

Multiple-Hazards and Their Interactions in Urban Low-to-Middle Income Countries: a Case Study from Nairobi

Robert Šakić Trogrlić¹, Bruce D. Malamud¹, Emmah Mwangi², Joel Gill³, Ekbal Hussain³, Faith Taylor¹

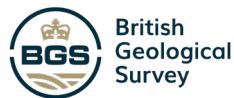
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Tomorrow's Nairobi

Population 5 million, 50% of which live in congested informal settlements. Population growth 4-5% per year. Key hazards: flooding, building collapse, fire, earthquakes.



Tomorrow's Cities is the UKRI GCRF Urban Disaster Risk Hub



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Objectives

Multi-hazards

Approach

Single hazards

Interrelationships

Scenarios

Summary

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Overview

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B. Multi-hazards background

C. Approach

D. Overview of single hazards in Nairobi

E. Multi-hazard interrelationships in Nairobi

F. Towards multi-hazard scenarios in Nairobi

G. Summary

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A. Objectives [1/1]

- **Objective A.** To provide a **coarse overview** of **single natural hazards** occurring and having a potential impact on Nairobi.
- **Objective B.** To map theoretical and evidenced **hazards interrelationships** in Nairobi.
- **Objective C.** To create an exemplar of **multi-hazard interrelationships scenarios** in Nairobi and explore **dynamic risk** (i.e., dynamic exposure and vulnerability).

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B. Multi-hazards background [1/2]

What is a multi-hazard?

UNDRR Terminology

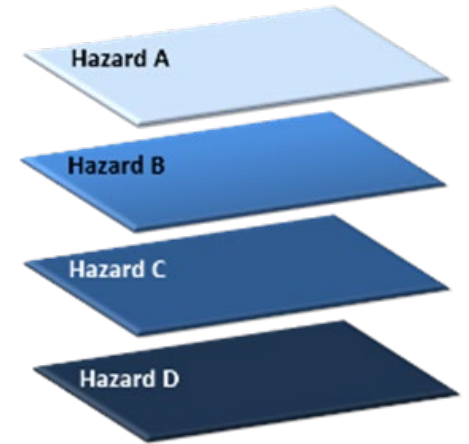
“Multi-hazard means:

- (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**.”

UNDRR = United Nations Office for Disaster Risk Reduction

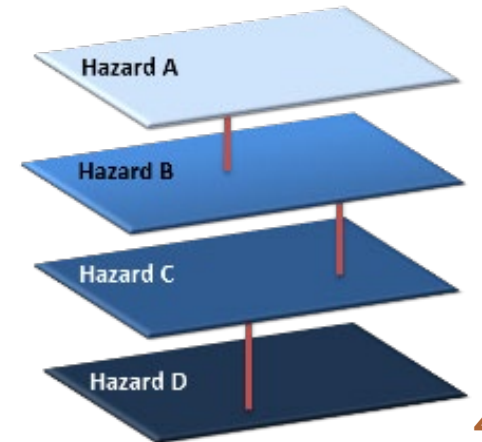
More-than-one-hazards-in-a-place (**multi-layer single hazard**)

- Discrete
- Independent



Holistic approach (**multi hazard**)

- Interconnected
- Interacting
- Interrelationships



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B. Multi-hazards background [2/2]

What are multi-hazard interrelationships?

Many types of interrelationships.

One categorization:

- **Triggering relationships:** one hazard causes another hazard to occur.
- **Increased (or decreased) probability relationships:** one hazard can change the likelihood and/or magnitude of additional hazards in the future.
- **Compound Hazards:** two or more hazards impacting same region/time period with impact different (greater, lesser) than their sum.

