV	E, 5
HYDROLOGICAL	Flood	FL	F, 6
	Seiche	SE	G, 7
	Drought	DR	H, 8
SHALLOW EARTH PROCESSES	Regional Subsidence	RS	I, 9
	Ground Collapse	GC	J, 10
	Soil (Local) Subsidence	SS	K, 11
	Ground Heave	GH	L, 12
ATMOSPHERIC	Storm	ST	M, 13
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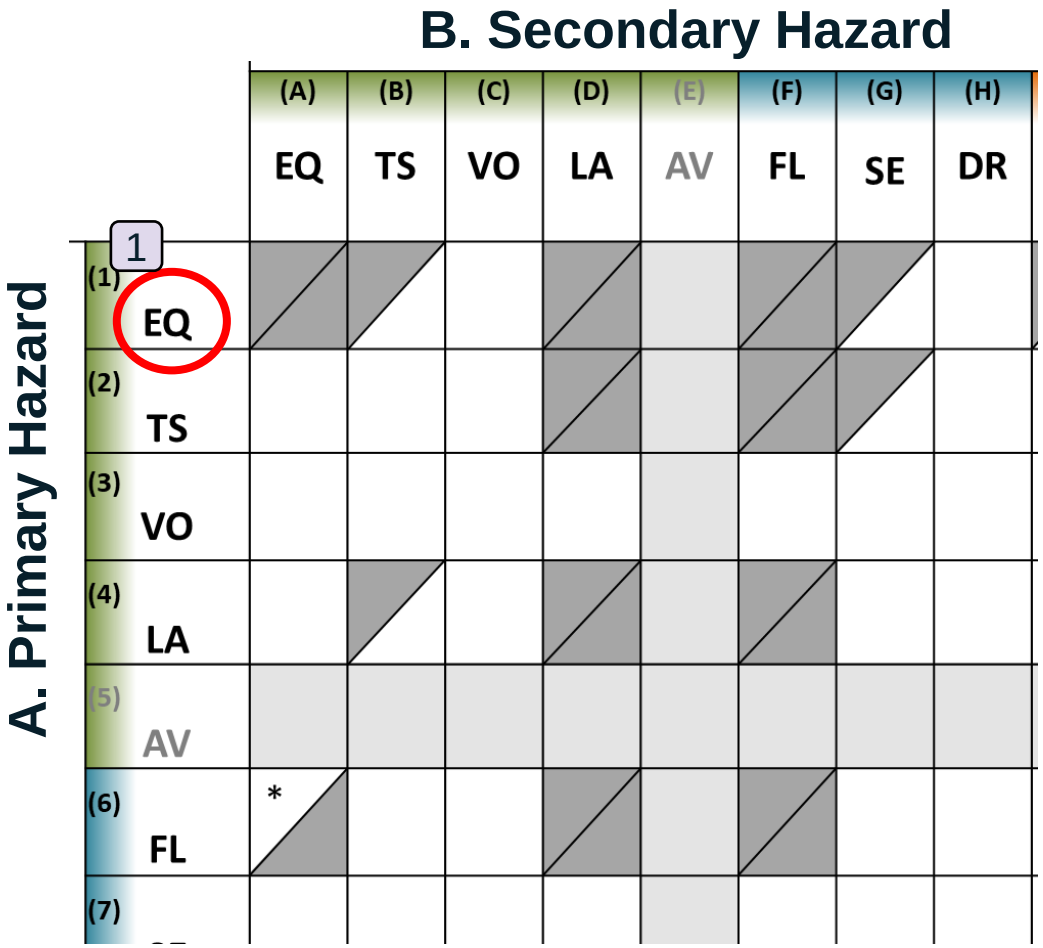
	Snowstorm	SN	Q, 17
	Lightning	LN	R, 18
	Extreme Temperature (Hot)	ET (H)	S, 19
	Extreme Temperature (Cold)	ET (C)	T, 20
BIOPHYSICAL	Wildfire	WF	U, 21
	Urban Fire	UF	V, 22
SPACE	Geomagnetic Storm	GS	W, 23
	Impact Event	IM	X, 24

SYMBOL	ISTANBUL EXPLANATION
	Primary Hazard **Triggers** Secondary Hazard (Influencing **Istanbul**)
	Primary Hazard **Increases Probability** of Secondary Hazard (Influencing **Istanbul**)
	Primary Hazard Both **Triggers and Increases the Probability** of Secondary Hazard (Influencing **Istanbul**)
E	**Evidence** for the Interrelationship Influencing **Istanbul** (see Supplementary Materials Excel Database)
	Single hazard (snow avalanche--AV) not found to influence Istanbul (entire row and column greyed)

- For **Istanbul** we found:
  - **163** of potential hazard interrelationships.

