Volcanic risk assessment and risk ranking

State-of-the-art and challenges

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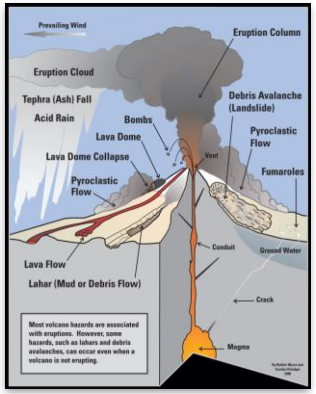
Risk assessment

*"A **qualitative or quantitative approach** to determine the **nature and extent of disaster risk** by **analyzing potential hazards** and evaluating **existing conditions of exposure and vulnerability** that together could **harm people, property**, **services, livelihoods** and the **environment** on which they depend."* UNDRR

Volcanic risk assessment is a systematic approach to bring together **understanding and characterization** of **dynamic** volcanic hazards (and their interrelationships), exposure, vulnerability, **resilience (and capacity)** and **impacts**, to evaluate the potential consequences of volcanic hazards.



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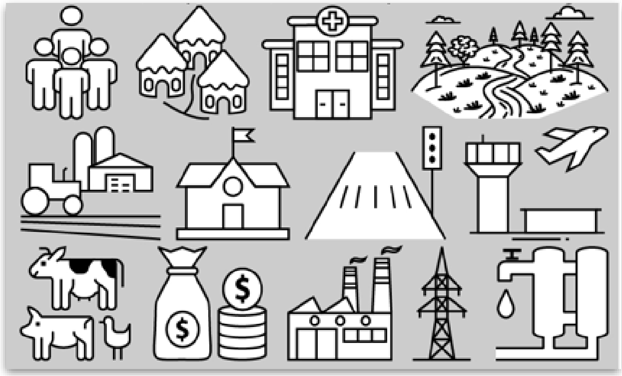

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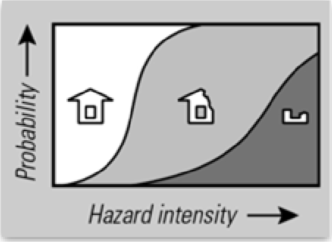

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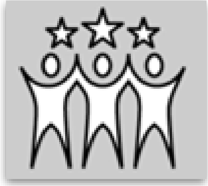

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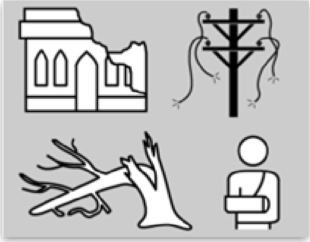

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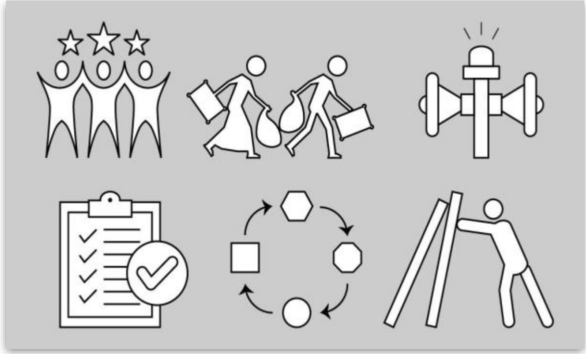
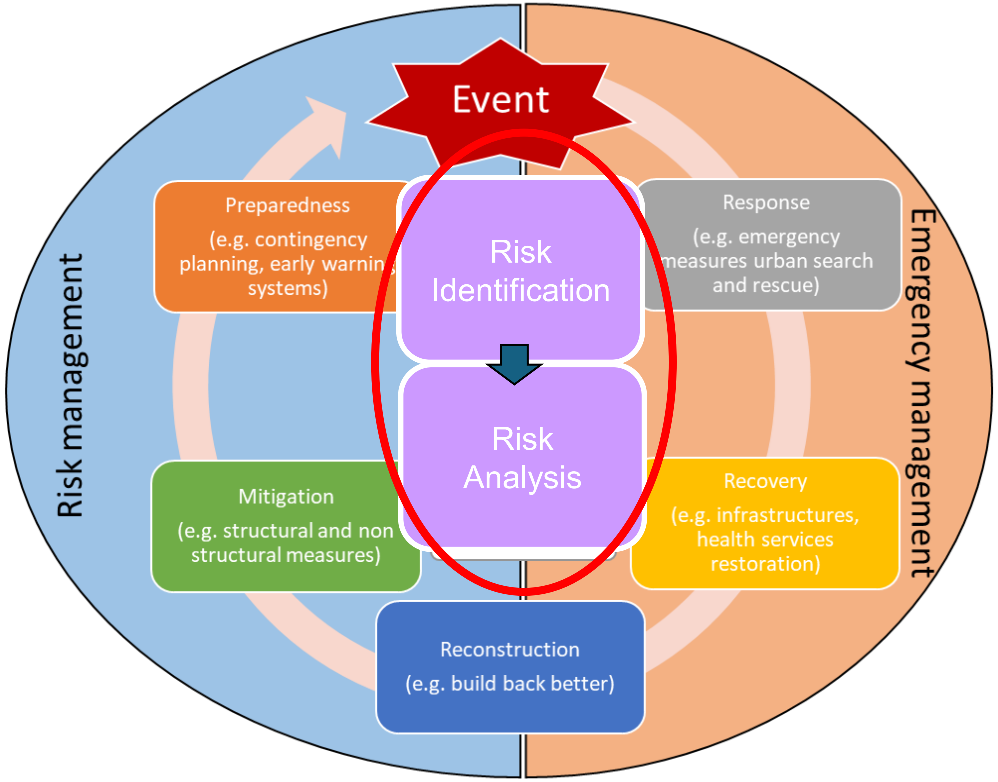
Risk management

*"The application of **risk reduction policies and strategies** to **prevent** new risk, **reduce** existing risk and **manage** residual risk, contributing to the **strengthening of resilience** and **reduction of losses**."* UNDRR

Volcanic risk assessment enables the **analysis of the potential effects** or **feasibility** of **mitigation and resilience building measures**, and **implementation** of those measures, which will differ depending on the scale of the risk assessment and the local context and **may change over time**.





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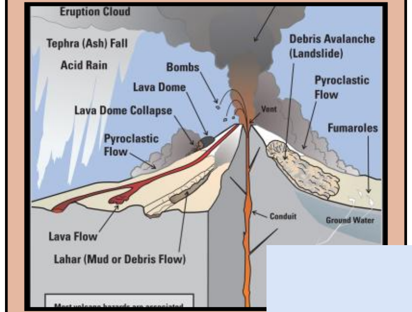
Risk assessment and risk ranking



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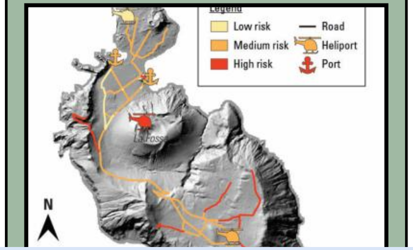

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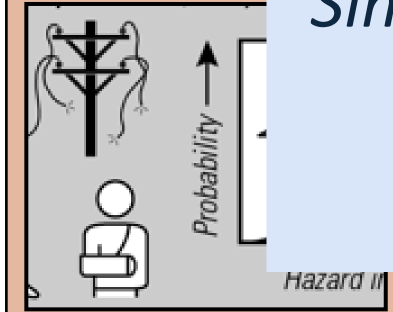
We will focus on **risk assessments** for remainder of presentation.

Similar principles apply for risk ranking. See poster session for more on risk ranking:

#10 Deligne et al. and #14 Di Maio et al.



Vulnerability

Capacity / Resilience / Adaptation / Mitigation

Risk ranking

A **systematic assessment** and **classification** of risks based on their **potential impact** and **likelihood**… to **determine** the **relative importance** of each risk.
Kyros

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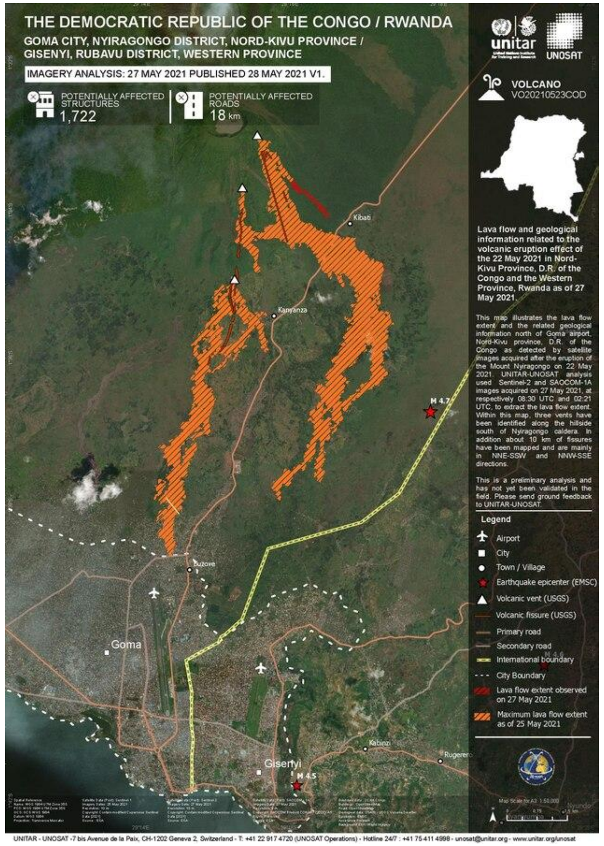
No one-size-fits-all approach