For further examples and explanations, see Gill and Malamud (2014) [\(LINK\)](#) and Tilloy *et al.* (2019) [\(LINK\)](#)

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C. Approach [1/1]

Coarse overview of single hazards and their interrelationships

- Peer-reviewed literature
- Grey literature (e.g., government and (I)NGO report, academic theses)
- Social media (e.g., YouTube, Twitter) and online newspapers
- Validation and input by local experts
- Methodology based on Gill and Malamud, 2014 ([LINK](#))

Exemplar multi-hazard scenarios and dynamic risk

- Workshop with stakeholders across the Tomorrow's Cities Hub ([LINK](#)) in August 2020
- Workshop report can be accessed here ([LINK](#))
- Planned engagement with stakeholders in Nairobi for May and June 2021

D. Overview of single hazards in Nairobi [1/3]

Hazard Group	Hazard	Nairobi
1. Geophysical hazards	1A. Earthquake	Y
	1B. Tsunami	N
	1C. Volcanic eruption	Y
	1D. Landslide	Y
	1E. Snow avalanche	N
2. Hydrological hazards	2A. Flood	Y
	2B. Drought	Y
3. Shallow Earth processes	3A. Regional subsidence	Y
	3B. Ground collapse	Y
	3C. Soil subsidence	Y
	3D. Ground heave	Y

Hazard Group	Hazard	Nairobi
4. Atmospheric hazards	4A. Storm	Y
	4B. Fog	Y
	4C. Tornado	N
	4D. Hailstorm	Y
	4E. Snowstorm	N
	4F. Lightning	Y
	4G. Extreme temperature (Heat)	Y
	4H. Extreme temperature (Cold)	Y
5. Biophysical hazards	5A. Wildfire	Y
6. Space/Celestial hazards	6A. Geomagnetic storm	Y
	6B. Impact event	Y
7. Anthropogenic hazards	7A. Urban fire	Y

Classification of 23 hazards in Nairobi, based on Gill and Malamud (2014) ([LINK](#))

Y = Potential for hazard to occur in Nairobi; N = No case studies or clear theoretical possibility of occurring in Nairobi

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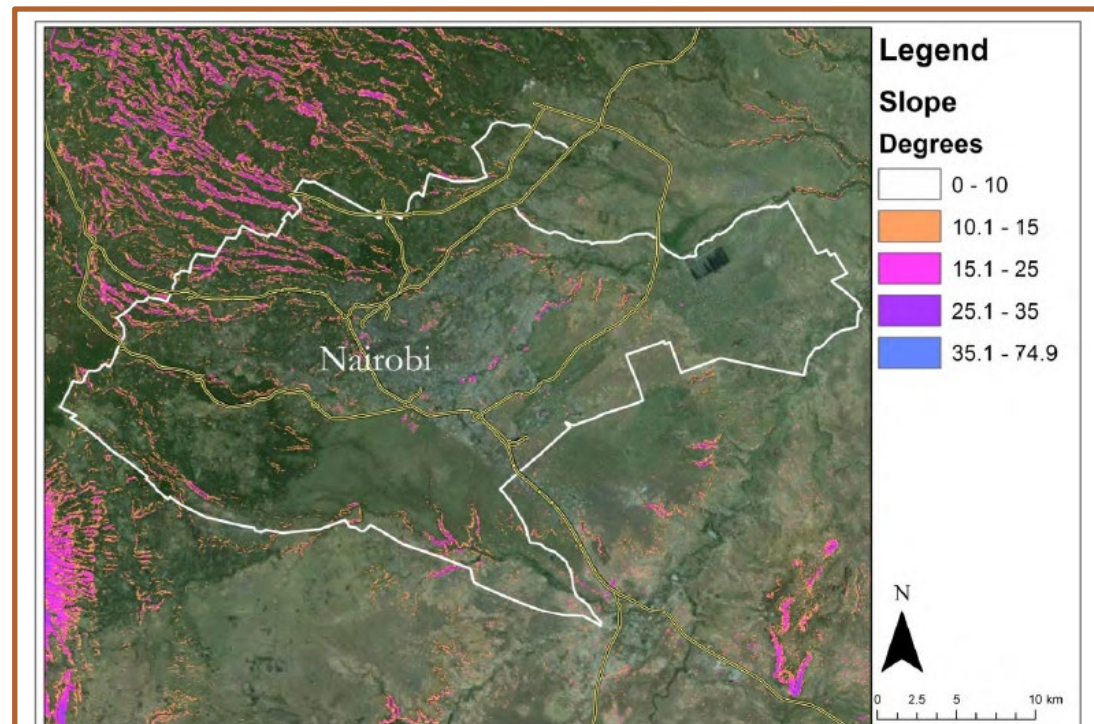
D. Overview of single hazards in Nairobi [2/3] *Example of landslides*