3A. BUILDING DYNAMIC RISK SCENARIOS



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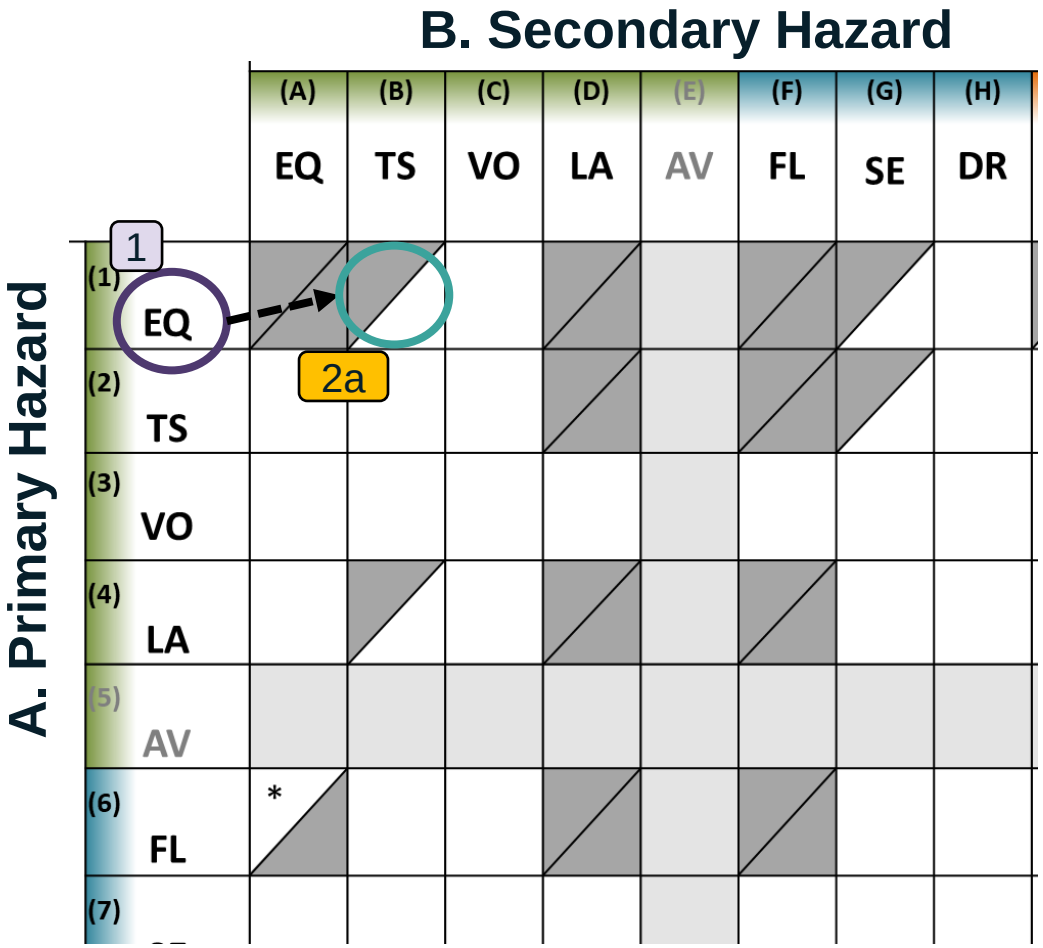
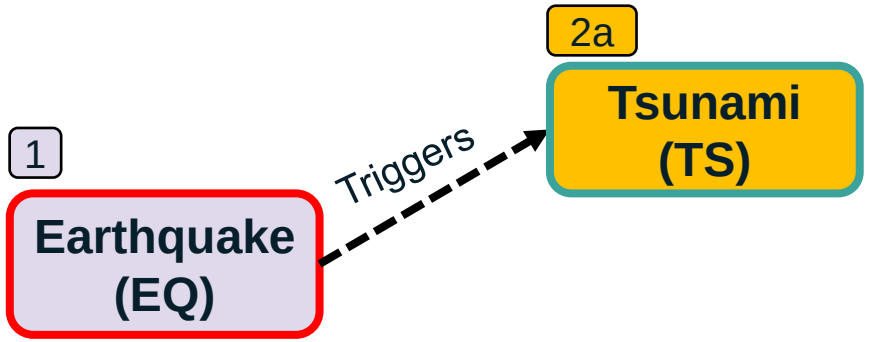
Earthquake (EQ)

