EGU22-10366

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European Geosciences Union

NH9.9 Natural hazards: urban growth and health impacts
(23 May 2022)

Dynamic risk scenarios for single and multi-hazards in the Global South: Nairobi, Istanbul and Kathmandu

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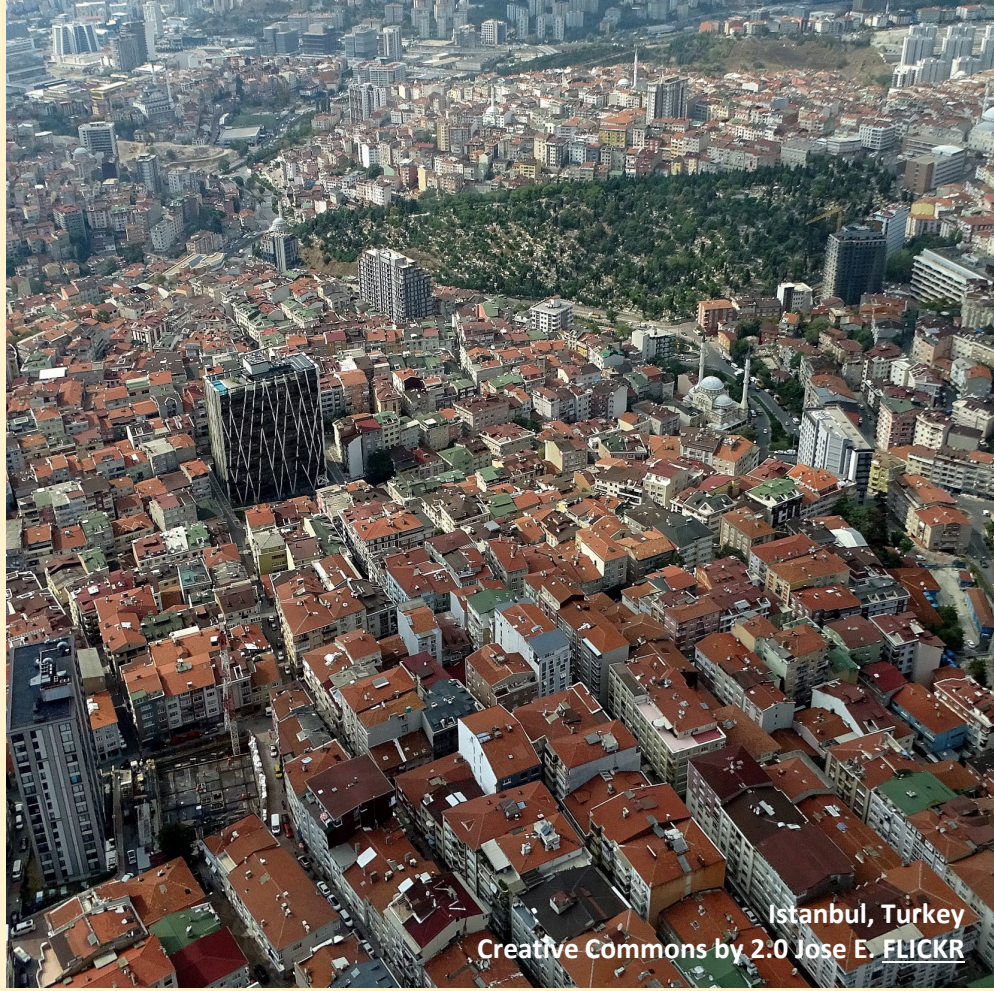

Istanbul, Turkey
Creative Commons by 2.0 Jose E. FLICKR

KING'S College LONDON

KANDILLI RASATHANESI VE DEPREM ARAŞTIRMA ENSTITÜSÜ 1868

BGS British Geological Survey

Kenya Red Cross

Tomorrow's CITIES Urban Risk in Transition
www.tomorrowscities.org

UK Research and Innovation

GCRF Global Challenges Research Fund

OUTLINE OF NEXT 8’
(+2’ FOR QS AND CROSS OVER)

EGU22-10366 (Malamud *et al.*, Dynamic risk scenarios for single and multi-hazards in the Global South: Nairobi, Istanbul & Kathmandu)

Tomorrow's CITIES
Urban Risk in Transition
www.tomorrowscities.org

1. **Single natural hazards** (influencing Nairobi, Istanbul, Kathmandu—peer/grey literature, social media)
2. **Hazard interrelationships** (influencing Nairobi, Istanbul, Kathmandu —peer/grey literature, social media)
3. **Building dynamic risk scenarios**
4. **Co-development of dynamic Risk Scenarios (for Istanbul, Nairobi)** (workshops, interviews)
5. **Challenges and opportunities identified by stakeholders in incorporating dynamic risk scenarios into planning**

1 Single Hazards

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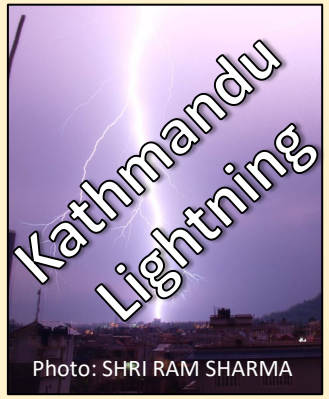
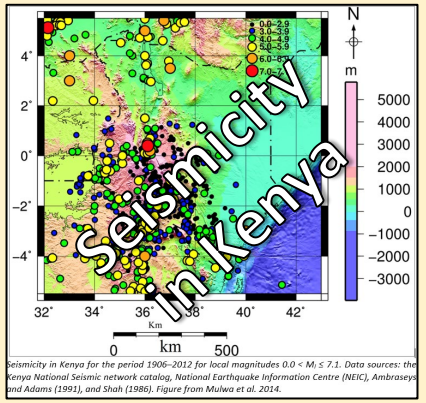
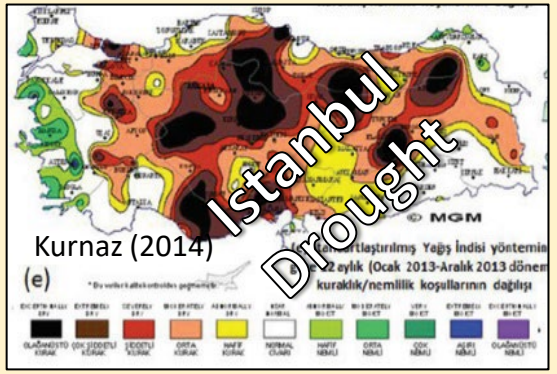
EGU22-10366 (Malamud *et al.*, Dynamic risk scenarios for single and multi-hazards in the Global South: Nairobi, Istanbul & Kathmandu)

- We mapped **all single hazards that might impact Istanbul, Nairobi & Kathmandhu** (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**







1 Single Hazards (The Database)

EGU22-10366 (Malamud *et al.*, Dynamic risk scenarios for single and multi-hazards in the Global South: Nairobi, Istanbul & Kathmandu)

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A Hazard Type | **B Source Info and URL** | **C Source Content**

1. Hazard type				2. Source information and link				3. Source content
1.1 Hazard Group	1.2 Hazard	1.3 Code	Component hazards	2.1 Case Study (C)/ Review (R)	2.2 Type of evidence: Academic (A); Grey Lit (G); Media (M); Database (D); Social Media (SM); Not Applicable (NA)	2.3 Source	2.4 Link	3.1 Description of the themes covered in the source
				C	M	Jacobson, D. (2018) *Giant cracks opens in East African Rift Valley*. [Online]. Available at: https://temblor.net/earthquake-insights/new-cracks-appear-in-east-african-rift-valley-6678/ [Accessed 25 January 2021].	https://temblor.net/earthquake-insights/new-cracks-appear-in-east-african-rift-valley-6678/	• Example of **ground rupture from 2018**. Not clear if over days, months, years. • In a vicinity of Nairobi, here as an example of impacts on Nairobi: a major road Mai Mahiu-Narok Road damaged.
				R	A	Onyancha, C.R. (2012) Geological and geotechnical conditions of Nairobi subsurface. Thesis (PhD). University of Nairobi.	http://erepository.uonbi.ac.ke/handle/11295/6945	• Note description on **liquefaction**: "Nairobi City Centre is unlikely to experience liquefaction. However, fault zones nearer to the epicenters can be affected thus experience defects in structures. The most susceptible areas are Ongata Rongai, Nkoroi and Mbagathi where faulting and cross-faulting is intense (Saggerson, 1991)." • I've included this as these areas are all part of Nairobi metropolitan area
				R	M	Campos Garcia, A., and Newman, P. (2018) Tackling the drivers of East Africa's surprising earthquake risk [Online] Available at: https://blogs.worldbank.org/nasikiliza/tackling-the-drivers-of-east-africas-surprising-earthquake-risk [Accessed on 9 March 2021]	https://blogs.worldbank.org/nasikiliza/tackling-the-drivers-of-east-africas-surprising-earthquake-risk	• Discussed earthquake hazard across the long Rift Valley System • **Potential for impact**: medidum magnitude earthquake between 5.0 and 6.0 could cause devastating losses • Places attention to **physical vulnerability** (e.g., informal housing and non-engineered buildings) and **future exposure** (e.g., population growth
	A. Earthquake	EQ	Ground Shaking, Ground Rupture, Liquefaction, Co-Seismic Subsidence, Co-Seismic Uplift	R	G	GFDRR (2019) *Disaster Risk Profile: Kenya*. Washington, D.C. USA: World Bank.	https://www.gfdrr.org/en/publication/disaster-risk-profile-kenya-2019	• Kenya has a **moderate seismic hazard**. • **Modeled impact** on population, buildings, education, health, and transport.
						Mulwa, J. K., Kimata, F., Suzuki, [illegible] and Kuria, Z. N. (2014) The	https://www.sciencedirect.com/science	• "Kenya is **seismically active** since the Kenya rift valley traverses through the country from north to south bisecting the country into eastern and western regions.[...]. The Kenya rift valley and the Kavirondo (Nyanza) rift are the most seismically active where earthquakes of local magnitude (Ml) in the order of ~3.0–5.0 occur. Furthermore, historical records show that earthquakes of

Hazard group | **Hazard** | **Code** | **Component hazards** | **Case study/ Review** | **Type of evidence** | **Source** | **Link** | **Description of themes covered**

1 Single Hazards (The Database)

EGU22-10366 (Malamud *et al.*, Dynamic risk scenarios for single and multi-hazards in the Global South: Nairobi, Istanbul & Kathmandu)

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D Hazard Interrelationships & Anthropogenic Influences