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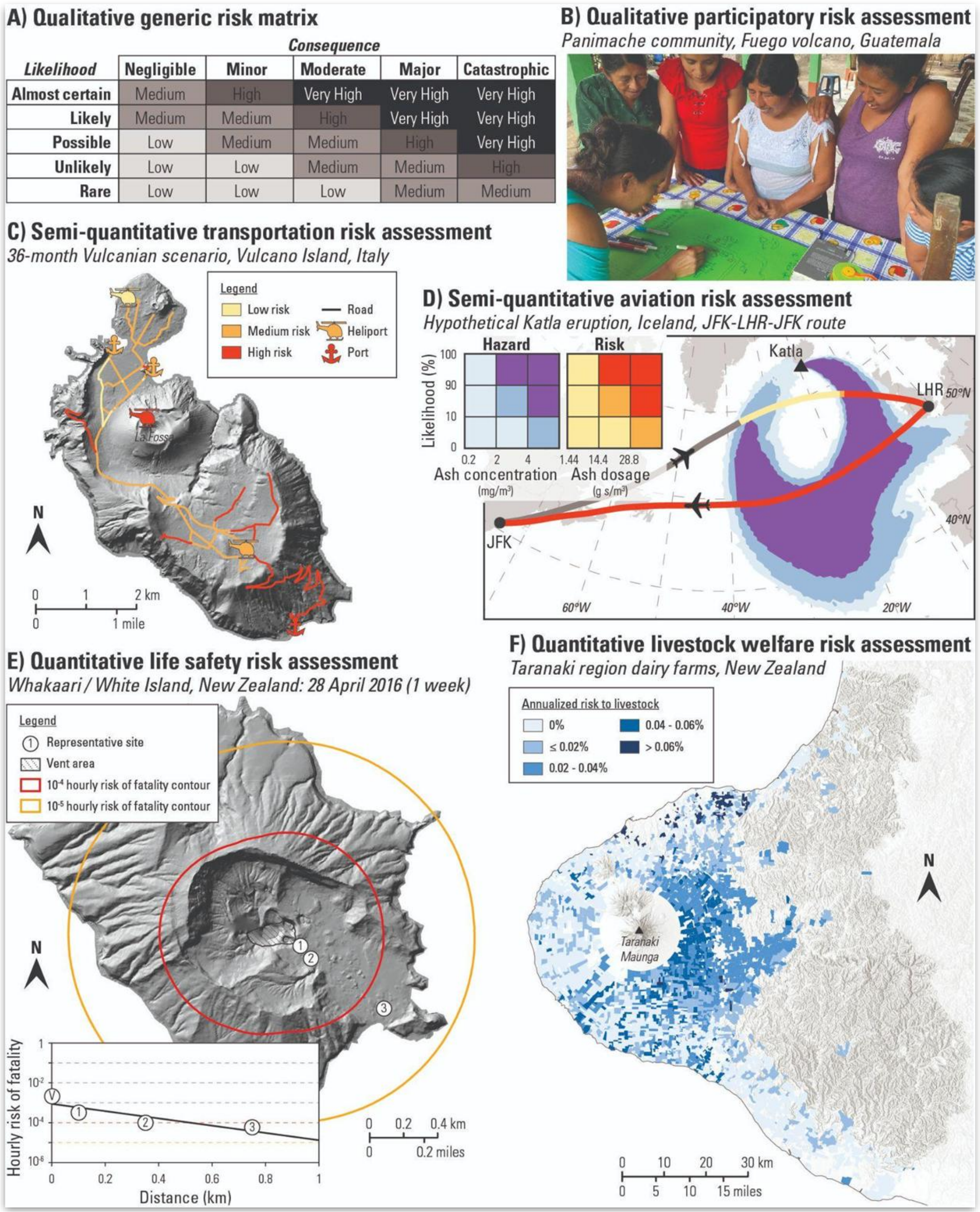
Types of volcanic risk assessments

Qualitative, quantitative, integrated semi-quantitative

- ❖ Needs: audience, purpose
- ❖ Time scale, spatial scale
- ❖ Hazard(s), asset(s)
- ❖ Metrics / units
- ❖ Team and time / resources available to complete
- ❖ Fit for purpose: acceptable / good enough uncertainty



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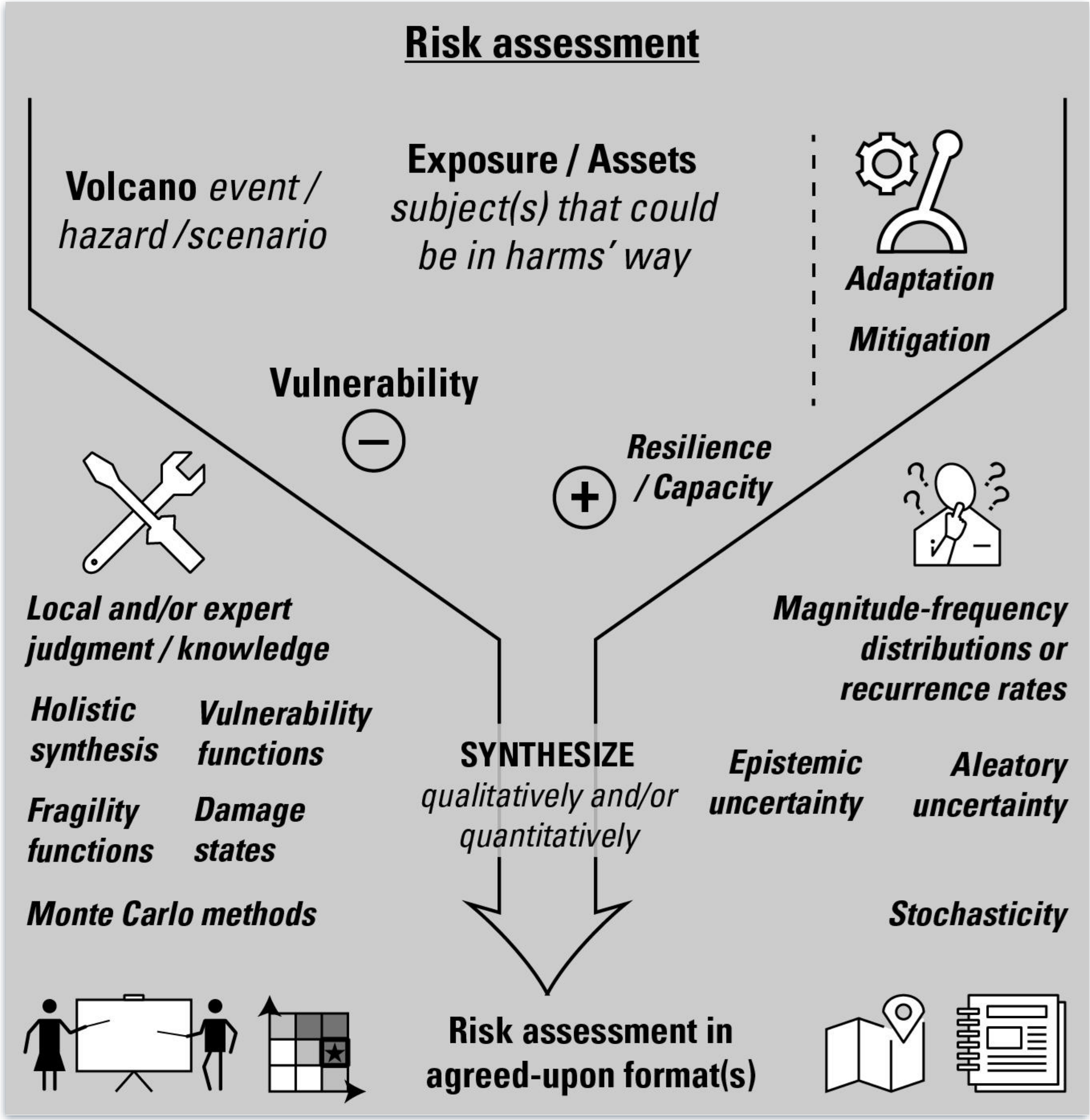
Minimum requirements

- Clear understanding of **needs / audience / purpose / timeframe**
- Identification of **multi-disciplinary team**
- **Local knowledge** and **context**
- "Enough" information regarding **hazards**, **exposure**, and **vulnerability**
- **Data in suitable format** for selected analysis
- Agreement on **acceptable level** of **uncertainty / precision**
- **Resources** to undertake analysis (could require community meetings, software, mathematical knowledge…)



Examples of state-of-art

RISK IDENTIFICATION

Five exposed systems

- Natural environment
- Built environment
- Infrastructure
- Social system
- Economic system

HAZARD: hazard assessment → evaluate spatial and time distribution of different hazard levels

VULNERABILITY:

1) PHYSICAL VULNERABILITY: vulnerability to stress
→ identify the primary factors making buildings, infrastructures, urban fabrics, people, etc. vulnerable to hazards

2) FUNCTIONAL VULNERABILITY: vulnerability to loss of functionality
→ loss of capacity of critical equipment to continue functioning (at the level of individual infrastructure)

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RESILIENCE: coping capacity, mitigation capacity and capacity to transform losses in opportunity
→ assess preparedness level, whether mitigation measures have been defined and/or implemented, the recovery potential of natural and building environment as well as of economic and social systems after hazardous events

RISK ANALYSIS

Risk management (Long term)

Damage to residential buildings and to infrastructures; impact on people; economic losses ***(Main objective: protection of people and assets)***

= **RISK ASSESSMENT**
$f(H, E, V, res)_{t,s}$

Extent of affected area; number of affected people and of key infrastructures (e.g. ports, heliports, roads, staging areas); economic impact of an evacuation ***(Main objective: save lives)***

Emergency management (Short Term)