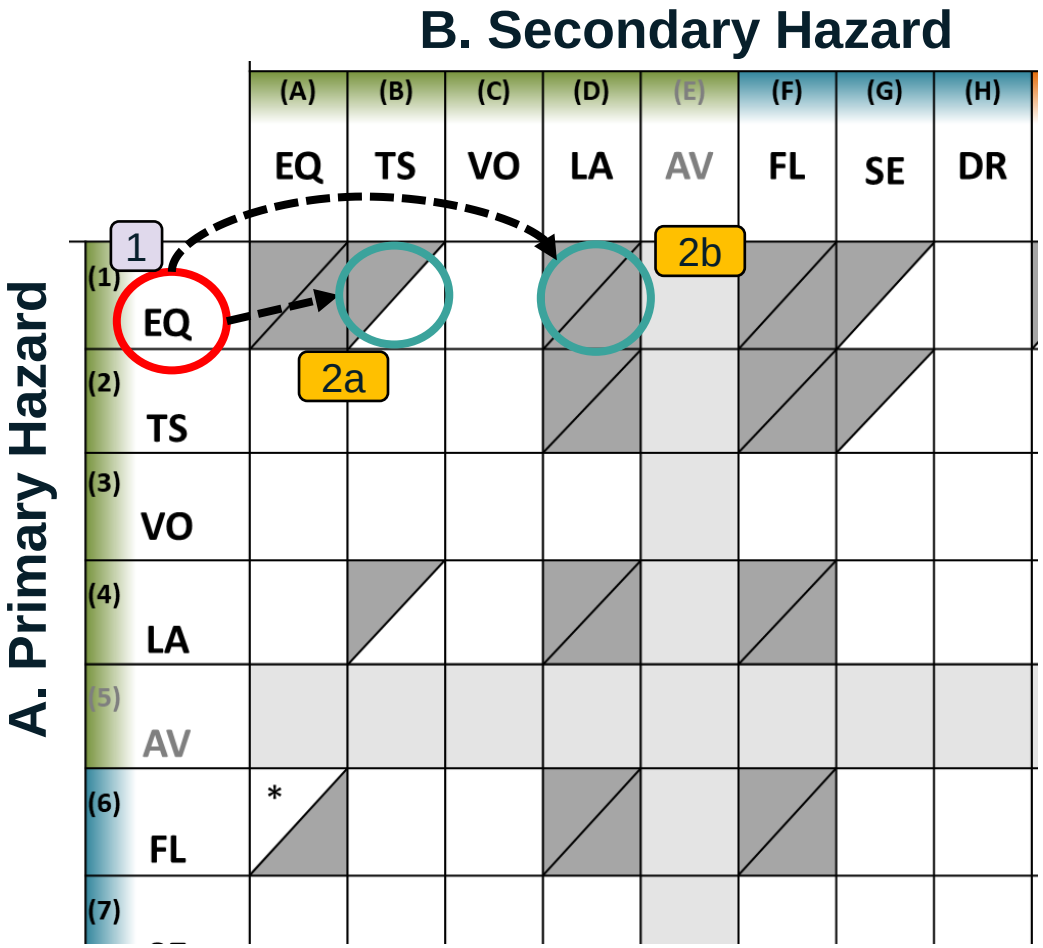
3A. BUILDING DYNAMIC RISK SCENARIOS

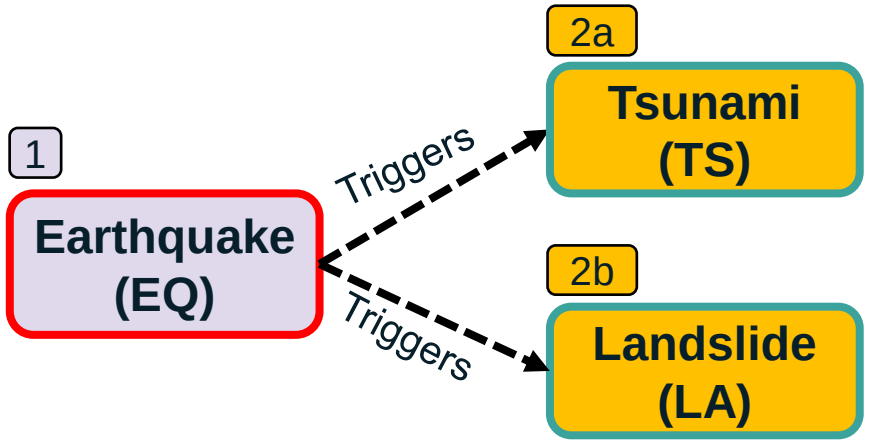




Paper in prep.