E Video Evidence

F Source Reflections

4. Hazard interrelationships and anthropogenic influences		5. Video evidence	6. Source reflections	
4.1 Interrelationships with other hazards mentioned in the source (with addition of bolding in the quotes)	4.2 Anthropogenic processes and influences mentioned in the source	5.1. Illustrative YouTube video of case study or type of hazard discussed [Multi-YouTube videos can also be used on separate sources]	6.1. Any other comments on the source	6.2 How much is the hazard evidenced by different types of sources (e.g., Earthquakes impacting Nairobi primarily mentioned in peer-
• "So, **what happened to make the crack appear** all of a sudd[en] the answer is simple: **rain**." • "Over the last month, Kenya has experienced **heavy rainfall**, which has resulted in **extensive flooding** across much of East Africa. While flooding alone would not do this, much of the soil has volcanic ash from nearby Mt Longonot (see below). **Volcanic ash can be easily washed away**, meaning when heavy rain came, the water followed the path of least resistance, revealing this crevice." • Note that these statements **need confirming** with **local geologis**[ts] and/or **peer-review paper** or **government report**s.		https://www.youtube.com/watch?v=RG-wx-KYnTk&feature=youtu.b[e]&ab_channel=CBSNews		• Primarily mentioned in the academic

Interrelationship with other hazard mentioned in the source

Anthropogenic processes and influences mentioned in the source

Illustrative YouTube video of case study or type of hazard discussed

Any other comments on the source

How much is the hazard evidenced by different types of sources

1 Single Hazards (The Database)

EGU22-10366 (Malamud *et al.*, Dynamic risk scenarios for single and multi-hazards in the Global South: Nairobi, Istanbul & Kathmandu)

G Hazard Frequency -Magnitude

H Other Reflections

7. Hazard frequency-magnitude reflection	8. Any other reflection on a single hazard
7.1. Reflection on how frequent a hazard of a given size occurs (e.g.earthquakes of a magnitude X or larger occur about every Y years) (Text in blue letters is input from the Kenya Red Cross)	**8.1. Additional reflection by local stakeholders** (Text in blue letters is input from the Kenya Red Cross)
• Nairobi has **a rare occurence of earthquakes/tremors**. Those that are felt in Nairobi caused rattling of houses and mostly have their epicenters towards the South ; near the Kenya /Tanzania border and in Tanzania • Global Risk Data Platform (UNEP/UNISDR, 2013) registers **Peak Ground Acceleration in Nairobi** for 97, 1500, and 2475 years (cm/seg2), and **Spectral Acceleration** for 0.2, 0.5, and 1 sec for 250, 475, 975, 1500, and 2475 years. • "A variety of estimates of seismic hazard exist for the South East African region, where estimates of **peak ground acceleration (PGA) range 0.4 – 1.8 m s-2 with a 10% exceedance probability within a 50-year period for the Nairobi county region** (Midzi et al., 1999; Hayes et al., 2014) based on historical earthquakes." (Taylor et al., 2019)	• "**Kenya faces a relatively low earthquake hazard** in comparison to neighbouring countries. There have been tremors in the past, but no significant damage or loss of life despite public alarm. [...]. **Nairobi faces a low degree of hazard** and Mombasa very low." (Riao, 2013)

Reflection on how frequent a hazard of a given size occurs

Additional reflection by local stakeholder

Eight broad classes:

A. Hazard type
B. Source information and link
C. Source content
D. Hazard interrelationships and anthropogenic influences
E. Video evidence
F. Source reflection
G. Hazard frequency-magnitude reflection
H. Any other reflection

1 Single Hazards (Results)

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EGU22-10366 (Malamud *et al.*, Dynamic risk scenarios for single and multi-hazards in the Global South: Nairobi, Istanbul & Kathmandu)

Y = Potential for hazard to impact given urban area (Istanbul, Nairobi, or Kathmandu)

N = No case studies or clear theoretical possibility of impacting the given urban area (Istanbul, Nairobi, or Kathmandu)

Istanbul: **23** natural hazards
(52 sources of evidence)

Nairobi: **18** natural hazards
(69 sources of evidence)

Kathmandu: **21** natural hazards
(58 sources of evidence)

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

2 Hazard Interrelationships

EGU22-10366 (Malamud *et al.*, Dynamic risk scenarios for single and multi-hazards in the Global South: Nairobi, Istanbul & Kathmandu)

- We then systematically noted **potential multi-(natural) hazard interrelationships** that might impact Istanbul, Nairobi & Kathmandhu
  - **Triggering relationships**
  - **Increased (or decreased) probability relationships [such as amplification]**
  - **Compound Hazards**

Example:

8 July 2018 Landslide

Storm (heavy rainfall)

Triggers

Landslide

Figure and information from Reuters / Ezgi Erkoyun

"Twenty-four people killed in northwest Turkey when a train headed for Istanbul derailed following heavy rain and a Landslide". Reuters (2018)

2 Hazard Interrelationships

EGU22-10366 (Malamud *et al.*, Dynamic risk scenarios for single and multi-hazards in the Global South: Nairobi, Istanbul & Kathmandu)

- For Nairobi, Istanbul & Kathmandu, we
  - **Examined each pair of hazards from the single hazard databases for potential interrelationships** (again using blended evidence)**.**
  - **Put systematically into a detailed database.**
  - **Created matrix visualization (next slide)**

	Istanbul	Nairobi	Kathmandu
# of potential natural hazard interrelationships identified* that theoretically might influence the urban/peri-urban area	**111**	**114**	**81**
Of the potential hazard interrelationships, how many have direct evidence for having occurring in the urban area?	**25**	**21**	**12**

***Note that hazard interrelationships identified, include both low-probability and high-probability potential interrelationships.**

2 Hazard Interrelationships

EGU22-10366 (Malamud *et al.*, Dynamic risk scenarios for single and multi-hazards in the Global South: Nairobi, Istanbul & Kathmandu)

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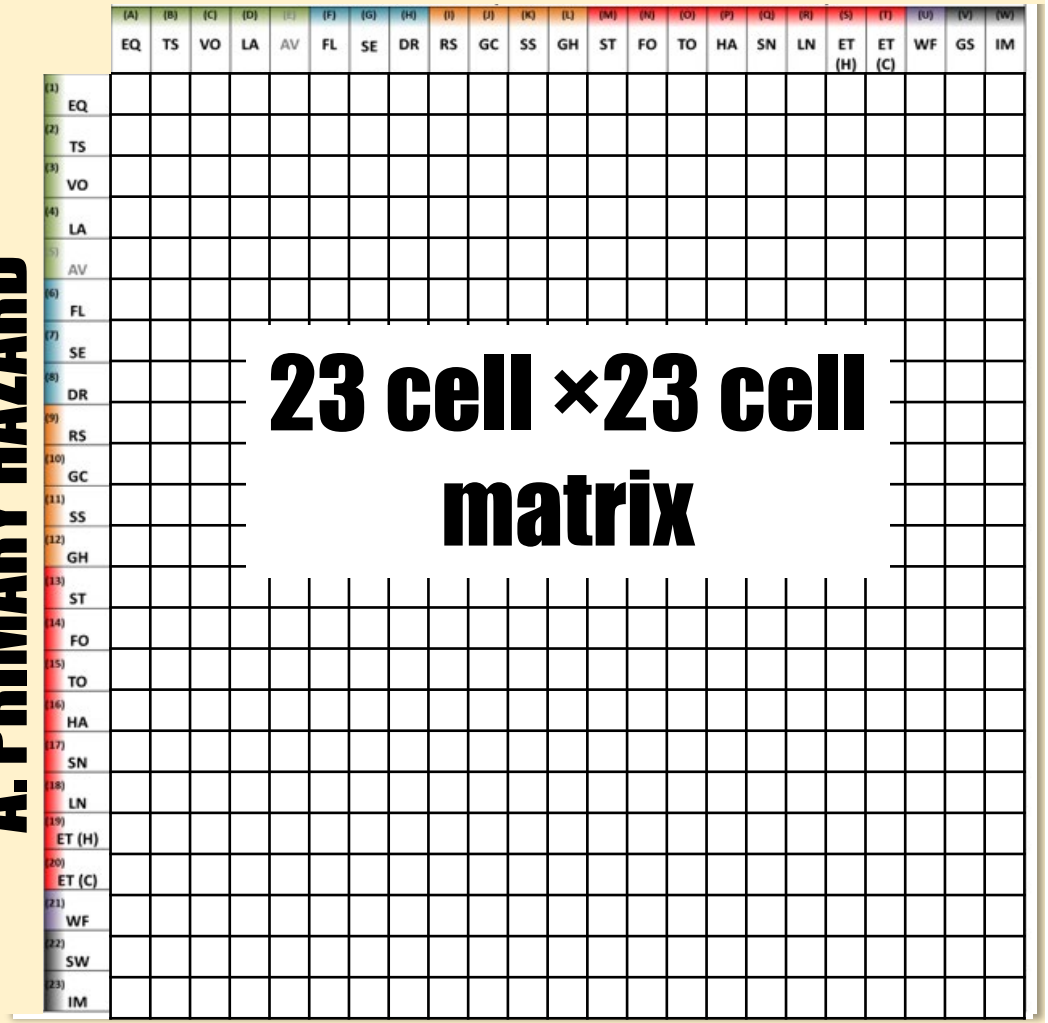
B. SECONDARY HAZARD
(Triggered or Increased Probability)