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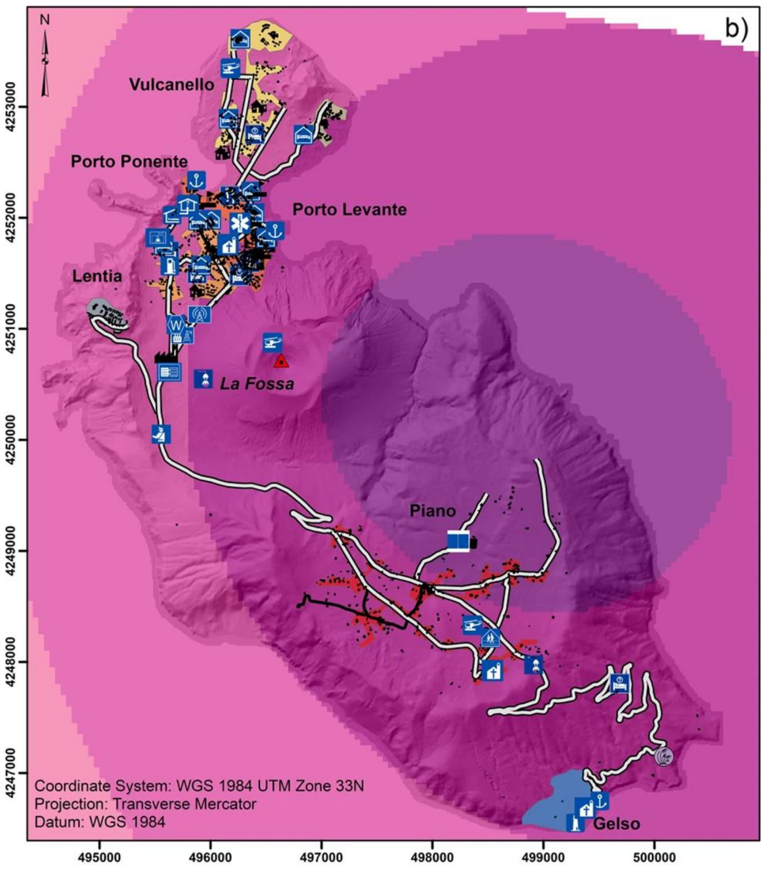
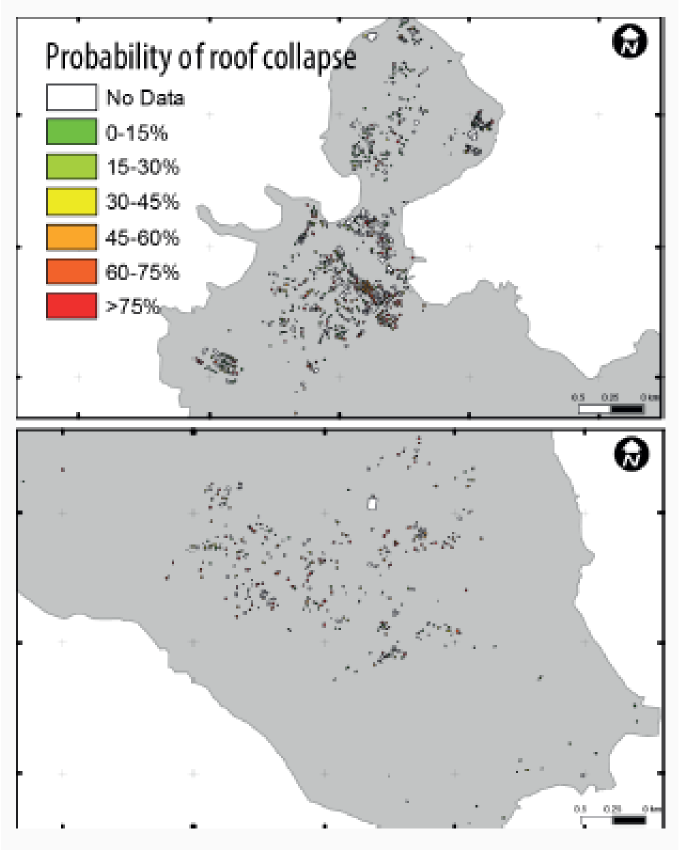
Option 1
Qualitative risk assessment



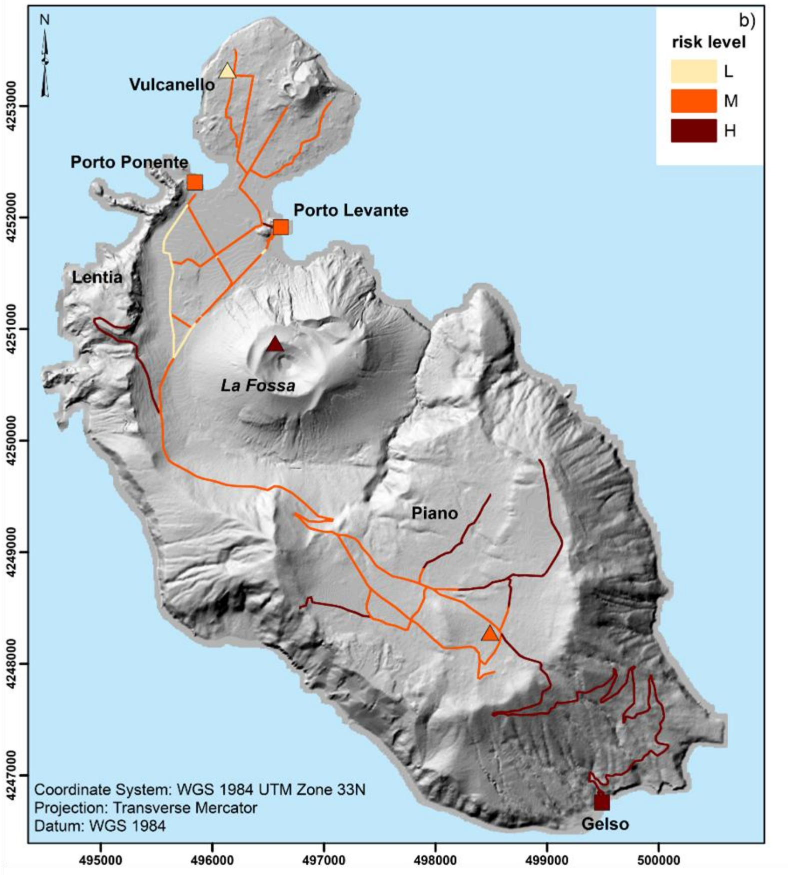
→ Hazard and exposure assessment
→ Vulnerability is not assessed

Option 2
Quantitative risk assessment



→ Hazard and exposure assessment
→ Vulnerability is assessed based on a quantitative function

Option 3
Semi-quantitative risk assessment



→ Hazard and exposure assessment
→ Vulnerability is assessed based on indicators

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CASE STUDY: Vulcano Island (Italy)

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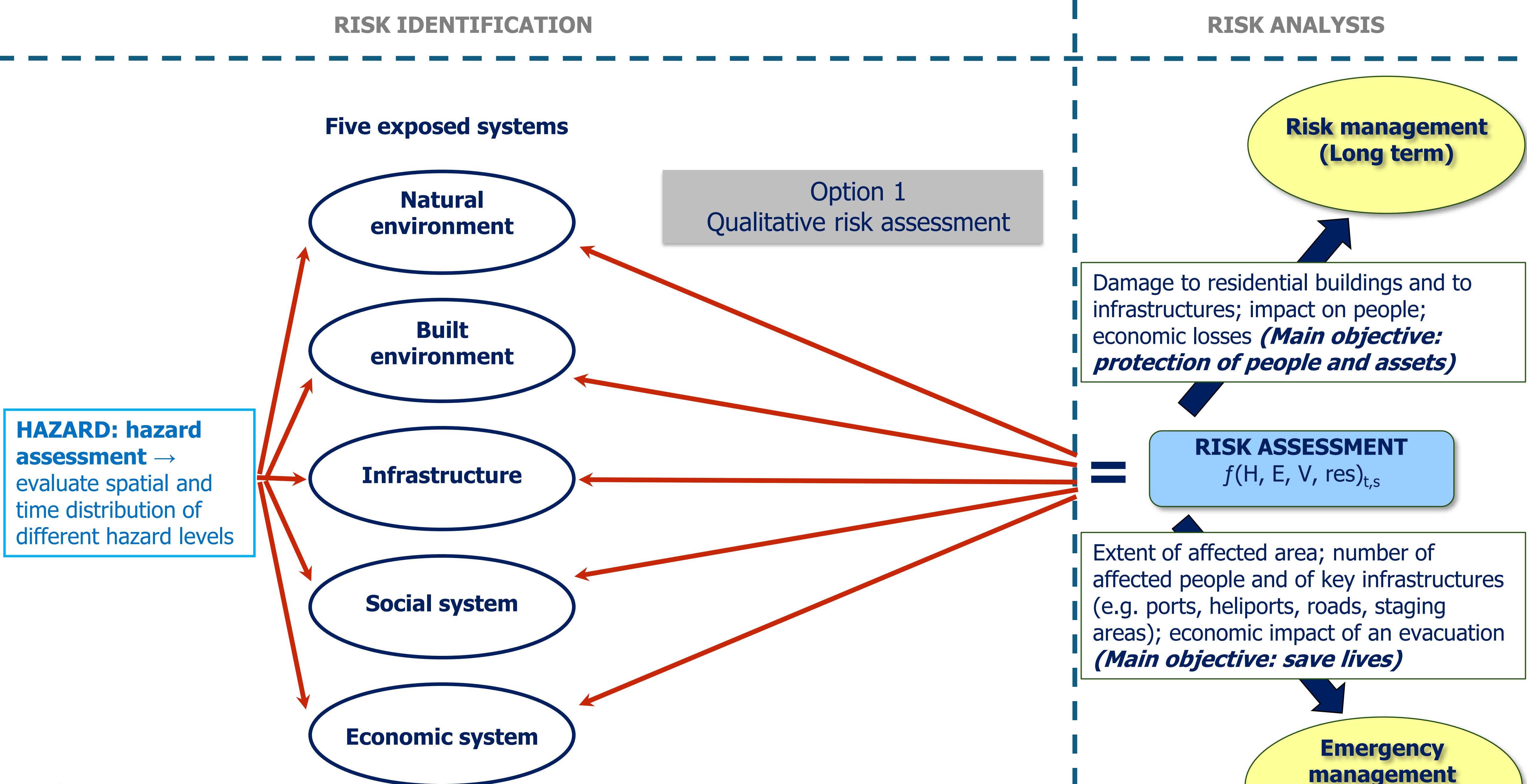