3A. BUILDING DYNAMIC RISK SCENARIOS





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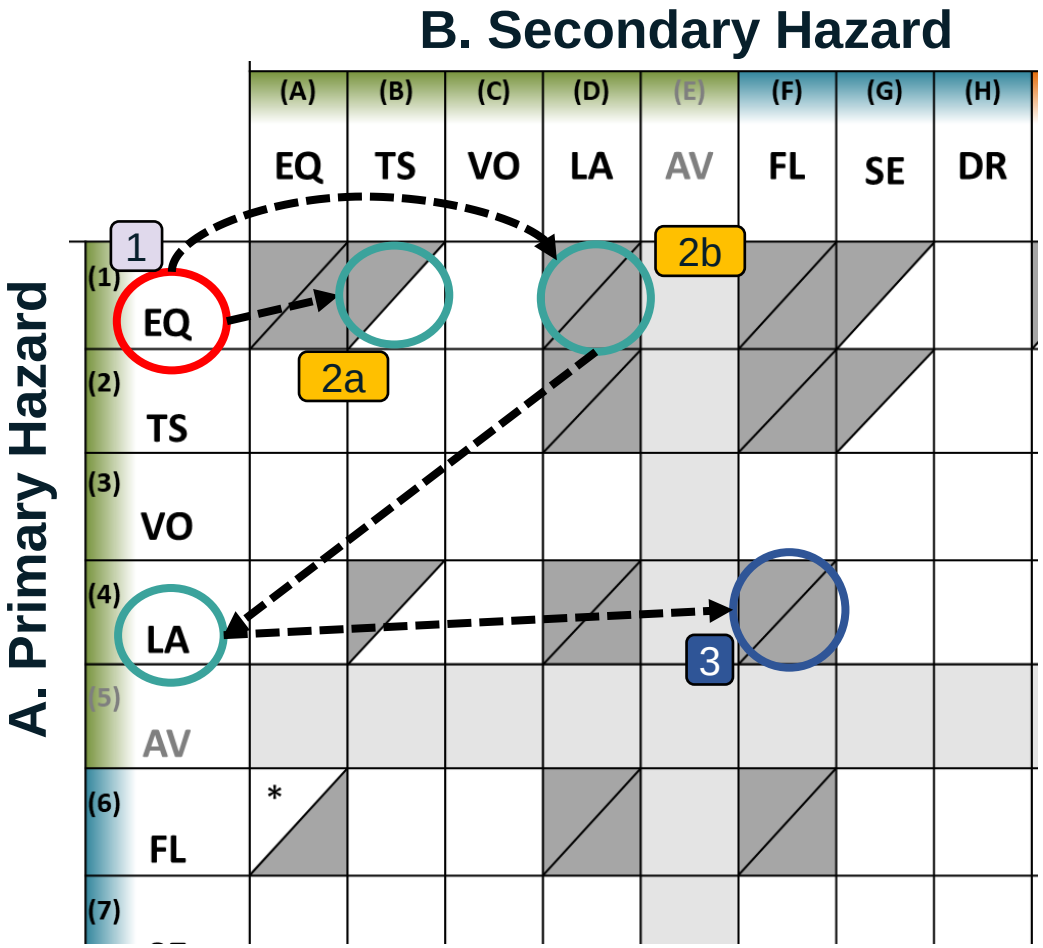
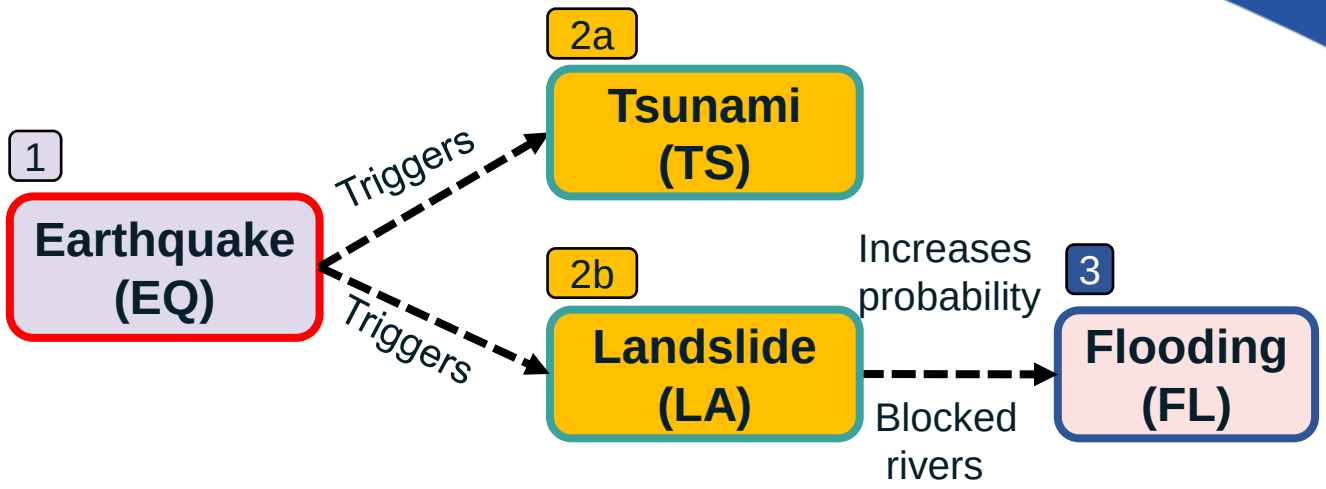