A. PRIMARY HAZARD



KEY		
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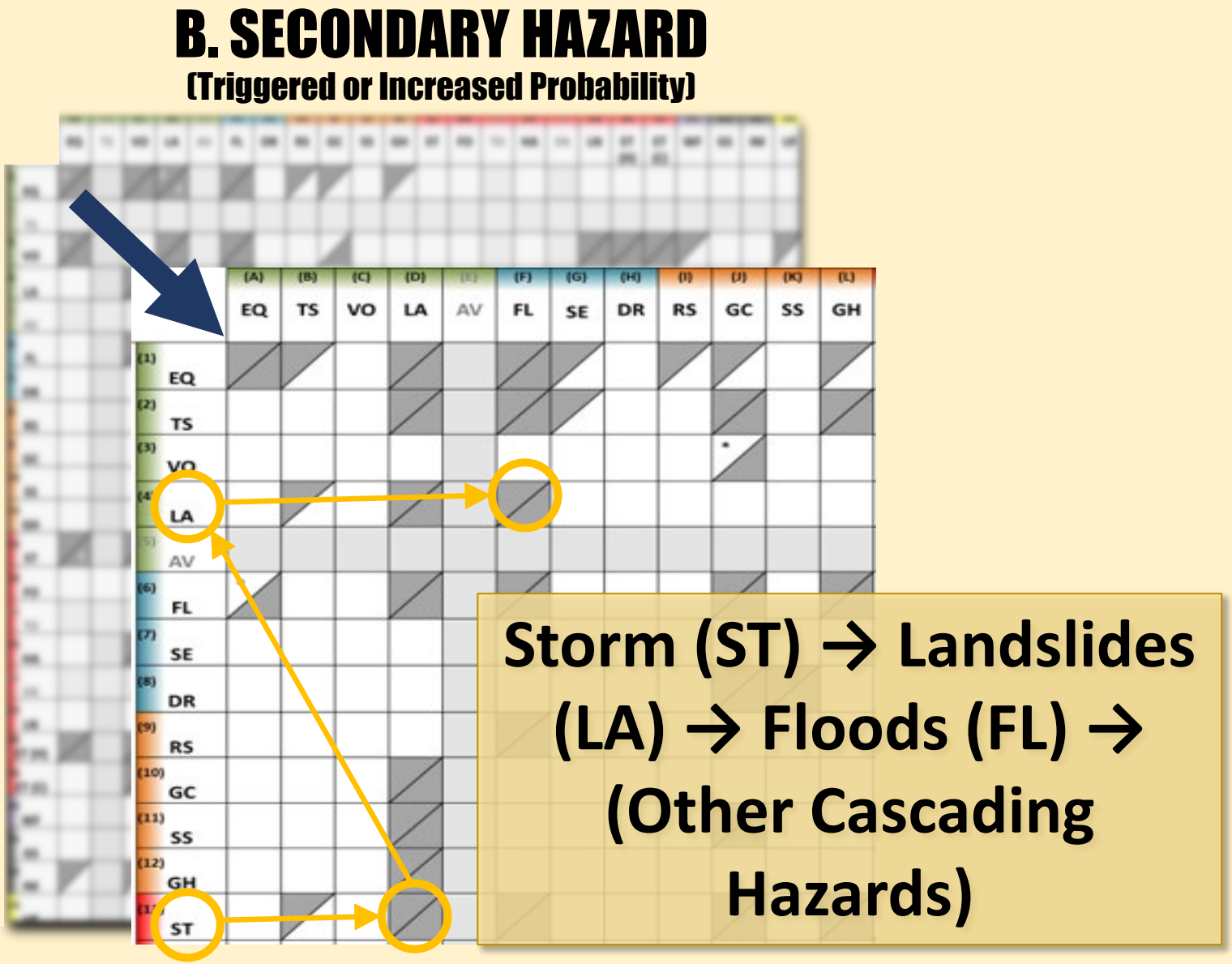
	Extreme Temperature (Hot)	ET (H)
	Extreme Temperature (Cold)	ET (C)
BIOPHYSICAL	Wildfire	WF
SPACE	Space Weather	SW
	Impact Event	IM

SYMBOL	EXPLANATION
	Hazard Triggers Secondary Hazard
	Hazard Changes the Probability of Secondary Hazard occurrence
	Hazard Both Triggers and Changes the Probability of Secondary Hazard occurrence
	No evidence of hazard occurrence in Istanbul

2 Hazard Interrelationships

EGU22-10366 (Malamud *et al.*, Dynamic risk scenarios for single and multi-hazards in the Global South: Nairobi, Istanbul & Kathmandu)



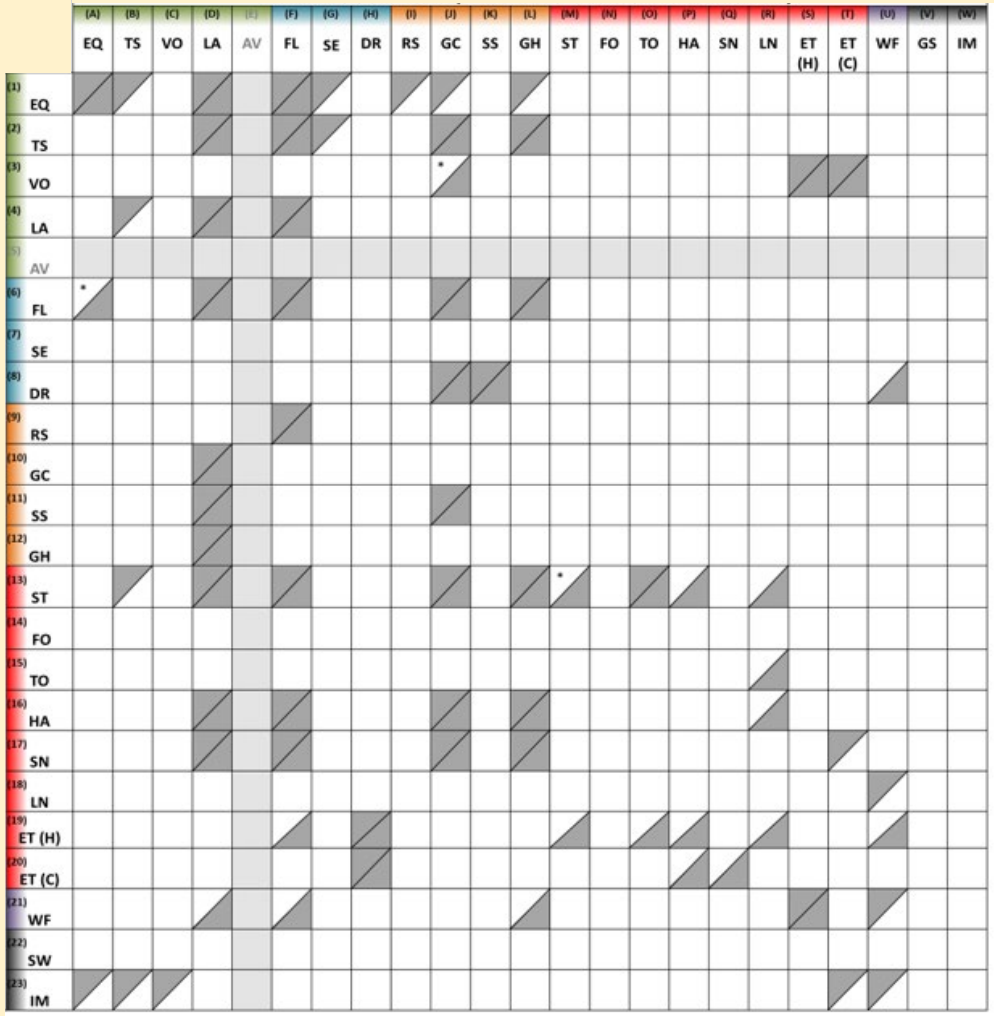
Example of triggered or increased probability relationships visualized on matrix (will later use these to build dynamic risk scenarios).

2 Hazard Interrelationships

EGU22-10366 (Malamud *et al.*, Dynamic risk scenarios for single and multi-hazards in the Global South: Nairobi, Istanbul & Kathmandu)

B. SECONDARY HAZARD
(Triggered or Increased Probability)

A. PRIMARY HAZARD



KEY		
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BIOPHYSICAL	Wildfire	WF
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SYMBOL	EXPLANATION
	Hazard Triggers Secondary Hazard
	Hazard Changes the Probability of Secondary Hazard occurrence
	Hazard Both Triggers and Changes the Probability of Secondary Hazard occurrence
	No evidence of hazard occurrence in Istanbul

Example from Instanbul on left

- 111 potential hazard interrelationships.
- 25 of these in Istanbul related literature.

2 Hazard Interrelationships

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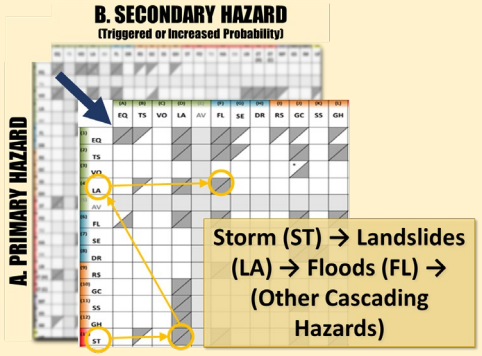
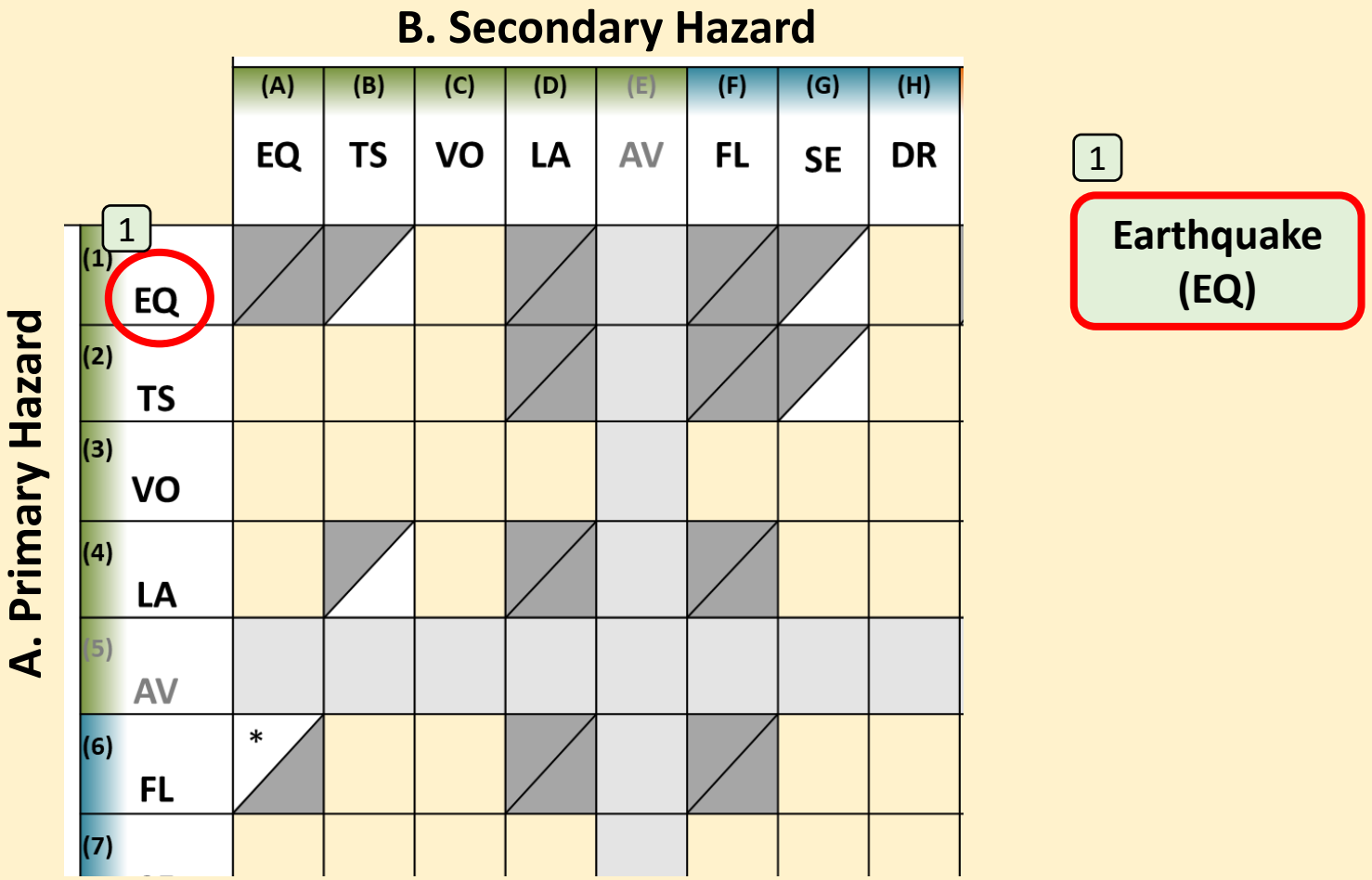


Can extend hazard interrelationships to **dynamic risk scenarios** that include **anthropogenic processes** and consider how **urban areas might change in the future**.