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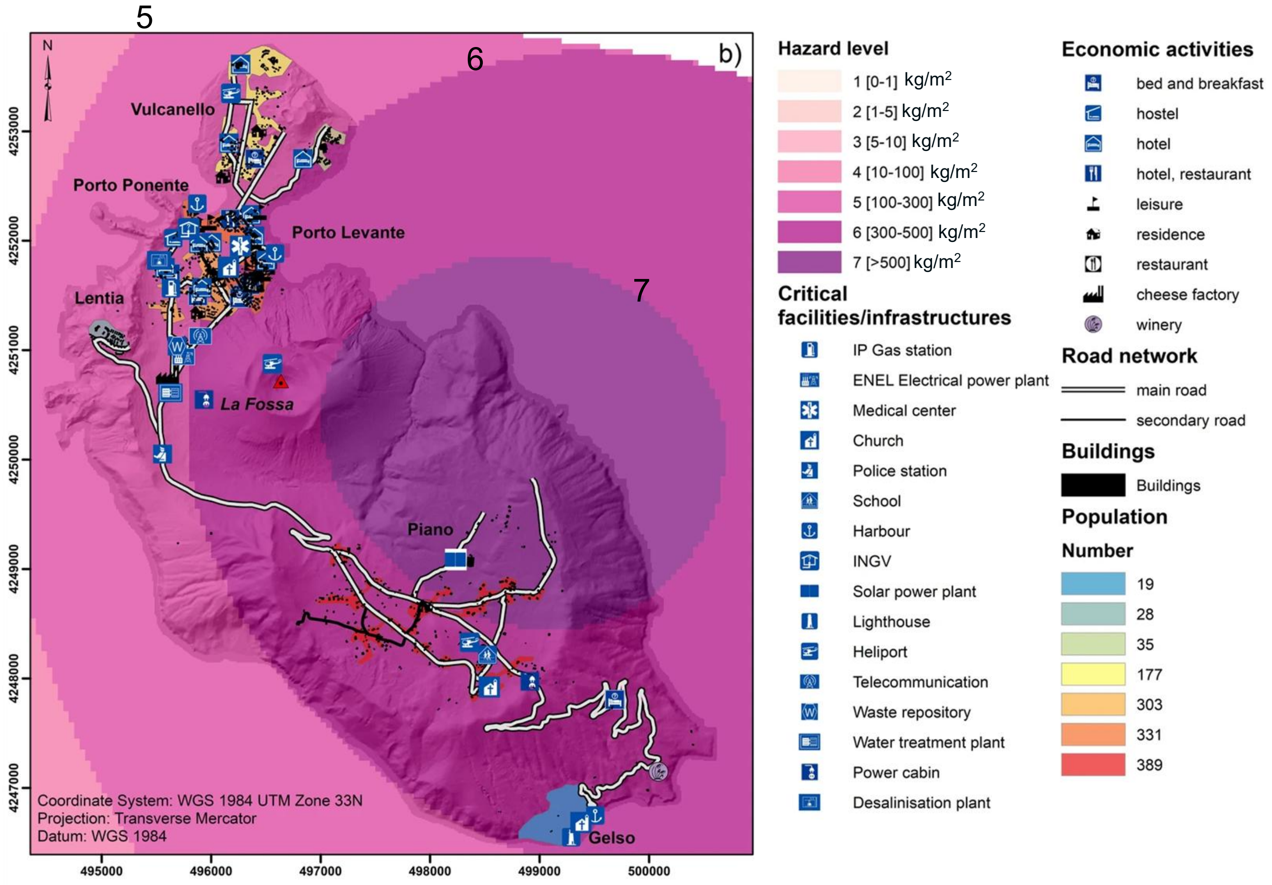
EXPOSURE-BASED RISK ASSESSMENT TO TEPHRA FALLOUT (QUALITATIVE)

25% of occurrence of the 1-36 month Vulcanian scenario (after 36 months) (Bonadonna et al. 2021)



(Spence et al., 2005; Jenkins et al., 2014, 2015; Blake et al., 2017; Wilson et al., 2017; Hayes et al. 2019)

Buildings	ND	No structural damage to buildings; possible infiltration and internal contamination and corrosion of metallic components; roofing materials may be abraded or damaged by human actions during ash removal		In rare instances, non-engineered and long span roofs may be vulnerable to damage, particularly when ash falls wet or is subsequently wetted; non-structural elements such as gutters and overhangs may suffer damage; some infiltration of dry ash into interiors	Structural damage; partial to complete collapse of weak (timber, corrugated metal) roofs	Structural damage; partial to complete collapse of concrete roofs	
Power system / telecommunication	ND	Temporary disruption of power system particularly with wet ash (e.g. flashovers); possible communication signal attenuation (e.g. radio); uninsulated lines may flashover.		Damage to telecommunication components and power cables through flashover; abrasion and or corrosion; failure of power generating plant (depending on system type and design); abrasion, clogging and flash-over causing disruption and/or damage to some electrical and mechanical equipment at substations	Damage to communication dishes and microwave towers due to excess of ash loading; structural damage to electrical distribution lines and support structures		Damage to communication dishes and microwave towers due to excess ash loading; permanent disruption and structural damage of power system
***Transport system**	Minor skid resistance reduction possible and covering of markings	Skid resistance reduction likely and covering of markings; poor visibility; windscreen abrasion	Minor skid resistance reduction possible and covering of markings, poor visibility, windscreen abrasion	Minor skid resistance reduction possible and covering of markings; poor visibility; clogging of roadside drains and ditches; increased wear of engine and brakes and windscreen abrasion	Impassable for some vehicles and covering of markings; poor visibility. Dry, windy conditions exacerbate remobilisation and drifting.		
Hazard score	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Tephra load (kg/m²) / thickness (cm)	0.1-1 (0.01-0.1)	1-5 (0.1-0.5)	5-10 (0.5-1)	10-100 (1-10)	100-300 (10-30)	300-500 (30-50)	>500 (>50)

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RISK IDENTIFICATION

RISK ANALYSIS

Option 2
Quantitative
risk assessment

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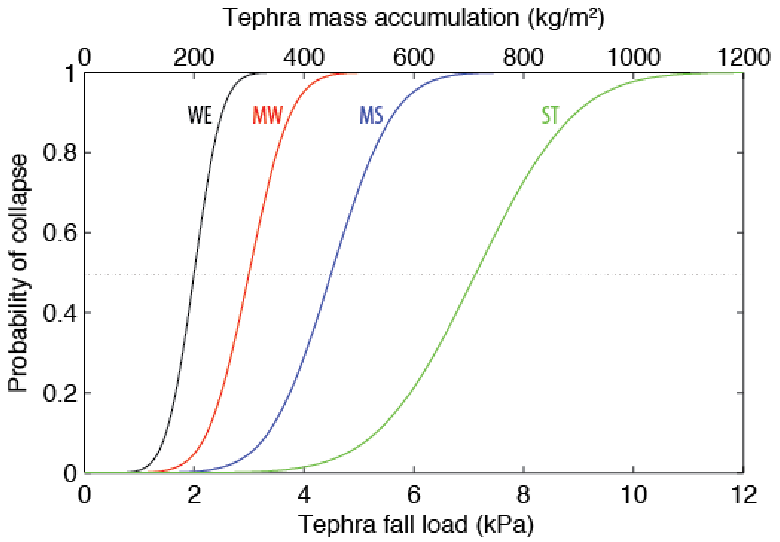
Emergency management (Short Term)

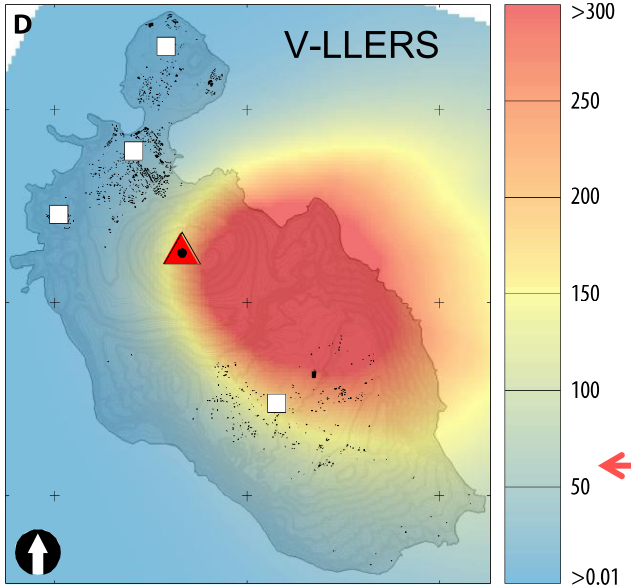
TEPHRA-FALLOUT RISK ASSESSMENT (QUANTITATIVE)

Option 2
Quantitative risk assessment

Roof class	Description	Roofing stock		
		Weak	Median	Strong
Weak (WE)	Tiled roof, poor condition	85.7%	34.3%	2.7%
Medium weak (MW)	Tiled roof, aver. or good	13.5%	44.1%	18.9%
Medium strong (MS)	Flat RC roof	0.7%	18.9%	44.1%
Strong (ST)	Flat RC roof < 20 years	<0.1%	2.7%	34.3%



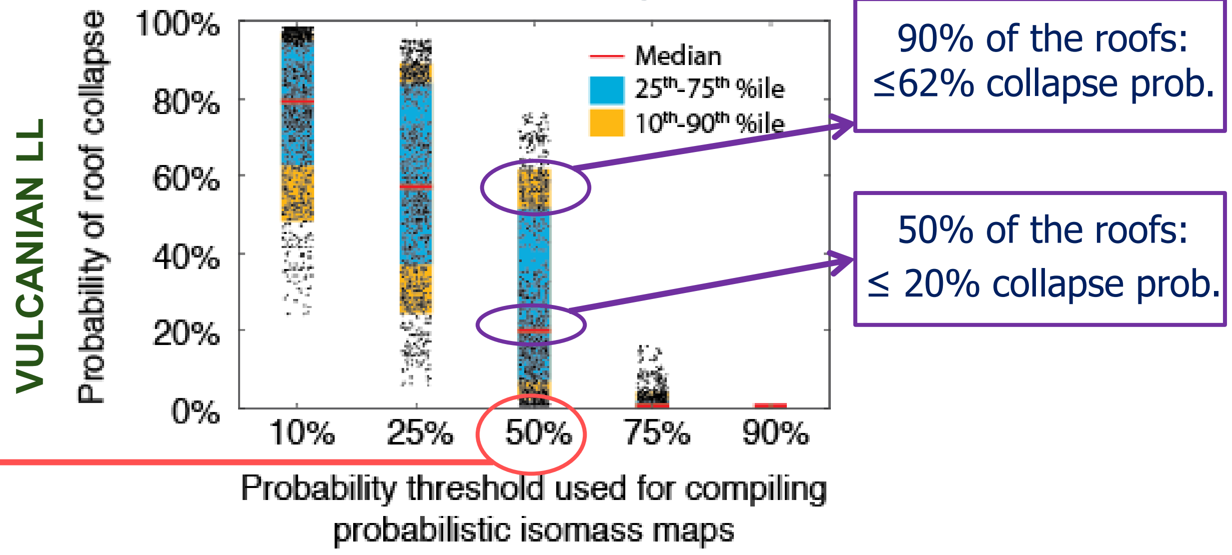
Mass accumulation (kg/m²) for a **50%** probability