Several killed in landslide at Nairobi slum

At least six dead and many trapped after massive boulders crashed onto houses in Kenyan capital following heavy rain.



2012 Landslide Event in Mathare, Nairobi (Al Jazzera, 2012) [\(LINK\)](#)



Slope map for the Nairobi region (Taylor *et al.* 2018)

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D. Overview of single hazards in Nairobi [2/3] *Example of floods*

Nairobi floods: Capital city choking under water

By [Duncan Mutwiri](#) For Citizen Digital
Published on: December 4, 2019 12:41 (EAT)



Flood event in 2019 in Nairobi (Mutwiri, 2019) ([LINK](#))

Click on the video to play



NTV Kenya reporting of a flood event in Nairobi in 2019 ([LINK](#))

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D. Overview of single hazards in Nairobi [3/3] *Example of urban fires*

Community fire response in Nairobi's informal settlements

PETER M NGAU AND SHARON J BOIT

ABSTRACT While the risk of fires in informal settlements has received attention in the literature, as has the longer-term community response to the resulting destruction, there is limited knowledge of how communities in informal settlements respond *during* fire disasters. This paper examines the role of community actors in fire response, using a case study of a group of informal settlements collectively called Mukuru Fuata Nyayo in Nairobi, Kenya. In earlier years, residents simply stayed put and watched properties get destroyed, and then waited for landlords to rebuild the houses. There is an emerging change in community fire response in these settlements, from a hands-off to a more hands-on approach in fire response. The paper examines the factors contributing to the change and draws conclusions about the strategies needed to build resilience in community fire response in informal settlements.

KEYWORDS community organizing / disaster response / emergencies / fire response / informal settlements / Nairobi

Ngau and Boit (2020) on fires in Mukuru Fuata Nyayo, published in *Environment and Urbanization* ([LINK](#))

Kenya fire: Several dead in Nairobi market

28 June 2018



Rescue workers and traders assess the damage after the fire at Gikomba market

Fire in June 2018 in Gikomba, Nairobi (BBC, 2018) ([LINK](#))

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E. Multi-hazard interrelationships in Nairobi [1/3]