3 Building Dynamic Risk Scenarios

EGU22-10366 (Malamud *et al.*, Dynamic risk scenarios for single and multi-hazards in the Global South: Nairobi, Istanbul & Kathmandu)



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Earthquake (EQ)

3 Building Dynamic Risk Scenarios

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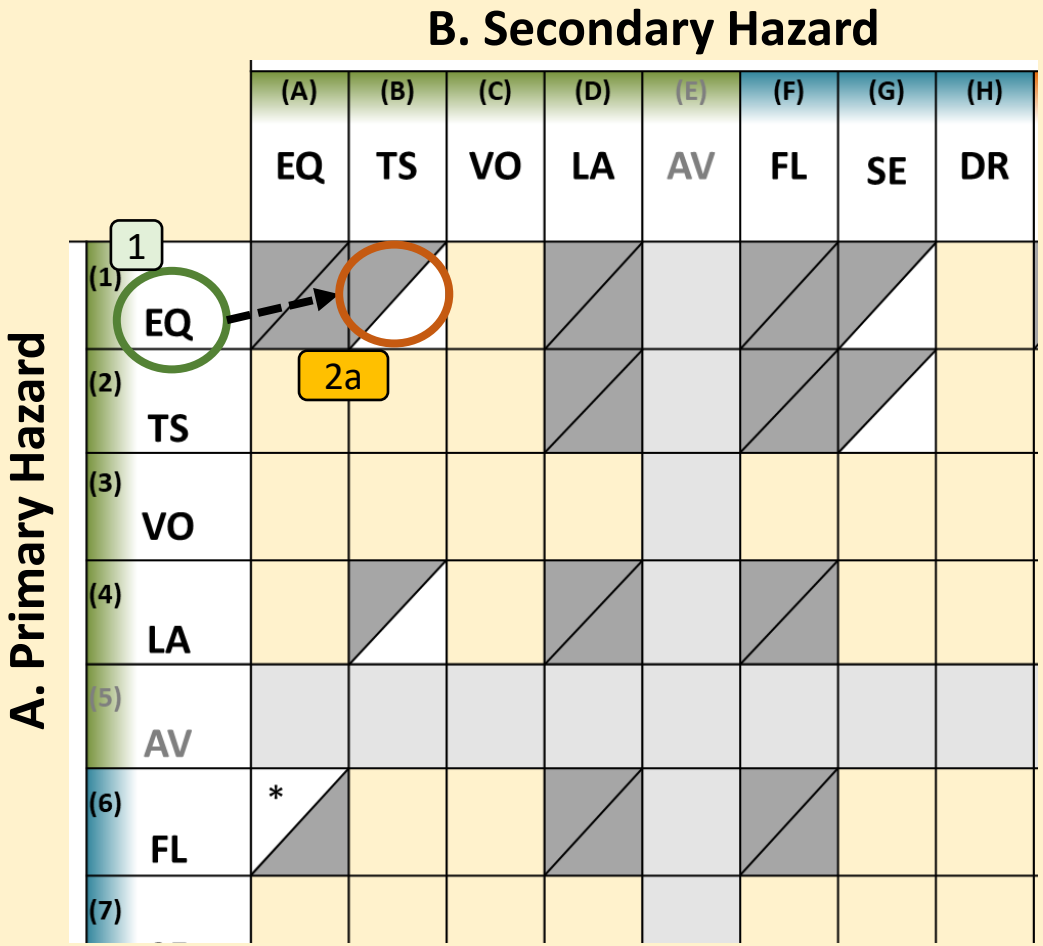

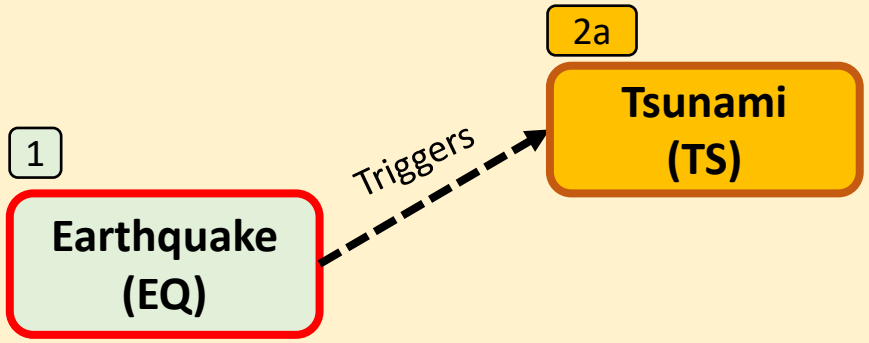

3 Building Dynamic Risk Scenarios

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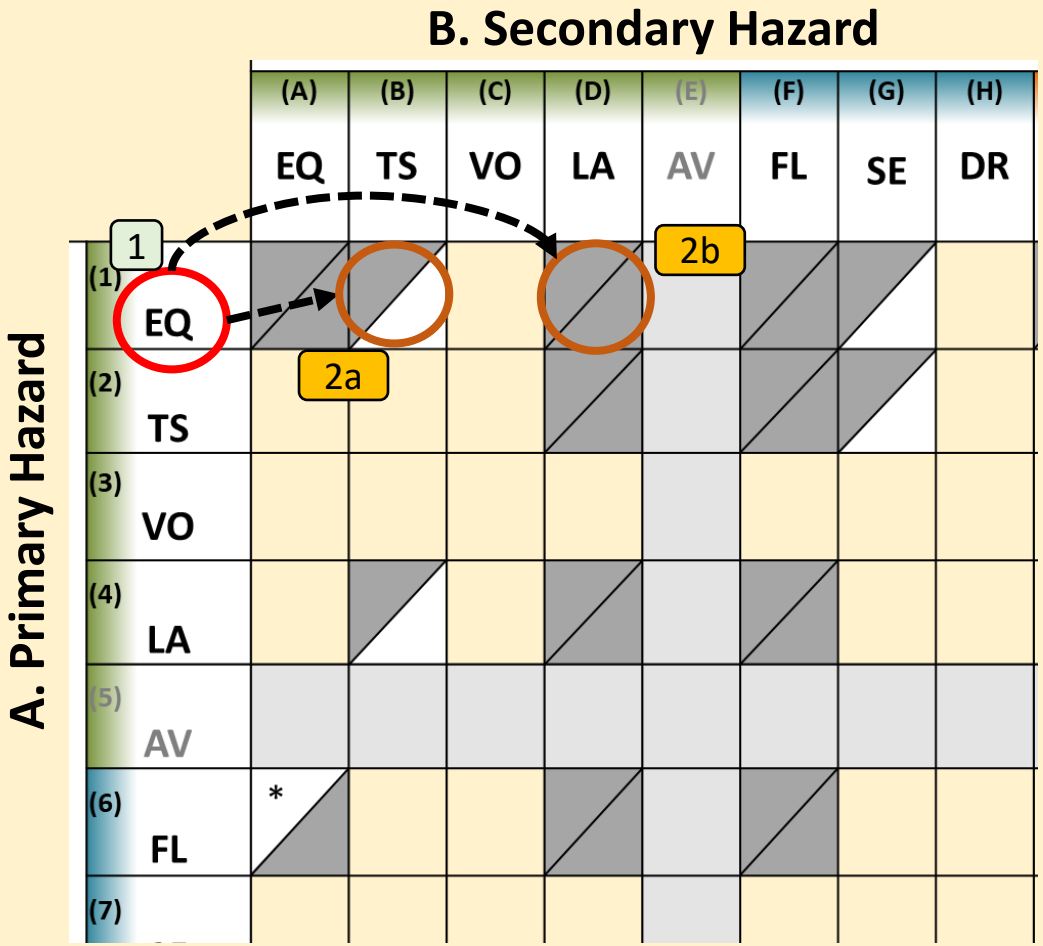