Probabilisitc isomass map

Biass et al. 2016

Median roofing stock



RISK IDENTIFICATION

RISK ANALYSIS

Option 3
Semi-quantitative risk assessment

HAZARD: hazard assessment → evaluate spatial and time distribution of different hazard levels

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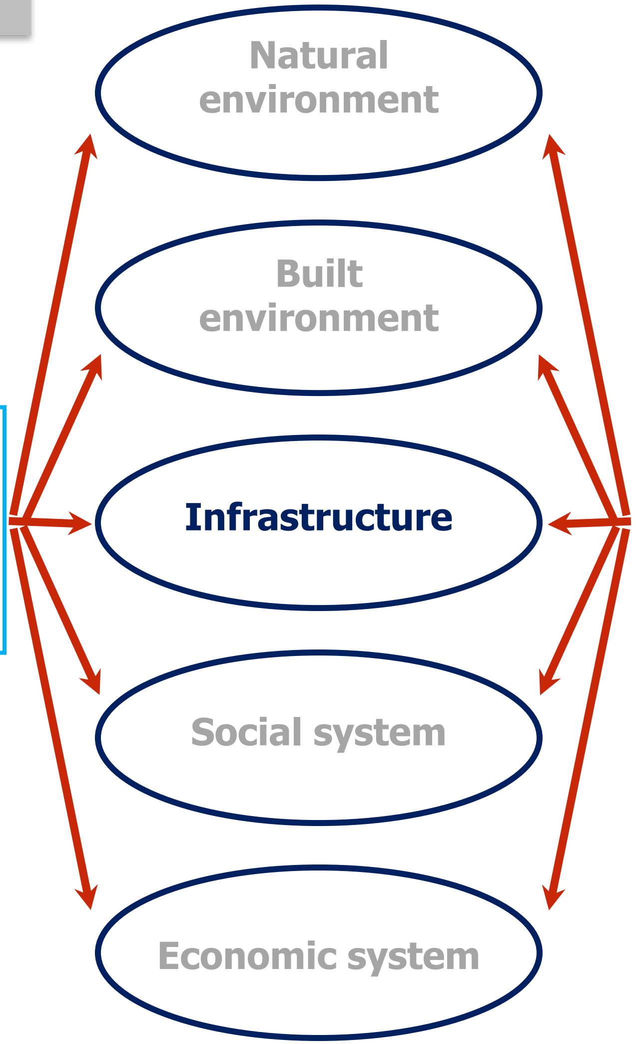

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Emergency management (Short Term)

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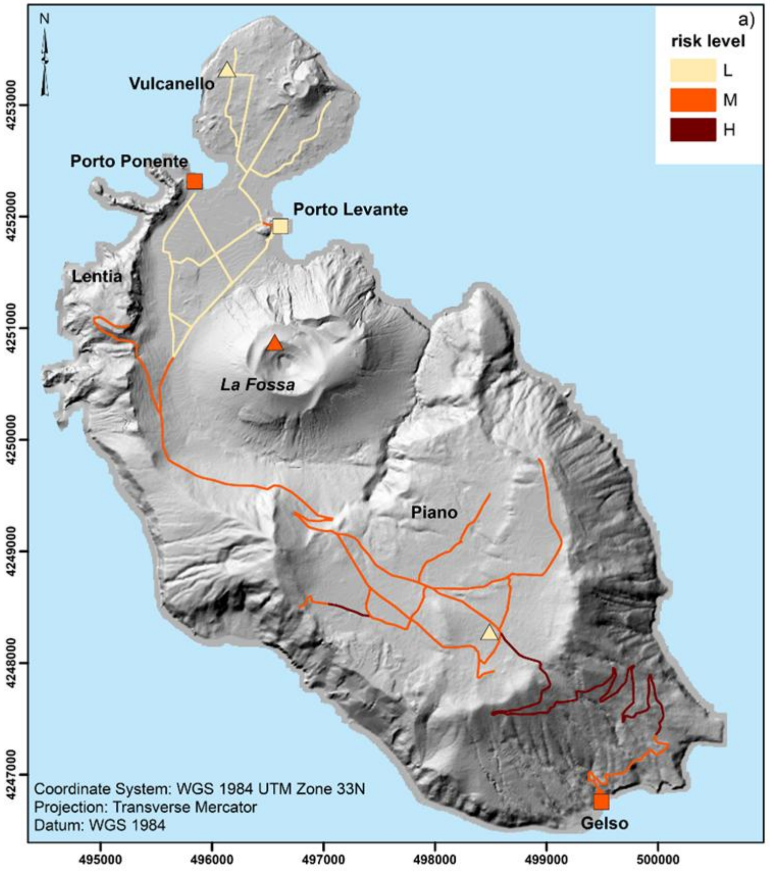
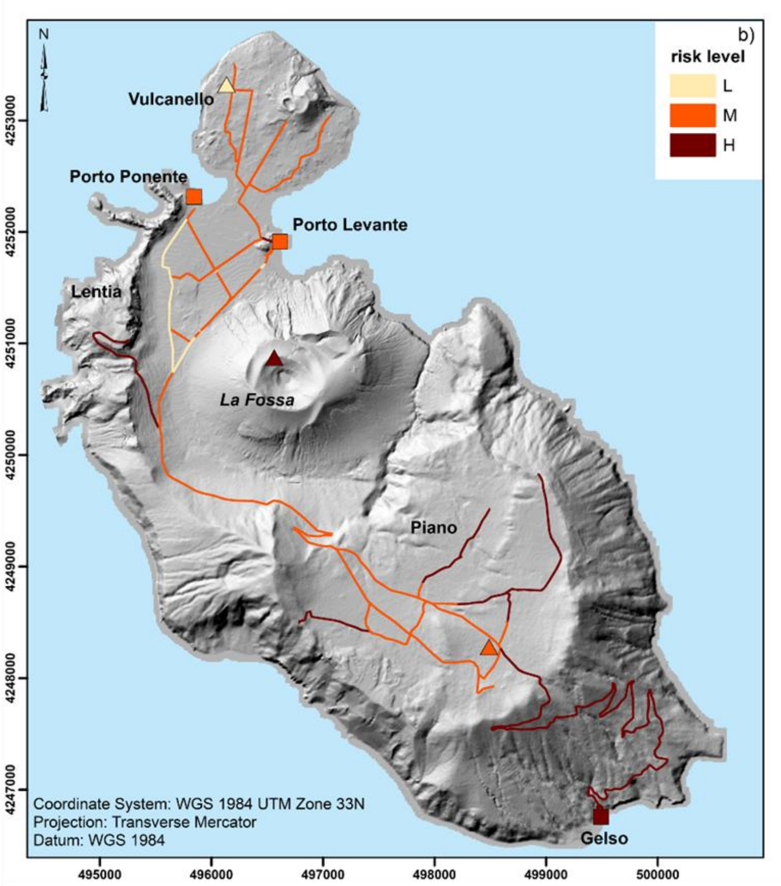
Option 3
Semi-quantitative
risk assessment

Risk of transport system to tephra fallout



after 6 months of accumulation



after 36 months of accumulation

Bonadonna et al. 2021

Scenario-based risk assessment
for 1–36 month Vulcanian eruption

long-term risk management → identification of parts of the transport system that require intervention to maintain interconnection between infrastructure and between inhabited areas and critical infrastructure and facilities even during volcanic activity

emergency management → identification of the weakest parts of the transport system that could inhibit rescue/evacuation operations

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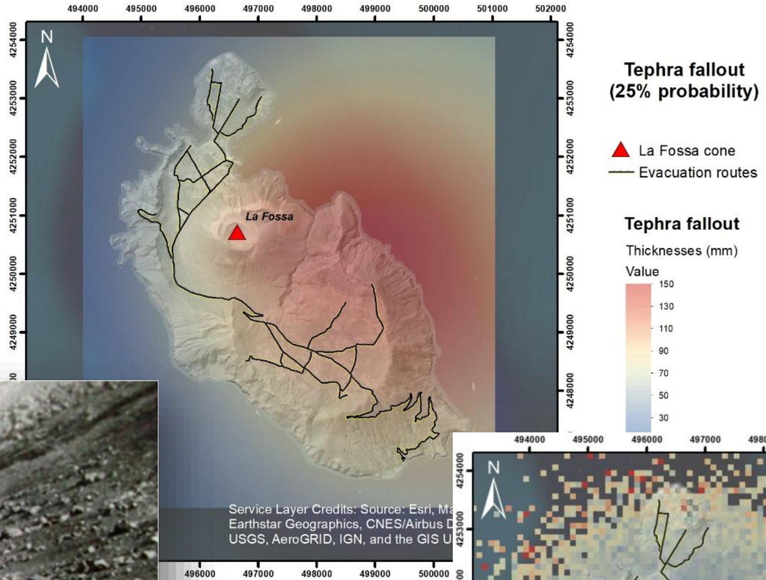
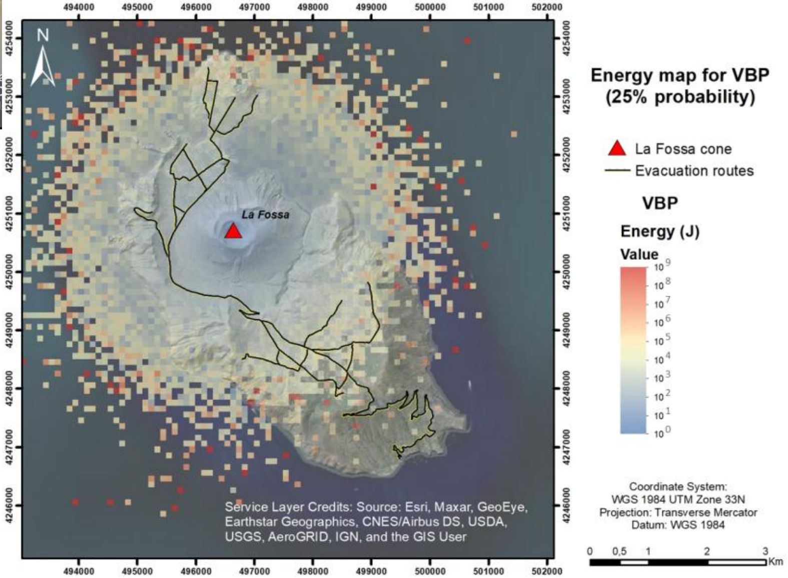
Example of Multi-Hazard Risk Assessment
Risk of transport system to tephra fallout and ballistic projectiles