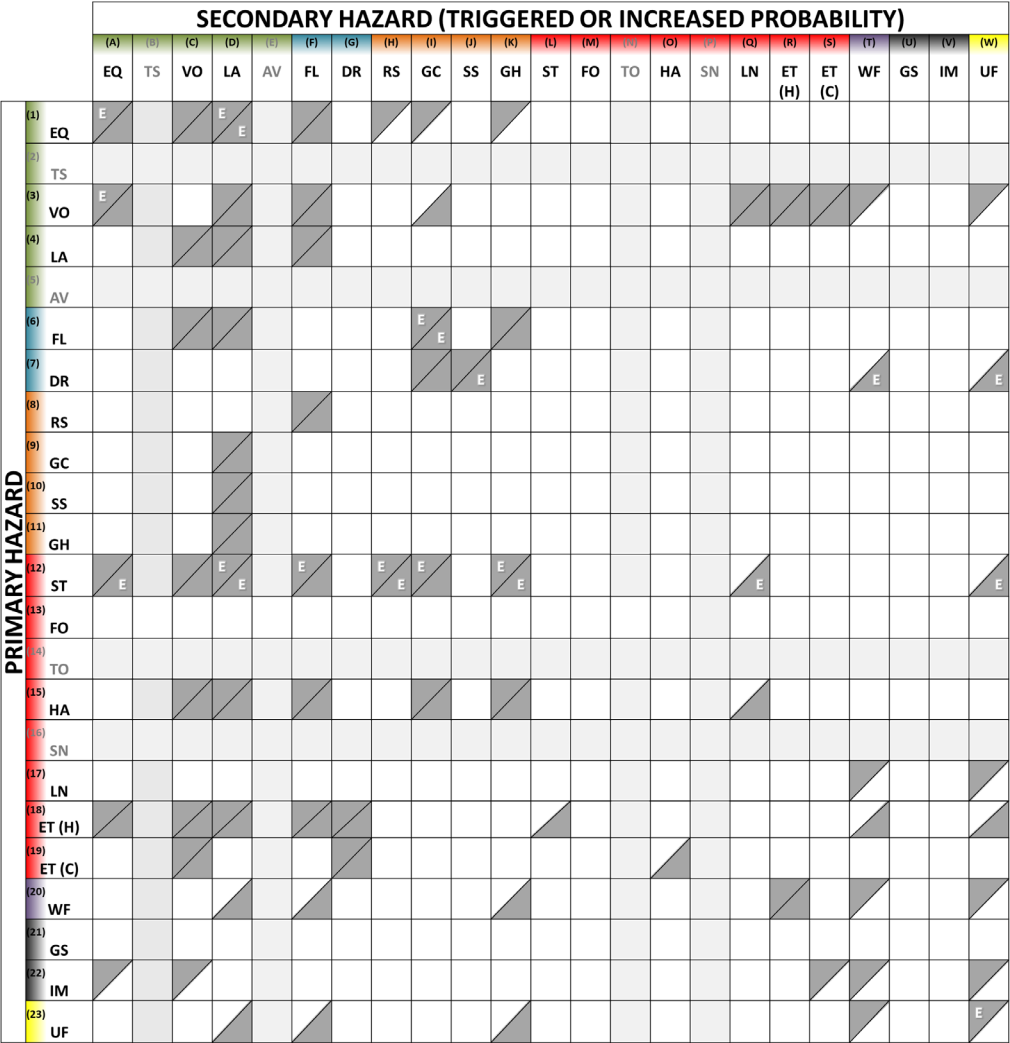
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KEY		
HAZARD GROUP	HAZARD	CODE
GEOPHYSICAL	Earthquake	EQ
	Tsunami	TS
	Volcanic Eruption	VO
	Landslide	LA
	Snow Avalanche	AV
HYDROLOGICAL	Flood	FL
	Drought	DR
SHALLOW EARTH PROCESSES	Regional Subsidence	RS
	Ground Collapse	GC
	Soil (Local) Subsidence	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
SPACE	Geomagnetic Storm	GS
	Impact Event	IM
ANTHROPOGENIC	Urban Fire	UF

SYMBOL	EXPLANATION
	Hazard Triggers Secondary Hazard
	Hazard Increases Probability of Secondary Hazard
	Hazard Both Triggers and Increases the Probability of Secondary Hazard
	Evidence Found in Nairobi

We have identified 114 theoretical interrelationships

Evidence (E) found for 20 interrelationships

Next slide shows example from upper left corner

Hazard interrelationship matrix in Nairobi, after Gill and Malamud (2014) ([LINK](#))