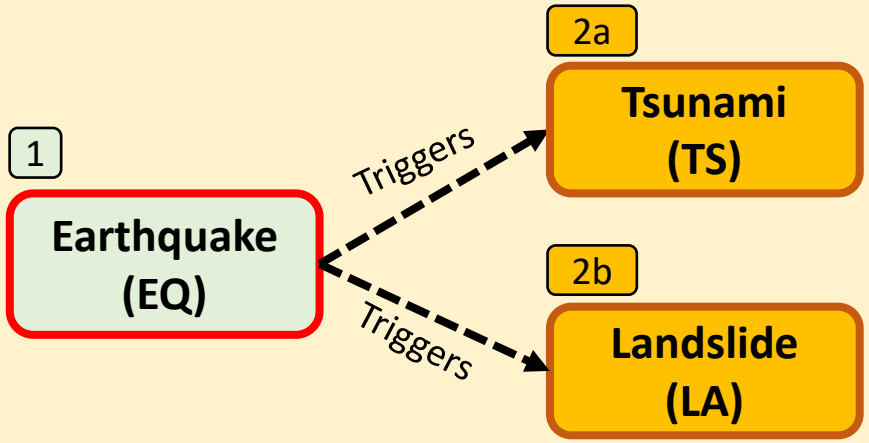

3 Building Dynamic Risk Scenarios

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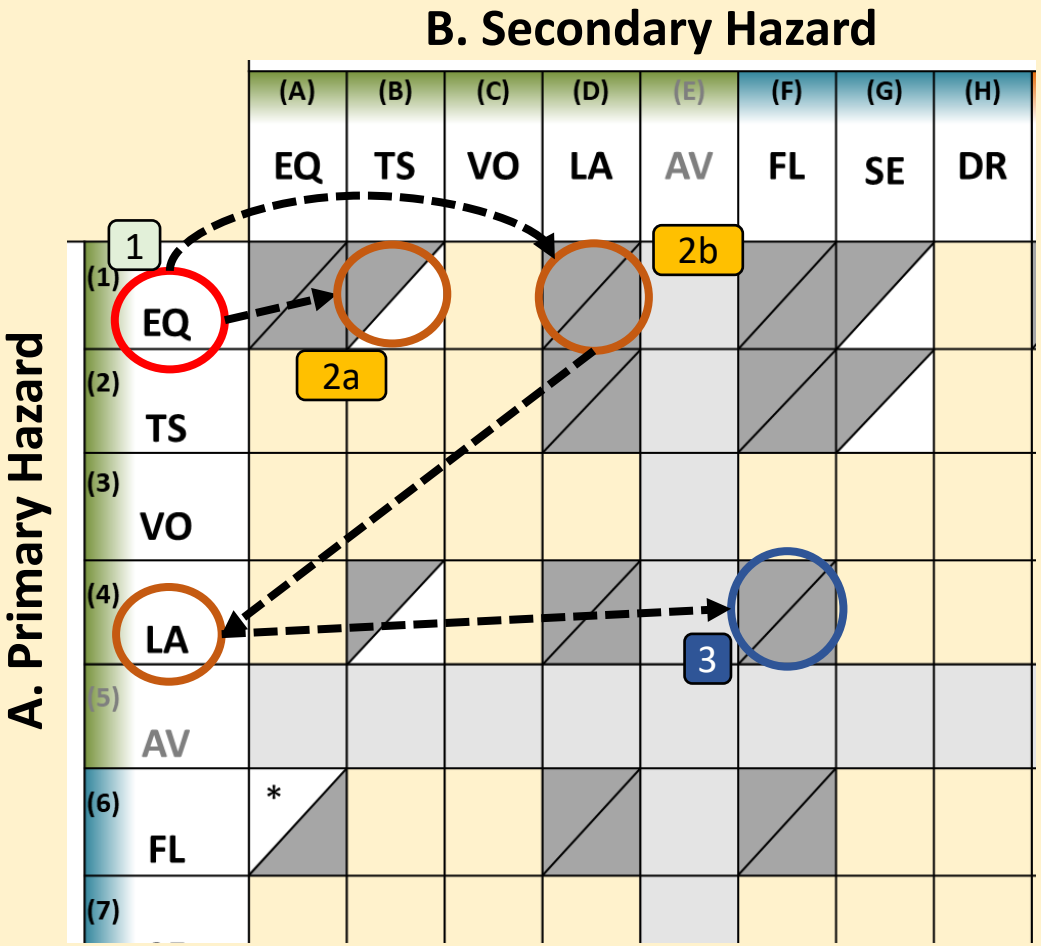

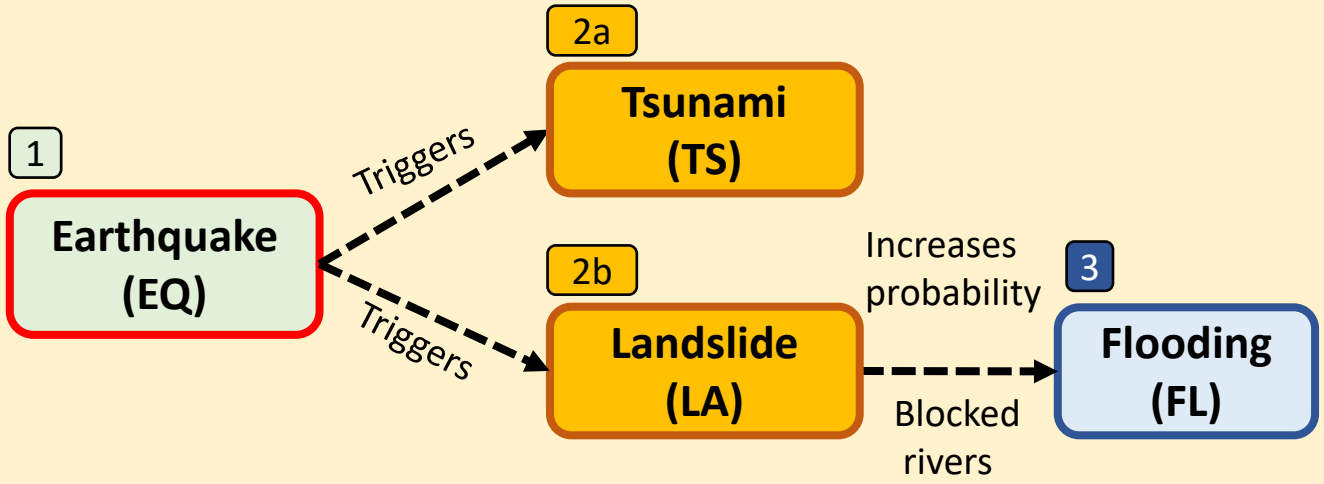

3 Building Dynamic Risk Scenarios

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

1

Heatwave (ET (H))

3 Building Dynamic Risk Scenarios

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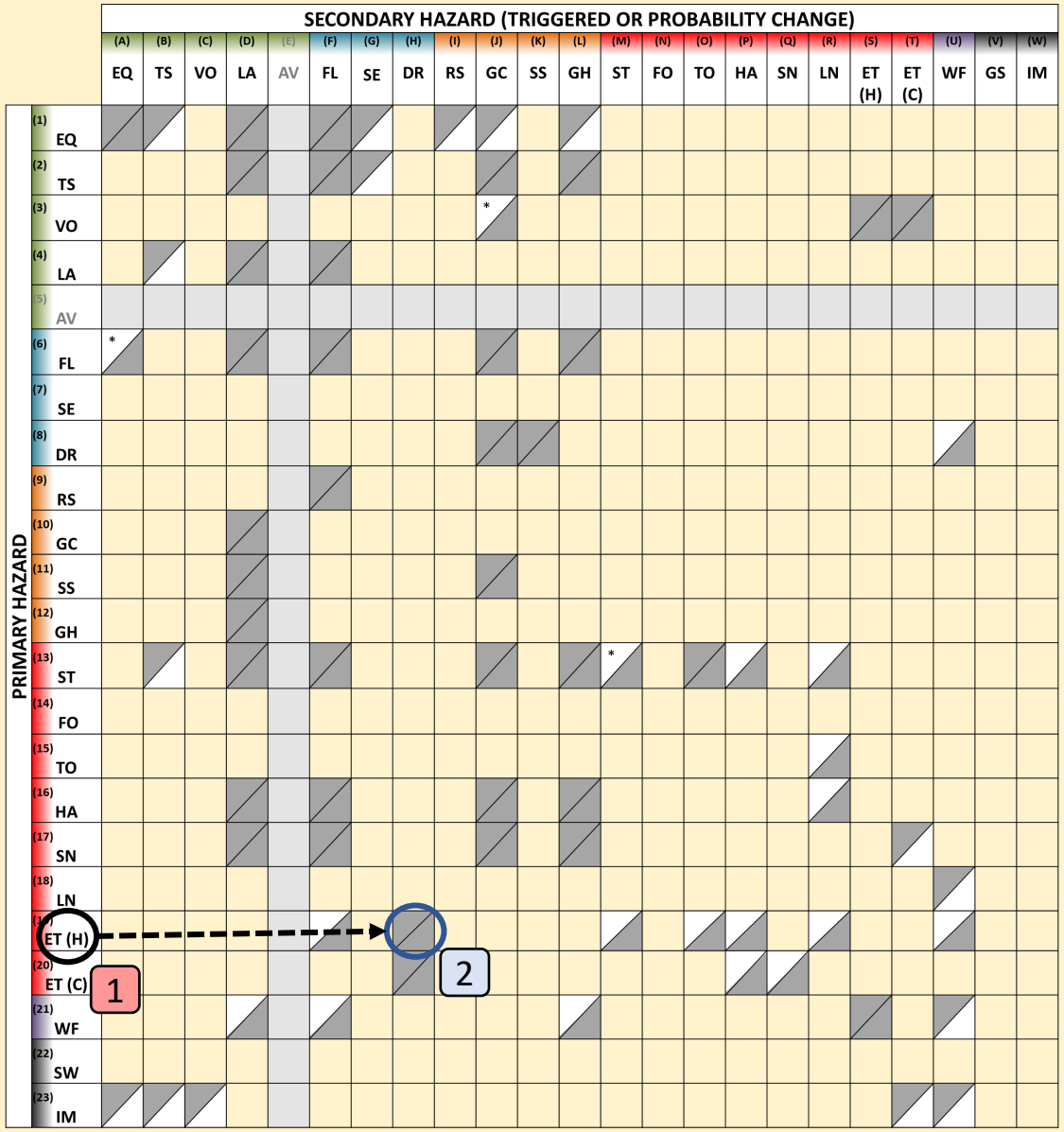