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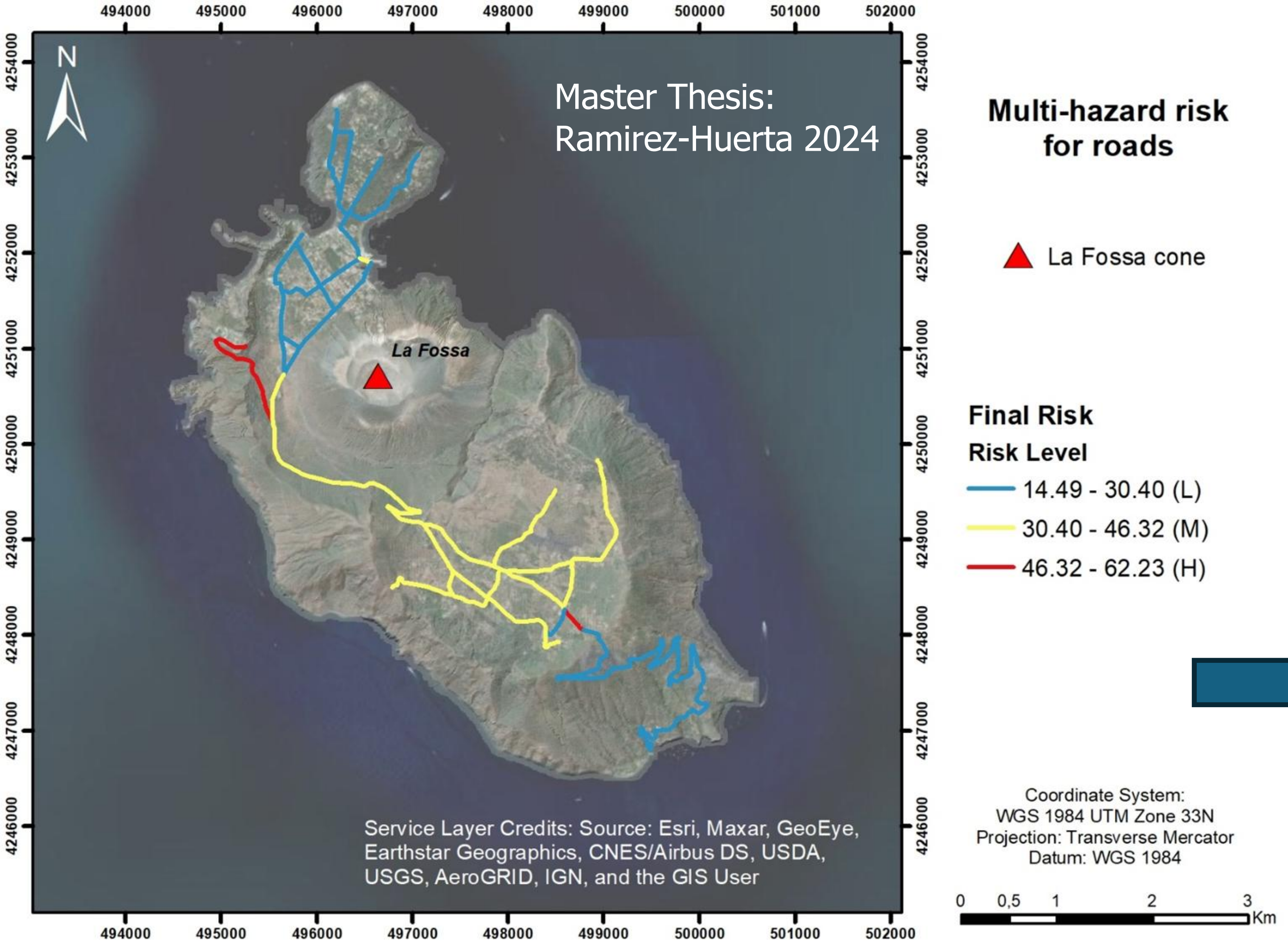

Multi-hazard risk assessment: estimated risk by the action of multiple independent hazards in a specific area without interaction at the vulnerability level
(Kappes et al., 2012; van Westen and Greiving, 2017; Zschau, 2017)

Open Questions

→ what if individual hazards impact the vulnerability of exposed assets?

→ is aggregated information more useful for long-term risk management and short-term crisis management than risk infos for individual hazards?

Limitations on VBP risk assessment

→ missing infos on VBP impact on roads and cars (only available for buildings)

→ only infos on physical impact (functional impact probably more related to other parameters such as spatial density, size, etc…)

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from **Prata and others (2019)** in *Meteorological Applications*
https://doi.org/10.1002/met.1759 [free access]

Example of state-of-art
Transatlantic flight

***** PROOF OF CONCEPT, not currently operational *****

Timeframe: Hours to day

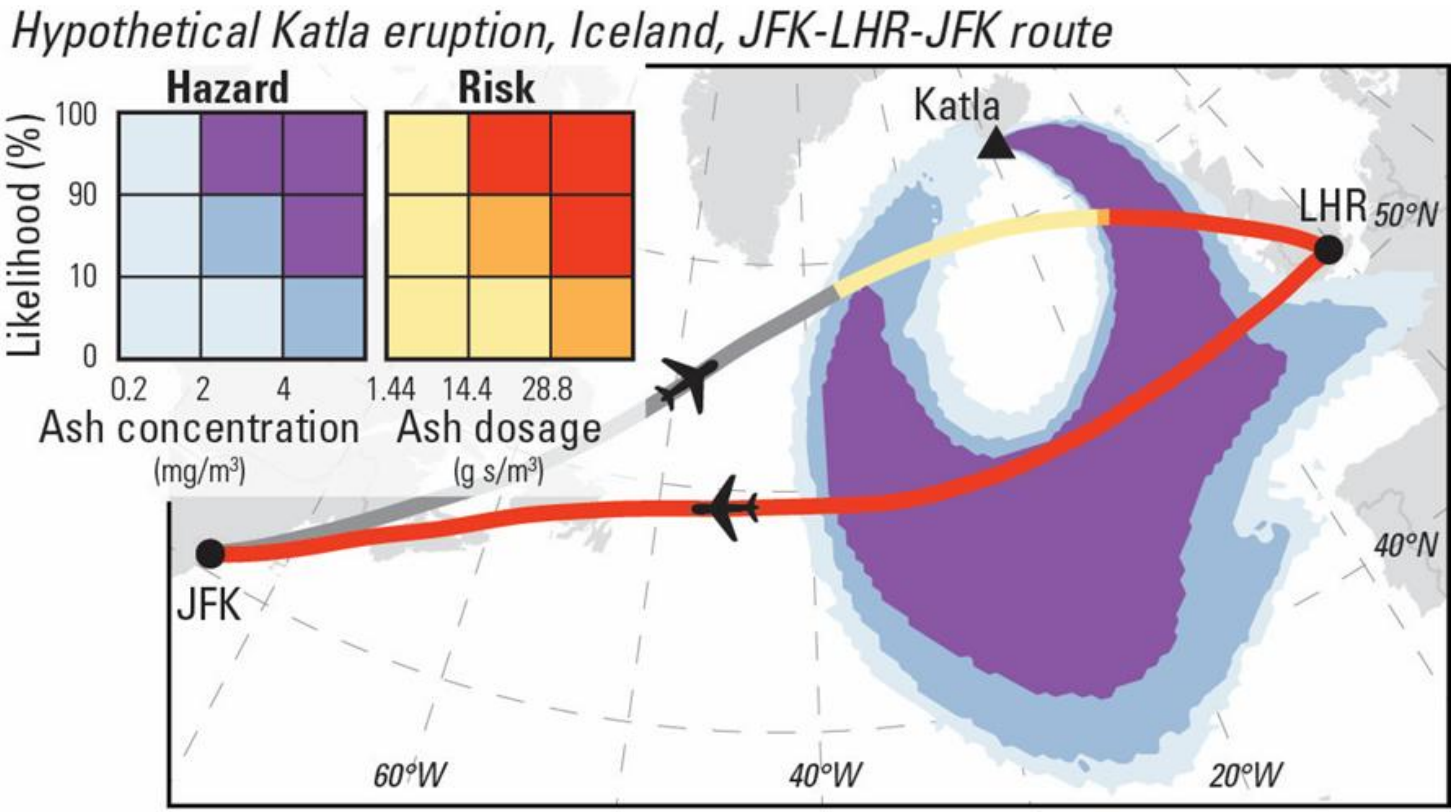
Hazard: Volcanic ash at jet cruising levels

- **What:** Map shows ash concentration based on ensemble modelling
- **How:** Models initiated using observed eruptive conditions and satellite observations
- **Time:** Volcanic Ash Advisory Centers update models every 6 hours for +0HR, +6HR, +12 HR, +18HR

Asset: Passenger jet

Vulnerability: Jet engine failure and/or reduced performance

- **Unit:** Cumulative ash dosage



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Example of state-of-art
Kelud Volcano, Indonesia