Paper in prep.

3. RESULTS

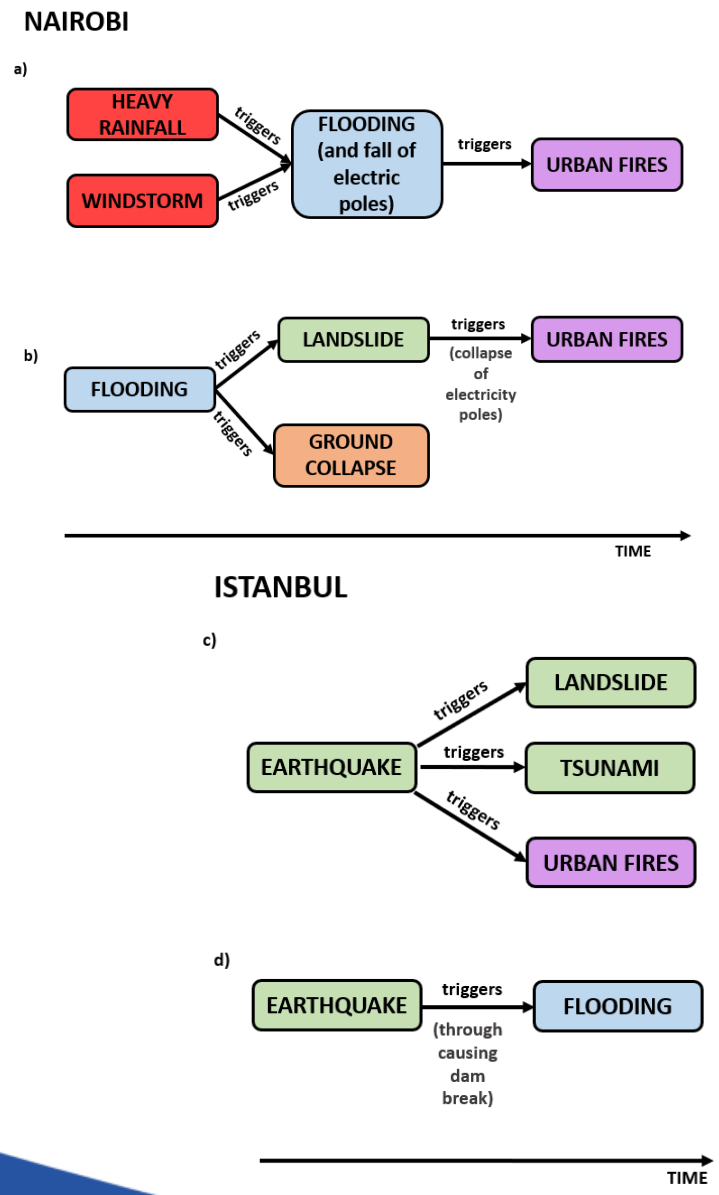
3B. WORKSHOPS AND INTERVIEWS

3B. MULTI-HAZARD SCENARIOS OF INTEREST FOR STAKEHOLDERS

	Example scenarios identified by Nairobi participants
WORKSHOPS	**Scenario 1**: **Storm** -> **Lightning** -> **Urban Fire** **Scenario 2**: **Earthquake** -> **Urban Fire** **Scenario 3**: Heavy Rain (**Storm**) -> **Flooding** -> **Landslides** **Scenario 4**: Heavy Rain (**Storm**) -> Flash Floods (**Flooding**) due to poor drainage -> Riverine Floods (**Flooding**) -> Collapse of buildings **Scenario 5**: Heavy Rain (**Storm**) -> **Flooding** -> Electricity blackout, people start using candles and paraffin -> **Urban Fire** **Scenario 6**: Heavy Rain (**Storm**) -> **Flooding** -> Short Circuits -> **Urban Fire** **Scenario 7**: **Storm** -> **Flooding** and **Landslides** and **Ground Collapse** **Scenario 8**: **Drought** and no waste management -> **Flooding** and **Urban Fire** **Scenario 9:** Heavy Rain (**Storm**) + **Windstorm** -> **Flooding** and fall of electric poles -> **Urban Fire** and electrocution **Scenario 10**: **Extreme Heat** -> **Wildfire** **Scenario 11**: Heavy Rainfall (**Storm**) + **Lightning** -> **Urban Fire** **Scenario 12**: **Heatwave** -> **Drought** and at the same time **WIldFire** followed at a later time by **Flooding** -> **Ground Collapse** **Scenario 13:** **Flooding** -> **Landslides** and **Ground Collapse** -> **Landslides** resulting in the Collapse of electricity poles -> **Urban Fire** **Scenario 14:** **Flooding** -> **Communicate Diseases** **Scenario 15:** **Flooding** + **Lightning** -> **Urban Fire**