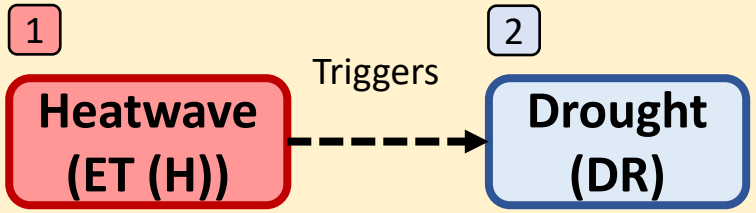

3 Building Dynamic Risk Scenarios

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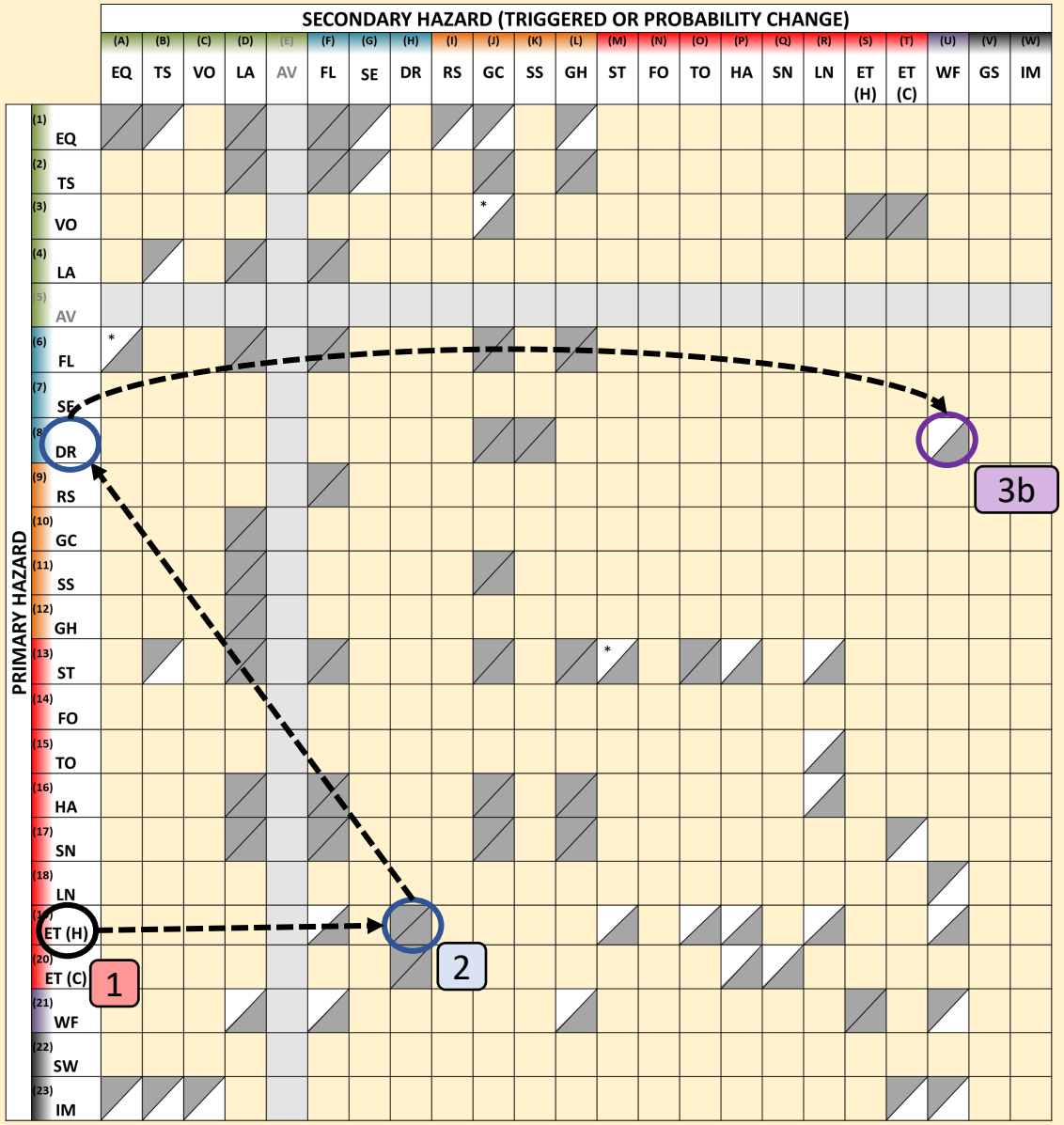
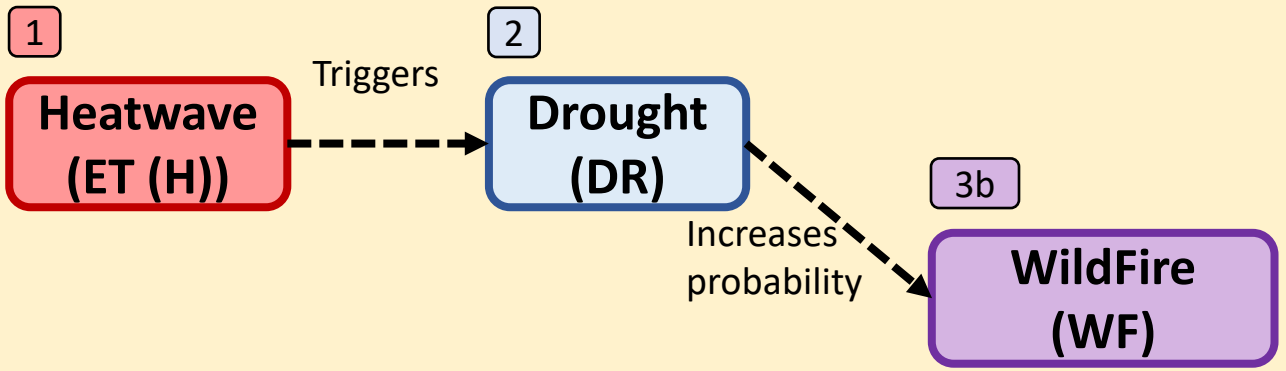
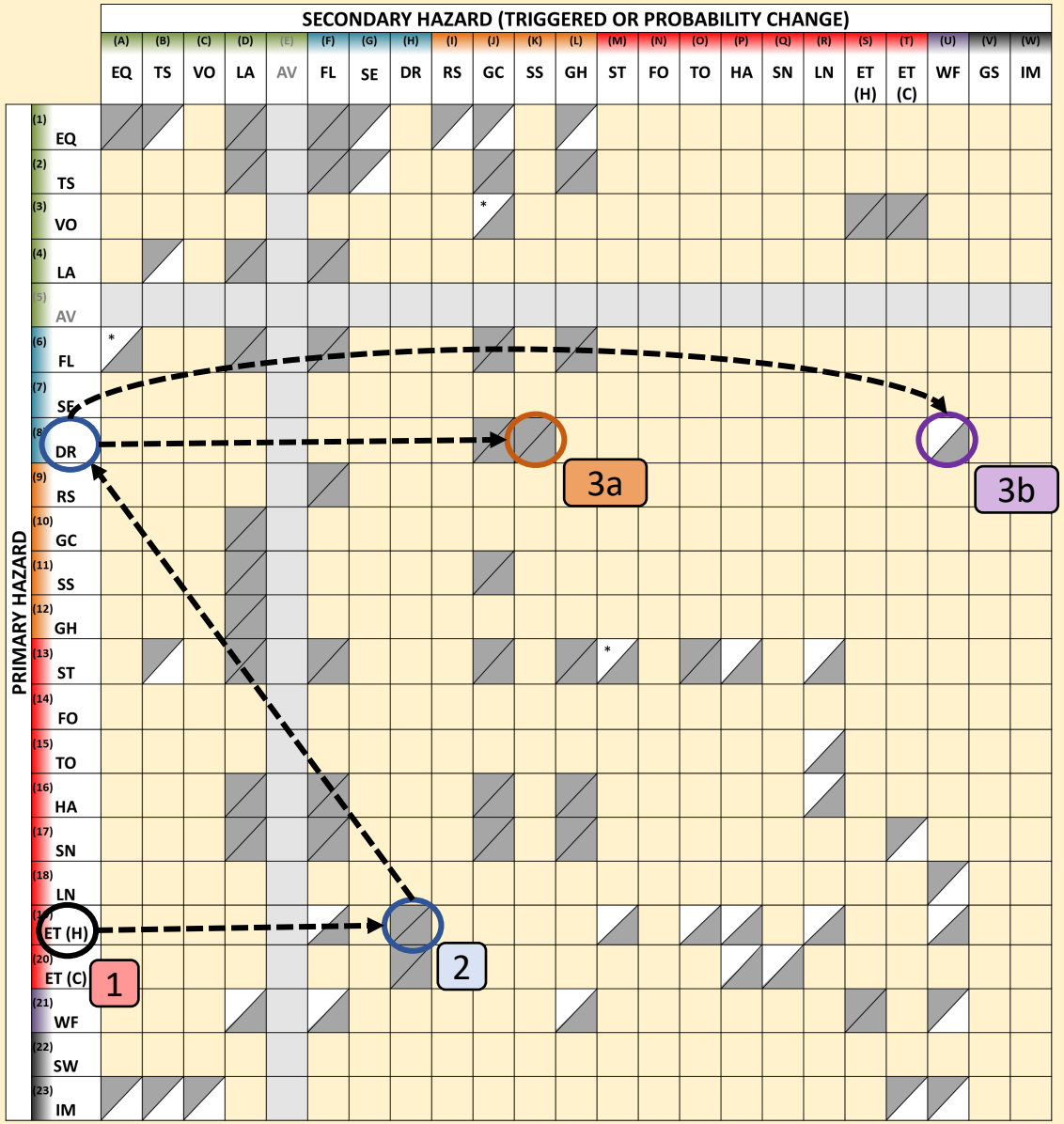
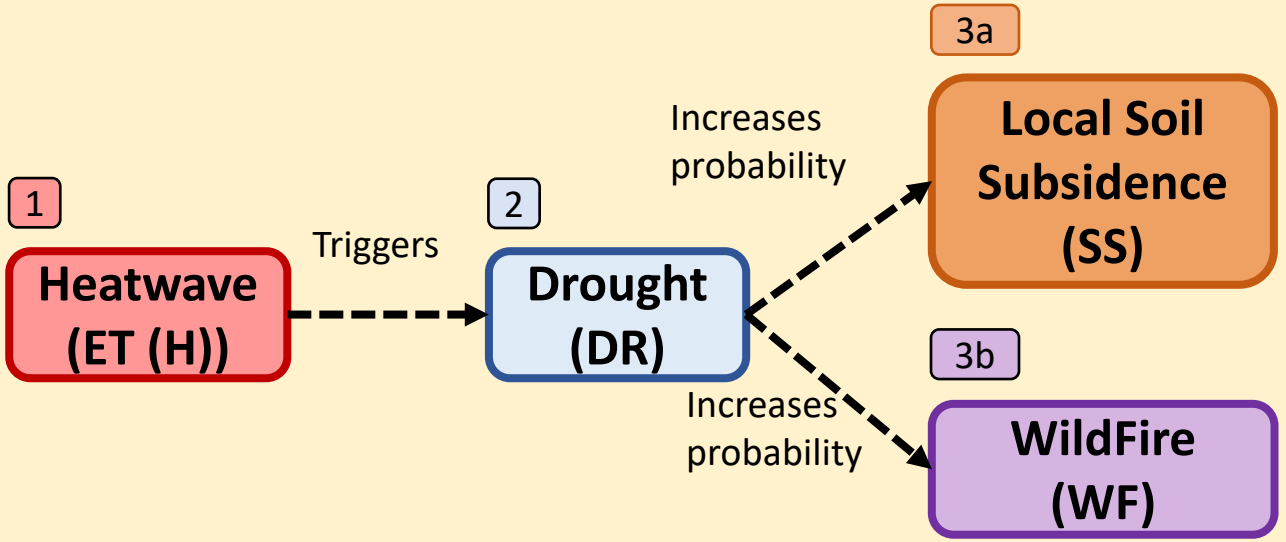




3 Building Dynamic Risk Scenarios

EGU22-10366 (Malamud *et al.*, Dynamic risk scenarios for single and multi-hazards in the Global South: Nairobi, Istanbul & Kathmandu)