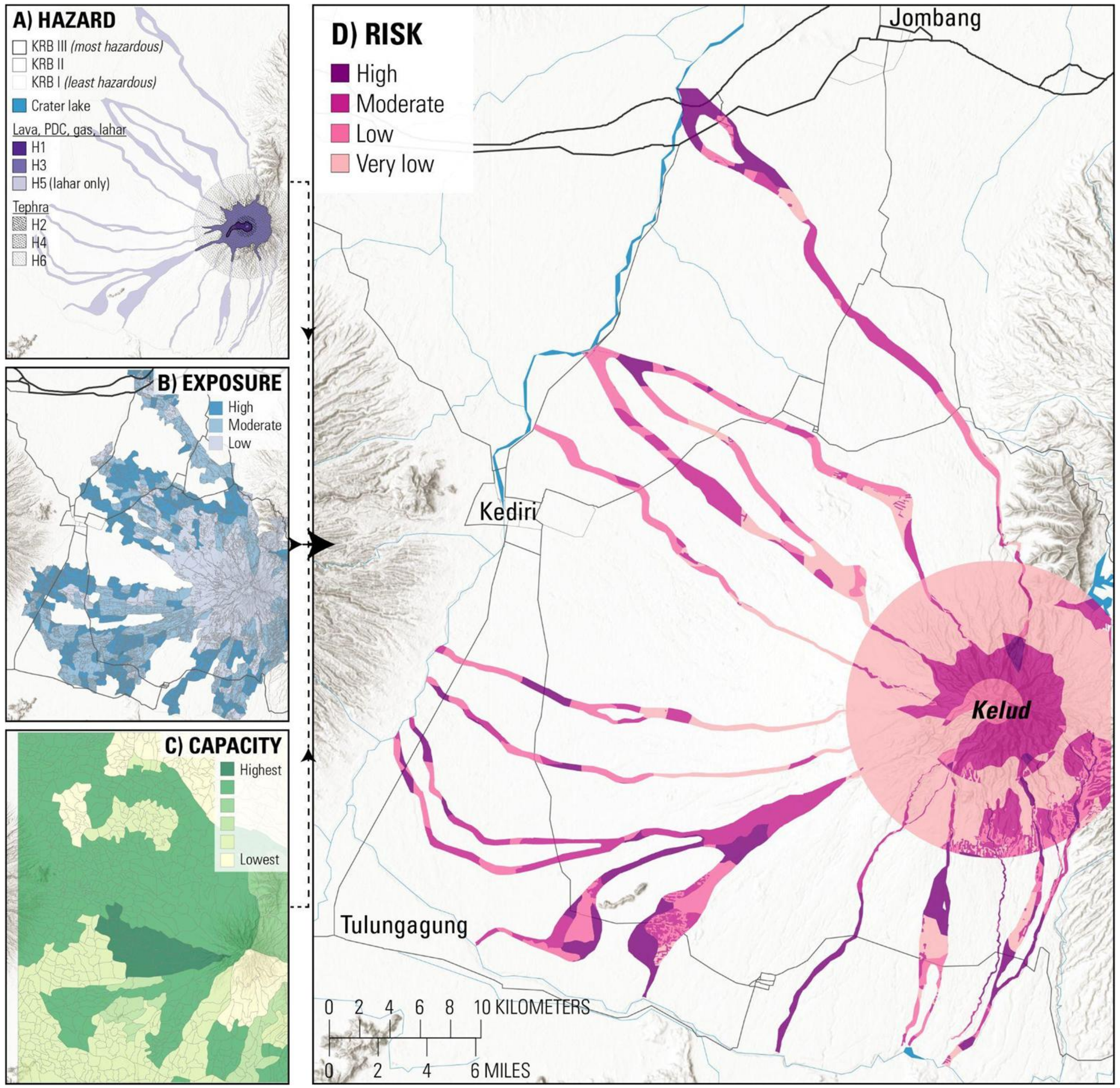
Timeframe: Long-term risk assessment

Focus: One volcano & surrounding area

Factors:

- **Hazards:** Lava flows, PDCs (flows and surge), hazardous gasses, lahar, tephra
- **Exposure:** Population density (60%), land-use (25%), and infrastructure (15%)
- **Capacity:** Early warning system (35%), preparedness (30%), disaster agency (20%), mitigation infrastructure (15%)

from **Heriwaseso and others (2017)** presented at *Geoweek UGM*



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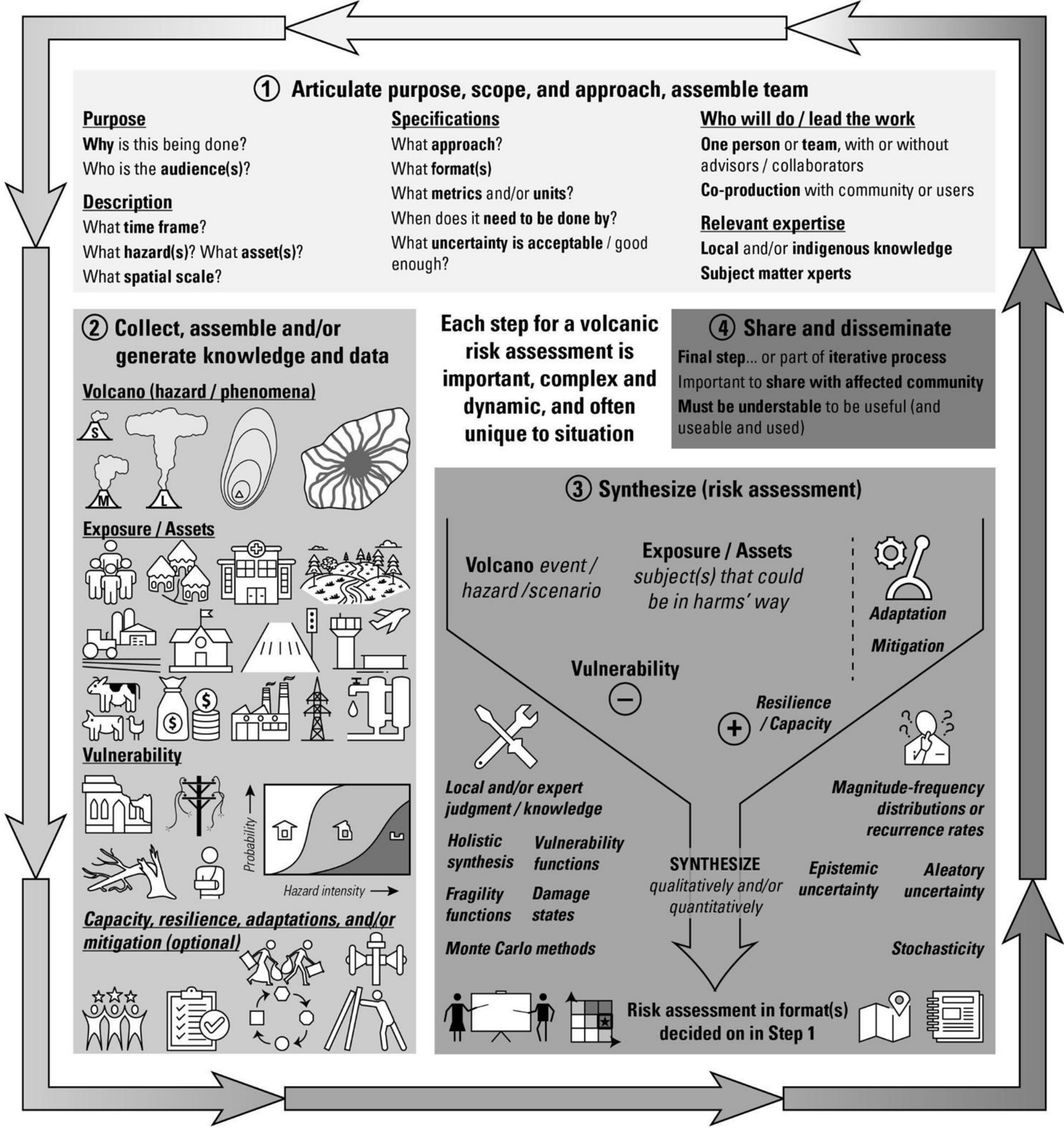
Challenges

Challenges associated with each step of risk assessment process… and each step is often complex and dynamic

We will look at each step more closely

See poster session for more details on some of the challenges of risk assessment: #4, #14, #19, #23, #24, #32, #42



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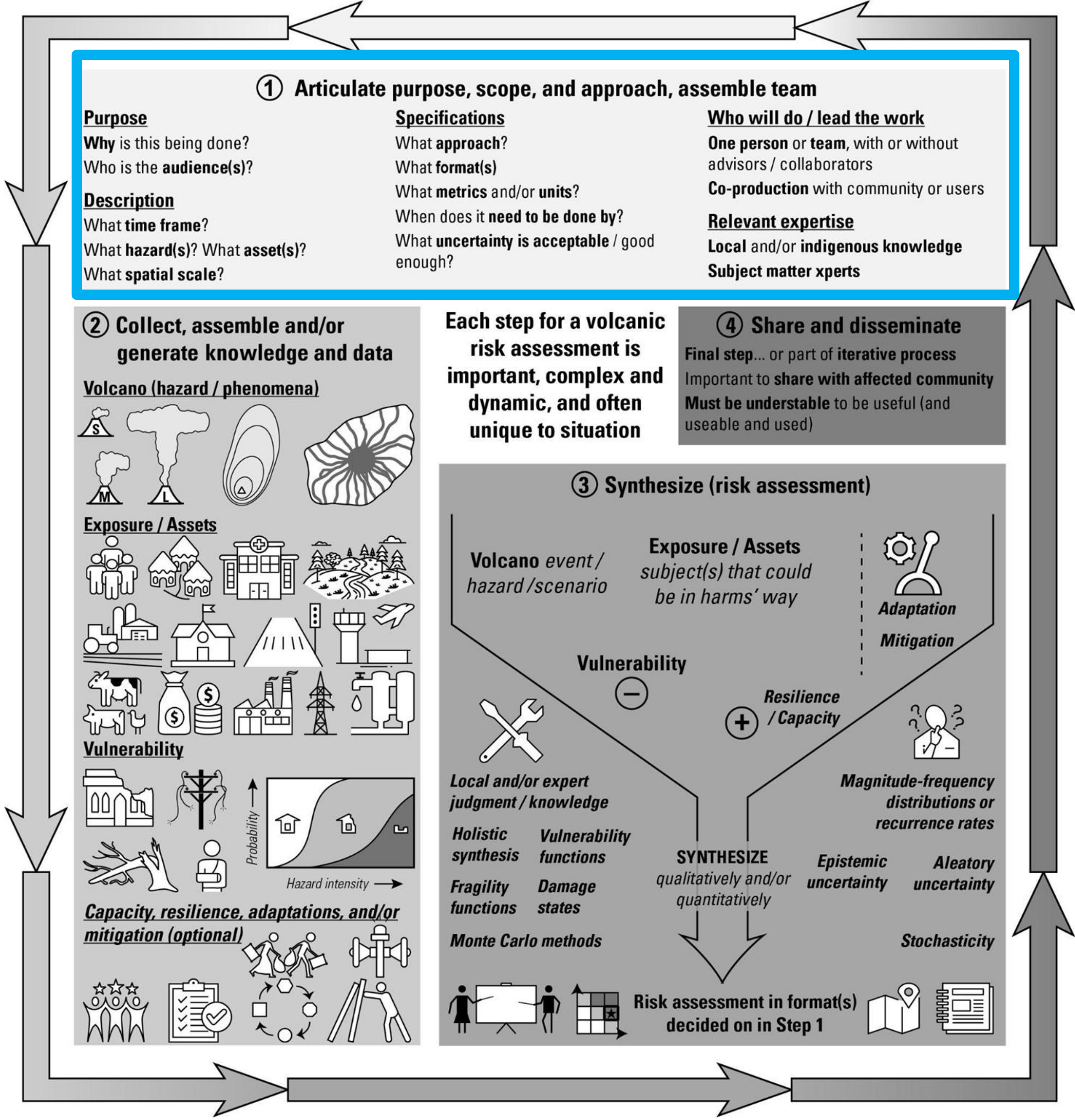
Challenges