INTERVIEWS	**Scenario 16**: **Drought** followed by a **Storm** -> **Flooding** **Scenario 17**: **Flooding** -> **Landslides** **Scenario 18**: **Flooding** -> **Urban Fire** due to improper wiring **Scenario 19**: **Lightning** -> **Urban Fire** **Scenario 10**: **Flooding** -> Water pollution and environmental contamination -> **Diseases** **Scenario 21**: **Storm** -> **Flooding** -> **Landslides**

	Example scenarios identified by Istanbul participants
WORKSHOPS	**Scenario 1:** Heavy rains (**Storm**) followed by **Earthquake -> Flood + Landslide + Tsunami + Regional subsidence + Ground Collapse** **Scenario 2:** **Earthquake -> Ground Collapse** + building Collapse **-> Urban Fire** **Scenario 3:** **Storm -> Flood** **Scenario 4:** **Storm -> Flood + Hail +** (coincident) **Earthquake** **Scenario 5:** **Earthquake ->** infrastructure damage **-> Flood** **Scenario 6:** rains (**Storm**) **->** dam Collapse **-> Flood** **Scenario 7:** **Lightning -> Fire** **Scenario 8:** **Extreme temperature (heat) ->** rain (**Storm**) **-> Flood ->** building Collapse **+ Landslide + Ground Collapse** or **heave** + infectious disease **Scenario 9:** **Earthquake -> Liquefaction** + Ground deformation **Scenario 10:** **Earthquake -> Landslide + Tsunami + Urban Fire** + release of hazardous chemicals/contaminants
INTERVIEWS	**Scenario 11:** **Earthquake -> Tsunami -> Landslide** **Scenario 12:** **Earthquake -> Liquefaction** **Scenario 13:** **Earthquake -> Landslide** **Scenario 14:** **Earthquake ->** dam damage -> **Flood** **Scenario 15:** **Earthquake -> Tsunami** + dam damage **+ Urban Fire -> Flood**