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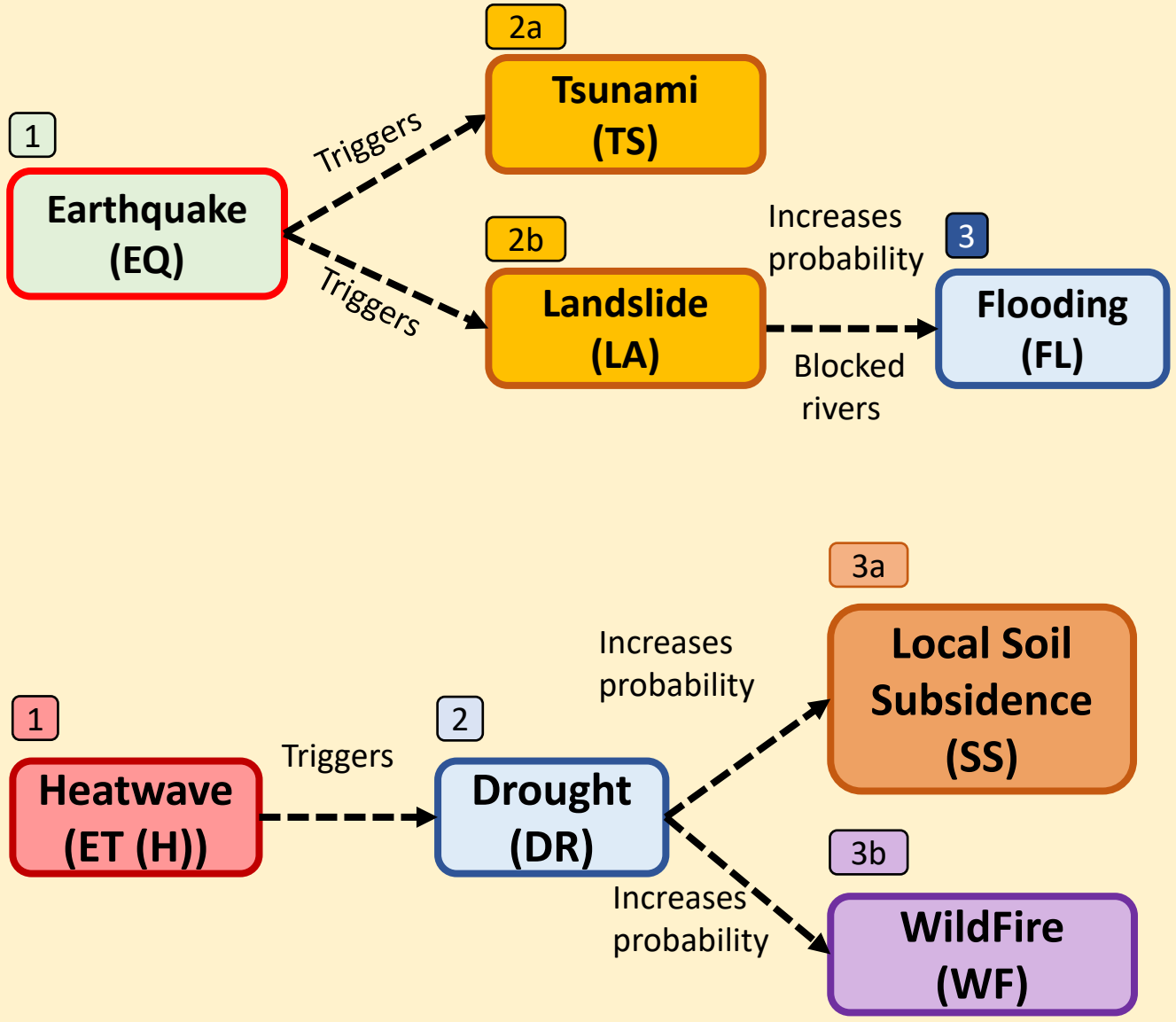

3 Building Dynamic Risk Scenarios

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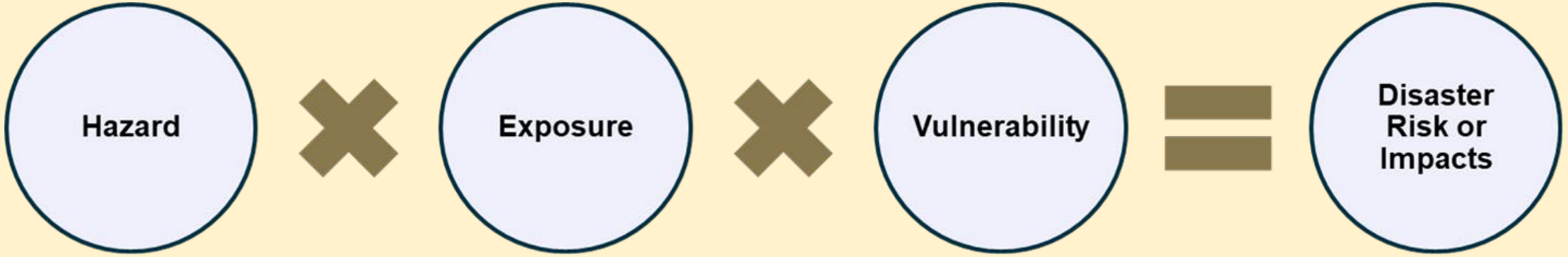
Common Representation of Risk



"A **process, phenomenon or human activity that may cause** loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation." *UNDRR Terminology*

"The **situation of people, infrastructure, housing, production capacities and other tangible human assets located** in hazard-prone areas." *UNDRR Terminology*

"The **conditions determined by physical, social, economic and environmental factors or processes** which increase susceptibility of an individual, a community, assets or systems to the impacts of hazards." *UNDRR Terminology*

3 Building Dynamic Risk Scenarios

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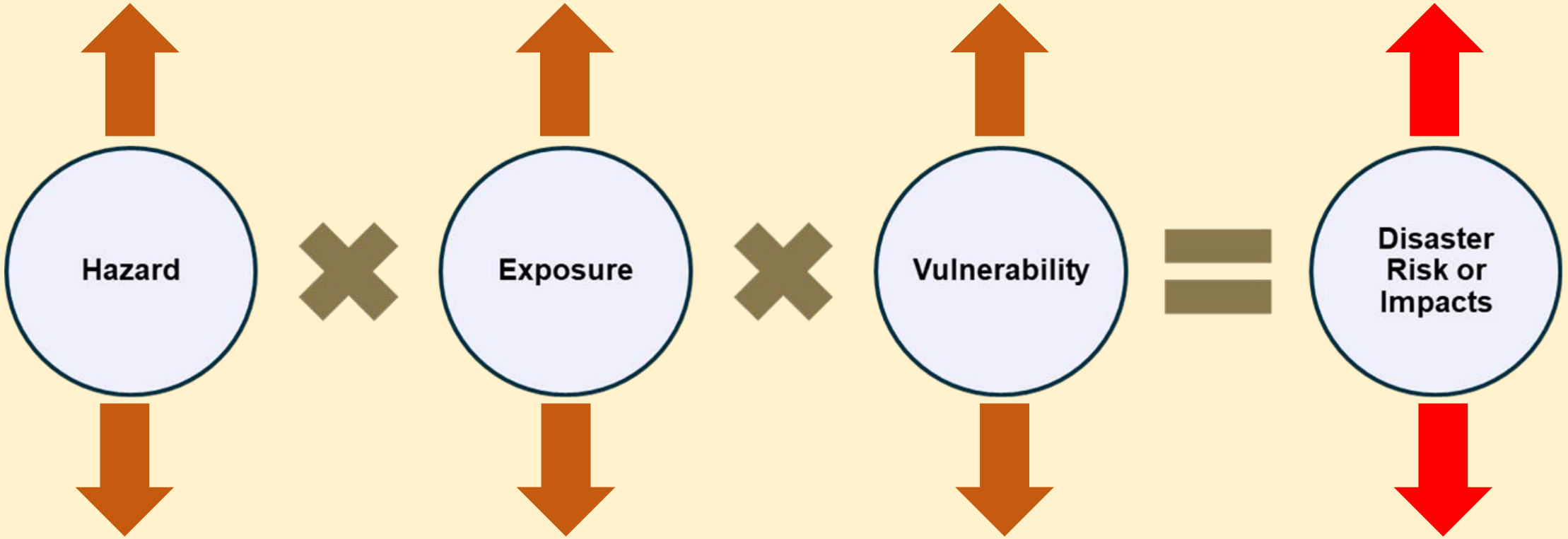

Hazard, Exposure, Vulnerability are dynamic
(increase or decrease over time)

Risk can be dynamic
(increase or decrease over time)

3 Building Dynamic Risk Scenarios

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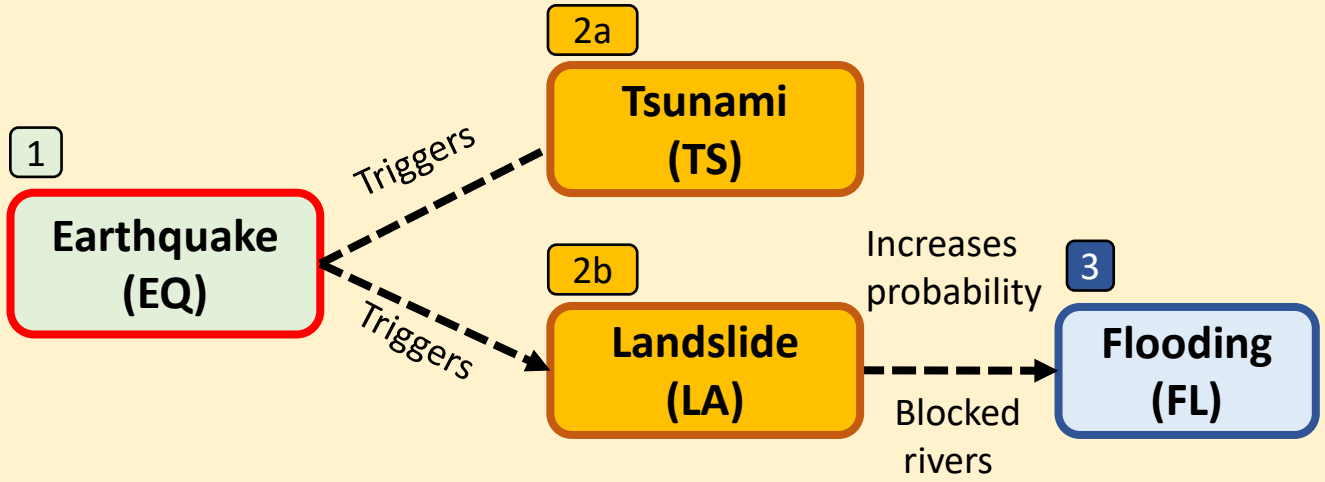