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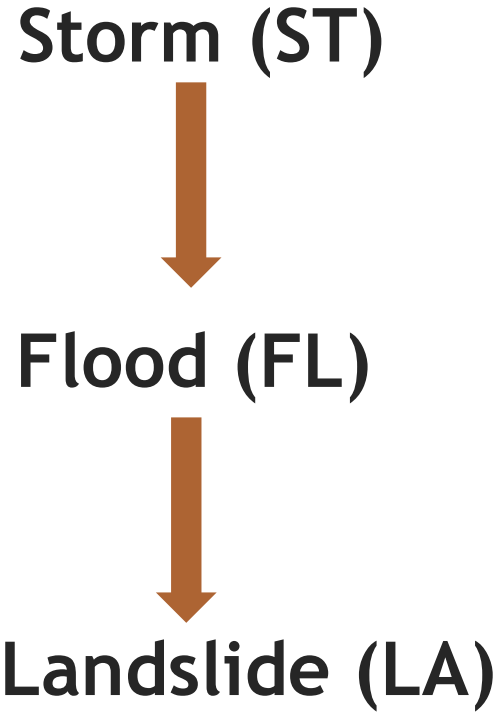
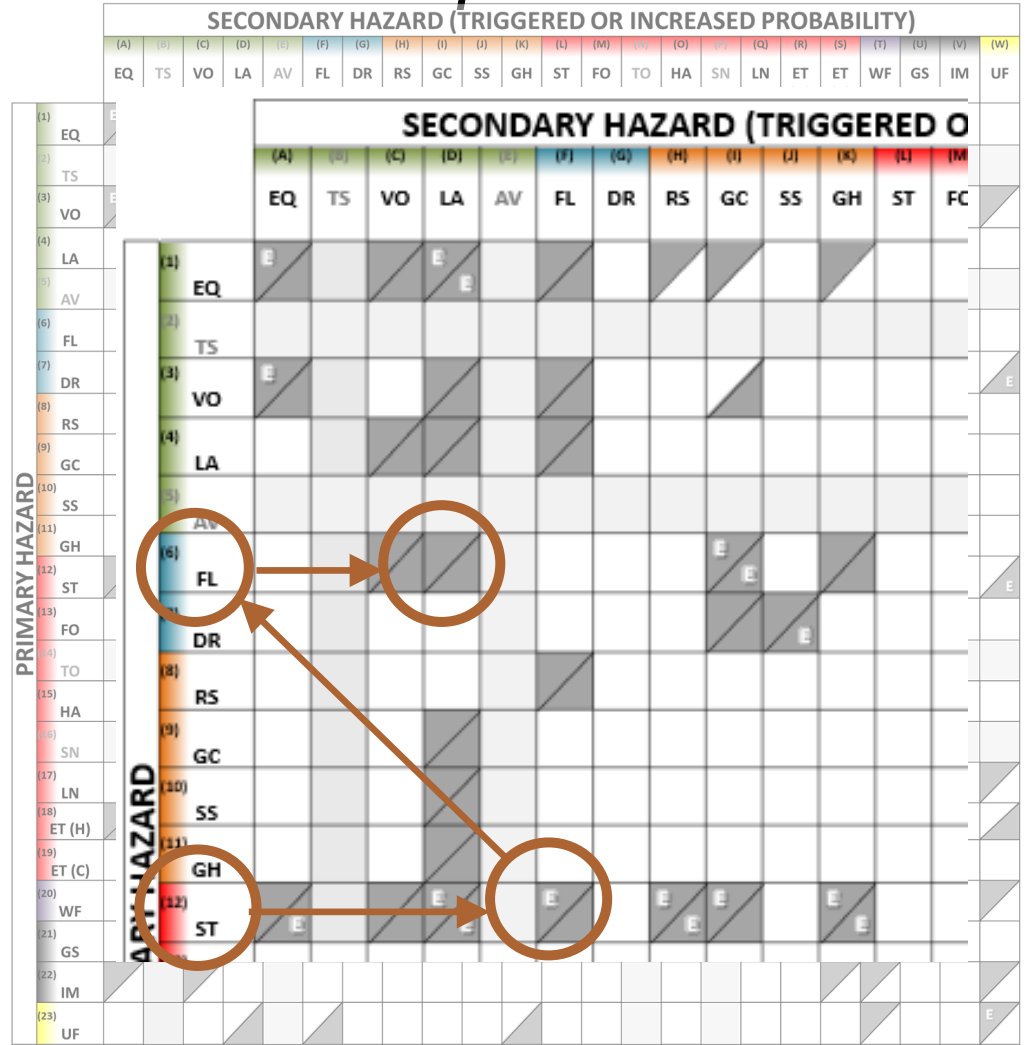
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E. Multi-hazard interrelationships in Nairobi [2/3] - Further example



[Left image shows excerpt of the matrix, clipped for clarity]

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E. Multi-hazard interrelationships in Nairobi [3/3]

Example floods

From our interrelationship matrix, theoretically,

[**Earthquakes, Volcanoes, Landslides, Regional Subsidence, Storms, Hail, Heatwaves, Wildfires, Urban Fires**] can all trigger or increase probability of a **Flood**.