3B. MULTI-HAZARD SCENARIOS OF INTEREST FOR STAKEHOLDERS



Some observations on co-produced scenarios:

- **Thinking beyond natural hazards**: e.g., the importance of including disease outbreaks and interactions with anthropogenic processes (e.g., waste management, illegal electricity connections) resulting in impacts.
- **Dynamics of exposure and vulnerability** in multi-hazard scenarios in Nairobi:
  - After floods, people move to higher grounds where they're now exposed to landslides.
  - After fires, people moved to flood zones.
  - After fires, people move to a new area, lacking social networks or access to previous sources of employment.

3B. PERCEIVED BENEFITS OF MULTI-HAZARD THINKING

- **Increased preparedness and understanding of impact**: planning around what might happen, awareness raising on cascading impacts, identification of vulnerable groups and targeted interventions, planning of early actions and impact-based EWS
- **Improved disaster response and recovery:** coordination of different institutions in response, reduction of recovery times through multi-hazard-informed preparedness plans
- **Prevention of risk creation:** prevention of new risks in the planning process
- **Understanding capacity and resource needs:** understanding capacity needs of different institutions and better response planning
- **Informing urban planning and regeneration:** risk-informed planning and stress-testing of existing policies
- **Creation of inclusive disaster risk management policies:** consideration of dynamic risk components helps in the identification of pro-poor approaches.
- **Improvement of existing plans:** Full consideration of multi-hazards would enhance already existing risk reduction initiatives (e.g., risk reduction plans and urban planning documents).

3B. PERCEIVED CHALLENGES AND OPPORTUNITIES IN INCORPORATING MULTI-HAZARD THINKING IN DISASTER RISK REDUCTION

Challenges

- **Governance-related challenges**
  - Siloes in policy and practice between different institutions, characterized by single-hazard focused thinking.
  - Lack of coordination and communication
  - Centralized policy-making
  - Lack of enforcement of regulations
  - Lack of implementation instruments
  - Human and financial resources
- **Understanding of multi-hazards and associated risks**
- **Response-focused disaster risk management**
- **Focus on imminent risks**

Opportunities:

- **Increased awareness** of the **factors** that might **influence risk dynamically** in their **urban region** as a possible catalyst.
- **Ongoing development and revision of policies and legislations.**
- **More studies** resulting in better understanding**.**

4. CONCLUSIONS

4. SOME CLOSING REMARKS

- We provide **an approach to characterize the full breadth of single hazards** and their **multi-hazard interrelationships** in urban areas, **co-develop multi-hazard scenarios** of interest for local stakeholders, and **identify practicalities of mainstreaming multi-hazard thinking** in DRR efforts.
- The approach can be used for **exploring multi-hazard interrelationships in different urban settings**, and could be particularly useful in **the context of urban areas** in low- and middle-income countries **where data is often scarce**.
- **Nairobi and Istanbul** are prone to **a vast array of possible natural hazards and** a large number of **interrelationships between them**.
- These **scenarios also offer an opportunity to engage in discussions** on the **dynamics of disaster risk and its components**.
- Considering multi-hazards **offers benefits across different aspects of disaster risk management**. However, mainstreaming of multi-hazard thinking in policy and practice remains hindered by **many challenges**; the main one being various aspects of **disaster risk governance**.

SOME ONGOING INITATIVES


EGU European Geosciences Union
Copernicus Publications
The Innovative Open Access Publisher
Inter-journal Special issue of NHESS/ESD/ESSD/GC/HESS
Methodological innovations for compound and multi-risk
Submit your paper
Early Career editorial team: Marleen de Ruiter, Robert Šakić Trogrlić, Anaïs Couasnon, Antonia Sebastian, Silvia De Angeli, Aloïs Tilloy, Avantika Gori

iScience

Call for papers:

Early warning systems (EWS) in the context of multi-hazard risk: Challenges and a way forward

Submission deadline: March 31st, 2024

Submit your paper

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3rd International Conference