- **Dynamic Risk:**
  - **Exposure** in Earthquake region **DIFFERENT before** and **after** Earthquake (**infrastructure damage, people moved**).
  - Hazard managers need to consider change in exposure for both **where people are** (has changed) and **layout of infrastructure (e.g., blocked roads).**

3 Building Dynamic Risk Scenarios

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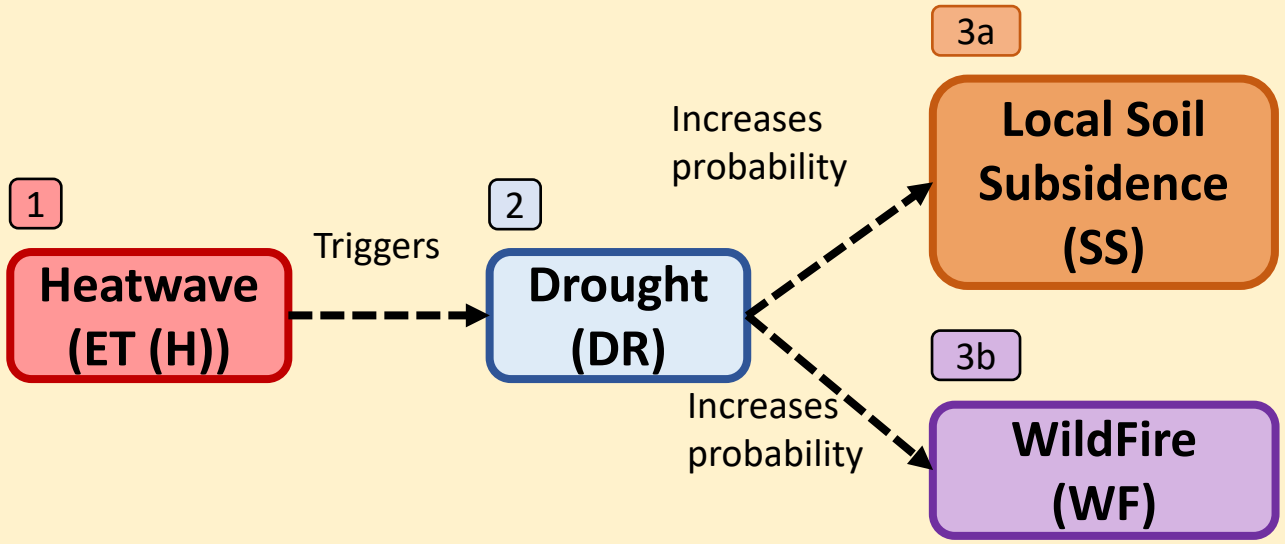

- **Anthropogenic Processes:**
  - **Humans** can influence the magnitude of these hazards through **anthropogenic processes.**
  - Medium time scales: For example, **vegetation removal** can increase the severity of the drought.
  - Longer time scales: **Climate change** can influence the magnitude and severity of the heatwaves.

4 Co-development of dynamic Risk Scenarios (for Istanbul, Nairobi)

Sharing is encouraged

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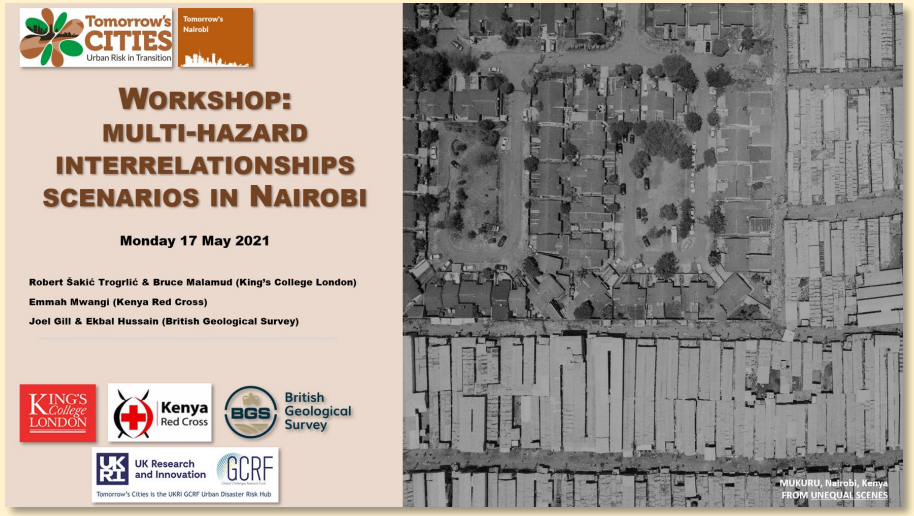
- We further **co-developed the dynamic risk scenarios** with natural **hazard stakeholders**:
  - **Istanbul**: Two (repeated) **workshops** of 2.5 hours (total 50 participants, 15 institutions) + 3 **expert interviews** (1 hr each).
  - **Nairobi**: Two (repeated) **workshops** of 2 hours (total 21 participants, 5 institutions) + 6 **expert interviews** (45-60 minutes each).



4 Co-development of dynamic Risk Scenarios (for Istanbul, Nairobi)

EGU22-10366 (Malamud *et al.*, Dynamic risk scenarios for single and multi-hazards in the Global South: Nairobi, Istanbul & Kathmandu)

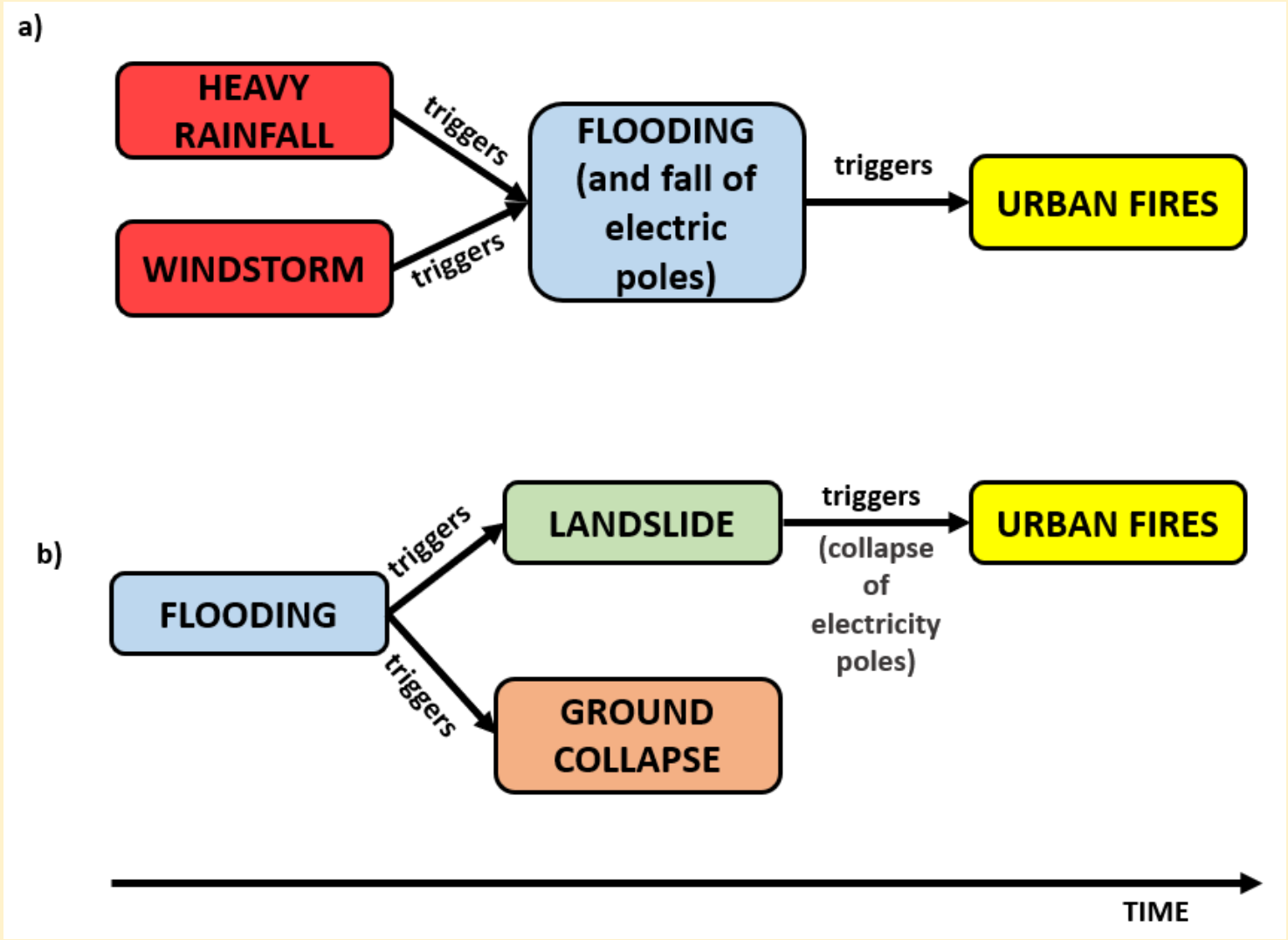
	Example scenarios identified by Nairobi participants
WORKSHOPS	Scenario 1: **Storm** -> **Lightning** -> **Urban Fire** Scenario 2: **Earthquake** -> **Urban Fire** Scenario 3: Heavy Rain (**Storm**) -> **Flooding** -> **Landslides** Scenario 4: Heavy Rain (**Storm**) -> Flash Floods (**Flooding**) due 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**

4 Co-development of dynamic Risk Scenarios (for Istanbul, Nairobi)

EGU22-10366 (Malamud *et al.*, Dynamic risk scenarios for single and multi-hazards in the Global South: Nairobi, Istanbul & Kathmandu)

Two multi-hazard dynamic risk scenarios created by Nairobi research participants that involve a hazard of urban fire.



5 Challenges & Opportunities Identified by Stakeholders in Incorporating Dynamic Risk Scenarios into Planning

Sharing is encouraged

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Challenges

- **Siloed approaches to hazards** (often single-hazard focused).
- **Lack of enforcement of regulations.**
- **Translation of planning to implementation.**
- **Centralised policy-making.**
- **Needs beyond electoral cycles.**
- Lack of **financial and human resources**.
- **Disconnect** between **scientific** and **policy-making communities**.
- **Lack of existing data & research** in their region on multi-hazard interrelationships, anthropogenic processes, and components that make up dynamic risk scenarios.

Opportunities:

- **Increased awareness** of the **factors** that might **influence risk dynamically** in their **urban region**.
- **Integration of these factors** into **existing urban regeneration project planning**.
- These scenarios have **a vast array of potential benefits for disaster risk management** in their cities, especially in terms of **enhanced preparedness and risk-informed planning**.

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Tomorrow's CITIES Urban Risk in Transition

www.tomorrowscities.org

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Thank you!

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