Floods can trigger or increase probability of [**Volcanoes, Landslides, Ground collapse, Ground Heave**].

Example to right:
 Heavy rains triggering floods in Nairobi in 2018 (NTV Kenya, 2018)
 ([LINK](#))



Click on the video to play

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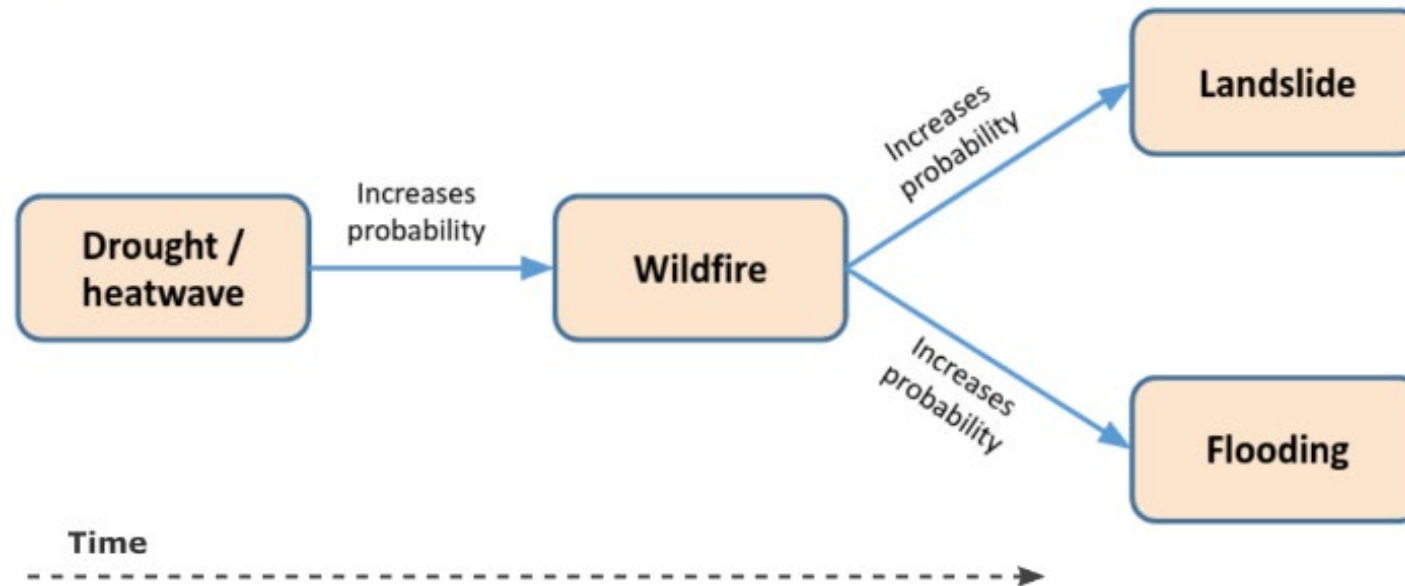
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F. Towards multi-hazard scenarios in Nairobi [1/3]



An exemplar multi-hazard scenario for Nairobi created during a Tomorrow's Cities Workshop in August 2020 (Gill *et al.* 2021) [\(LINK\)](#)