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Adressing Compound and Multi-Hazard Risk

JUNE 12–14, 2024
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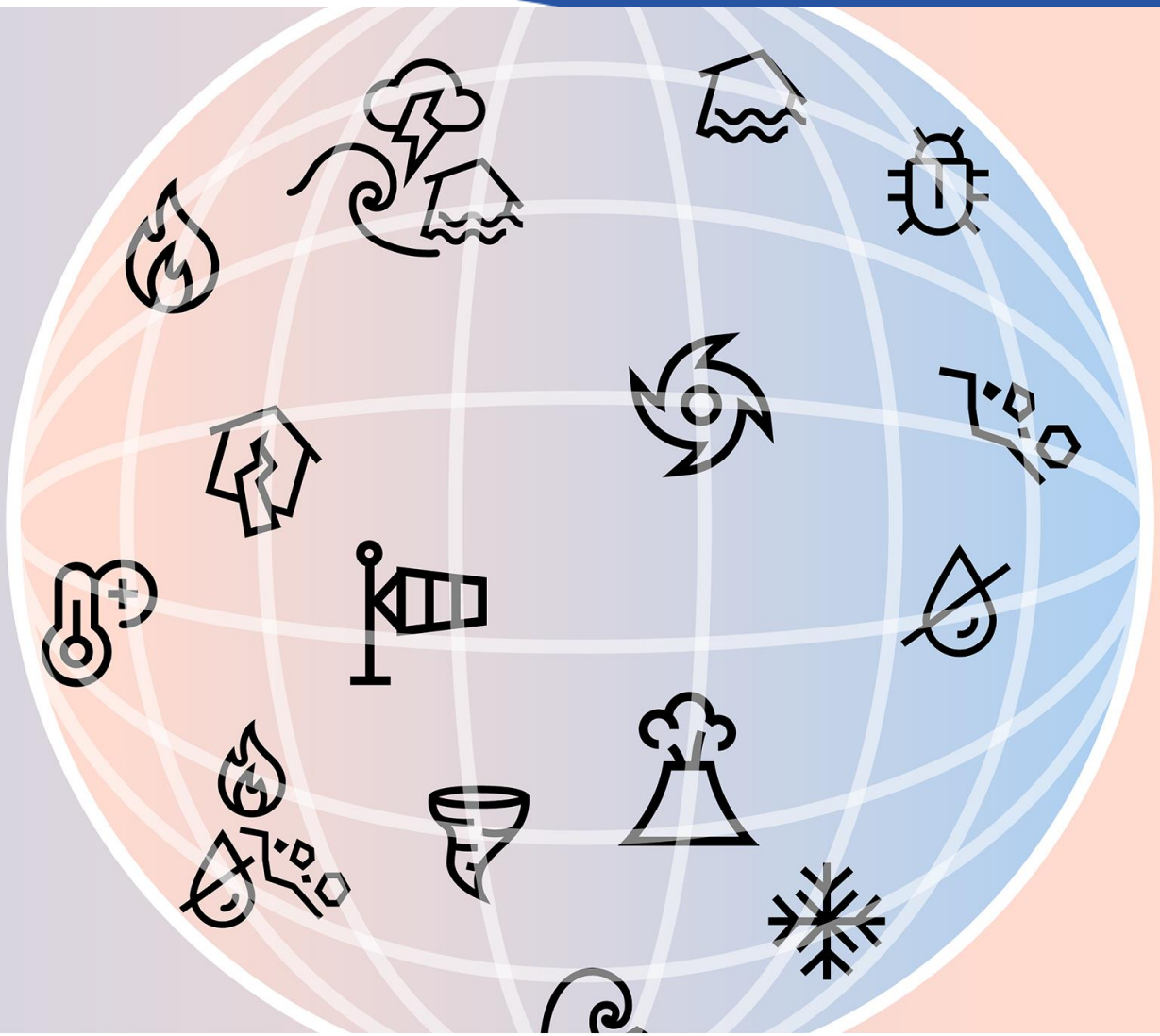

NatRiskChange

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Reducing risks together

RISKKAN
Knowledge Action Network

The MYRIAD-EU project has received funding from the European Union's Horizon 2020 research and innovation programme call H2020-LC-CLA-2018-2019-2020 under grant agreement number 101003276

Thank you for your time

Any questions?

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