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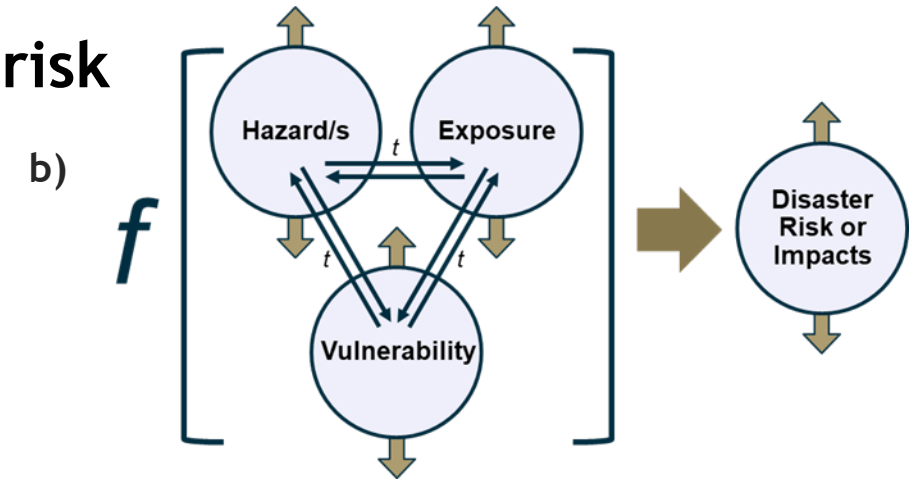
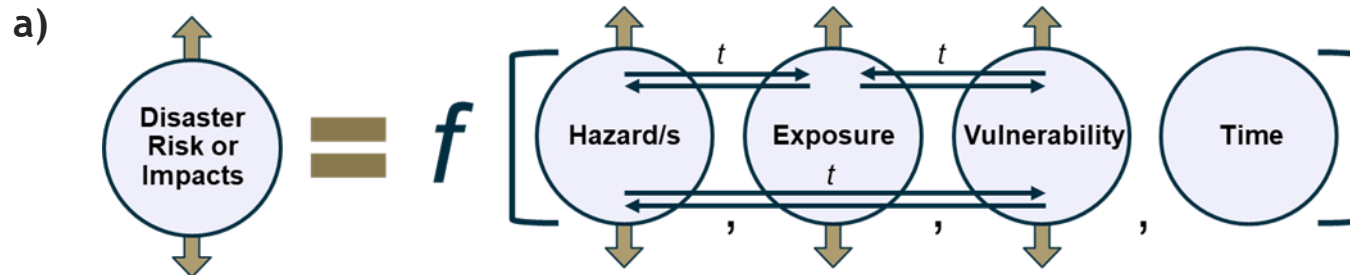
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F. Towards multi-hazard scenarios in Nairobi [2/3]

- Next step is to engage with a notion of **dynamic risk**



Examples of 'Dynamic Risk' Equations. Risk is a function $f [\]$ of **hazard**, **exposure**, **vulnerability**, and **time**, where terms are not simply multiplied and interactions between them are recognised. As each of the three terms and their interactions can change over time (i.e., they are dynamic), this equation also includes a time variable. **From Gill *et al.* (2021) ([LINK](#))**

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F. Towards multi-hazard scenarios in Nairobi [3/3]

- Multi-hazard scenarios can help us to:
 - **Raise awareness** on the importance of interrelationships between natural hazards.
 - Explore components of **dynamic risk**.
 - Explore what can be done to **reduce the impact** of a multi-hazard event across different stages of disaster cycle (i.e. mitigation, preparedness, response, and recovery).

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G. Summary

- Our results indicate a **breadth of natural hazards and their interactions** in Nairobi
 - **19 (evidenced) natural hazards** relevant for Nairobi.
 - **114 theoretical hazard interrelationships**, with **20 evidenced interrelationships**.
- **Blended evidence sources** effective for gathering in-depth insights in a relatively short period of time.
- Exemplars of **multi-hazard scenarios** based on multi-hazard interrelationships can be used as a **starting point** to engage stakeholders in **conversations around dynamic risk** and how they think these could be managed and reduced.
- Importance of including **multi-hazard scenarios** in the context of future urban planning (more on Tomorrow's Cities [LINK](#))