1: Articulate purpose, scope, and approach, assemble team

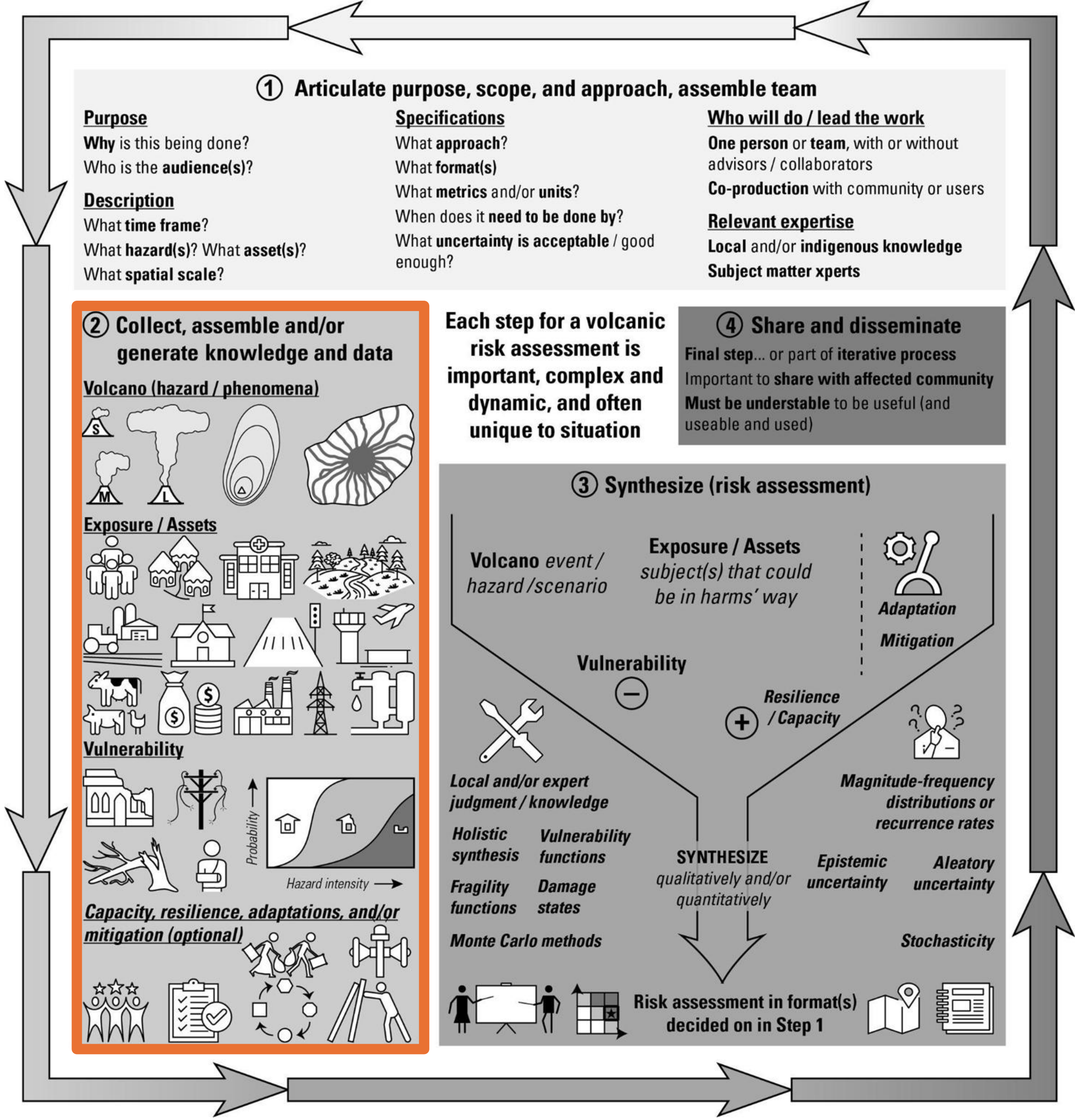
- Who are the actors? Who should be involved?
- What is the purpose, need of decision-makers?
- How much time will have to undertake?
- What temporal and spatial scale?
- This step is often not done well-enough - and it sets the foundation
- Funding



Challenges

2: Collect, assemble, and/or generate knowledge and data

- Some volcanoes, hazards, and vulnerabilities more studied than others
- How to combine / consolidate different datasets (such as municipal vs global asset data)
- Data collection and interpretation benefits from more collaboration - such as social scientists, practitioners, wisdom holders, engineers….
- Understanding what data and information decision-makers need



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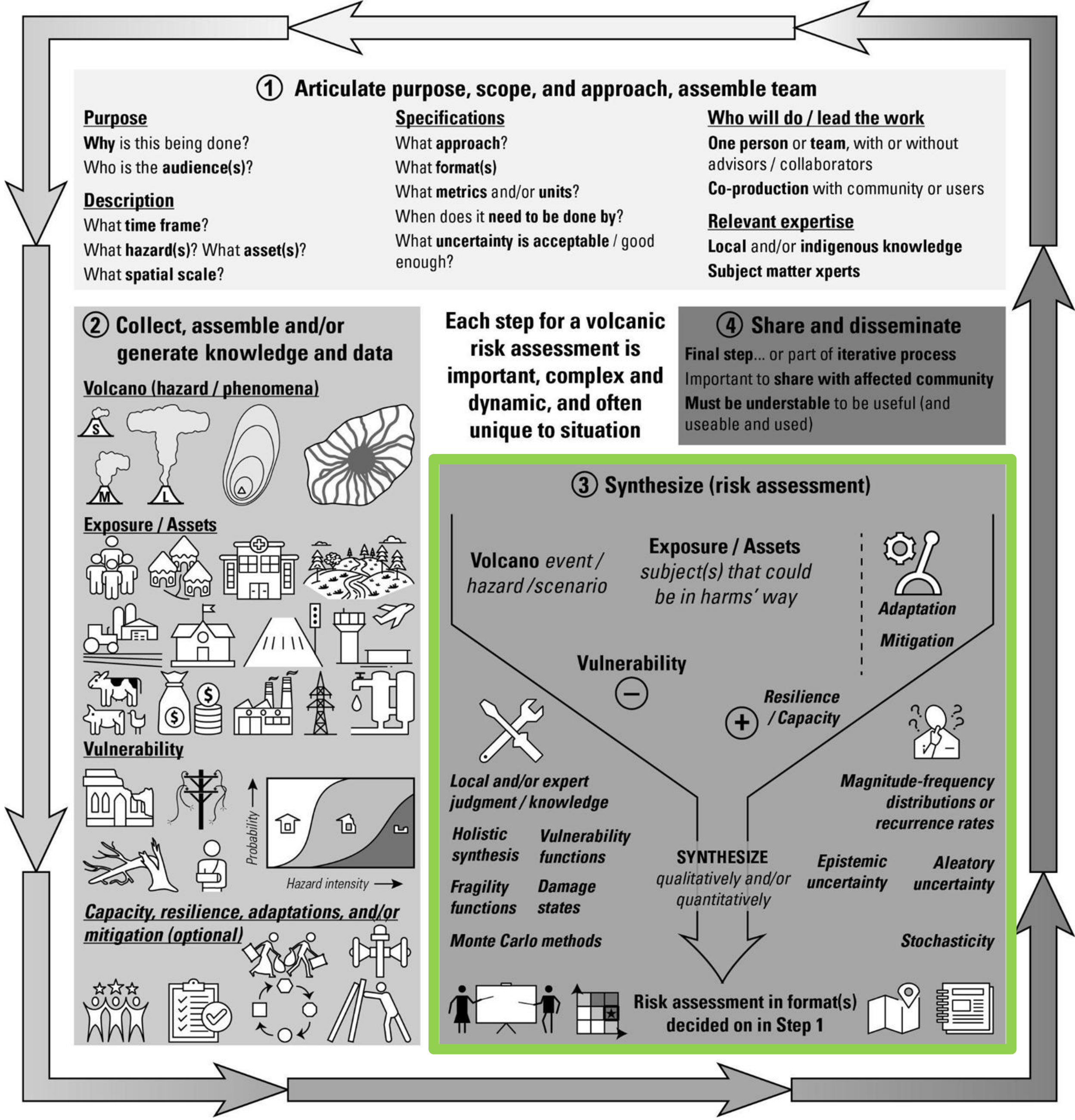
Challenges

3: Risk assessment

Big challenge is <u>how</u> to put components together

- ❖ What do the data allow?
- ❖ How are multiple hazards handled? (There are many hazards, and sequence / duration can matter)

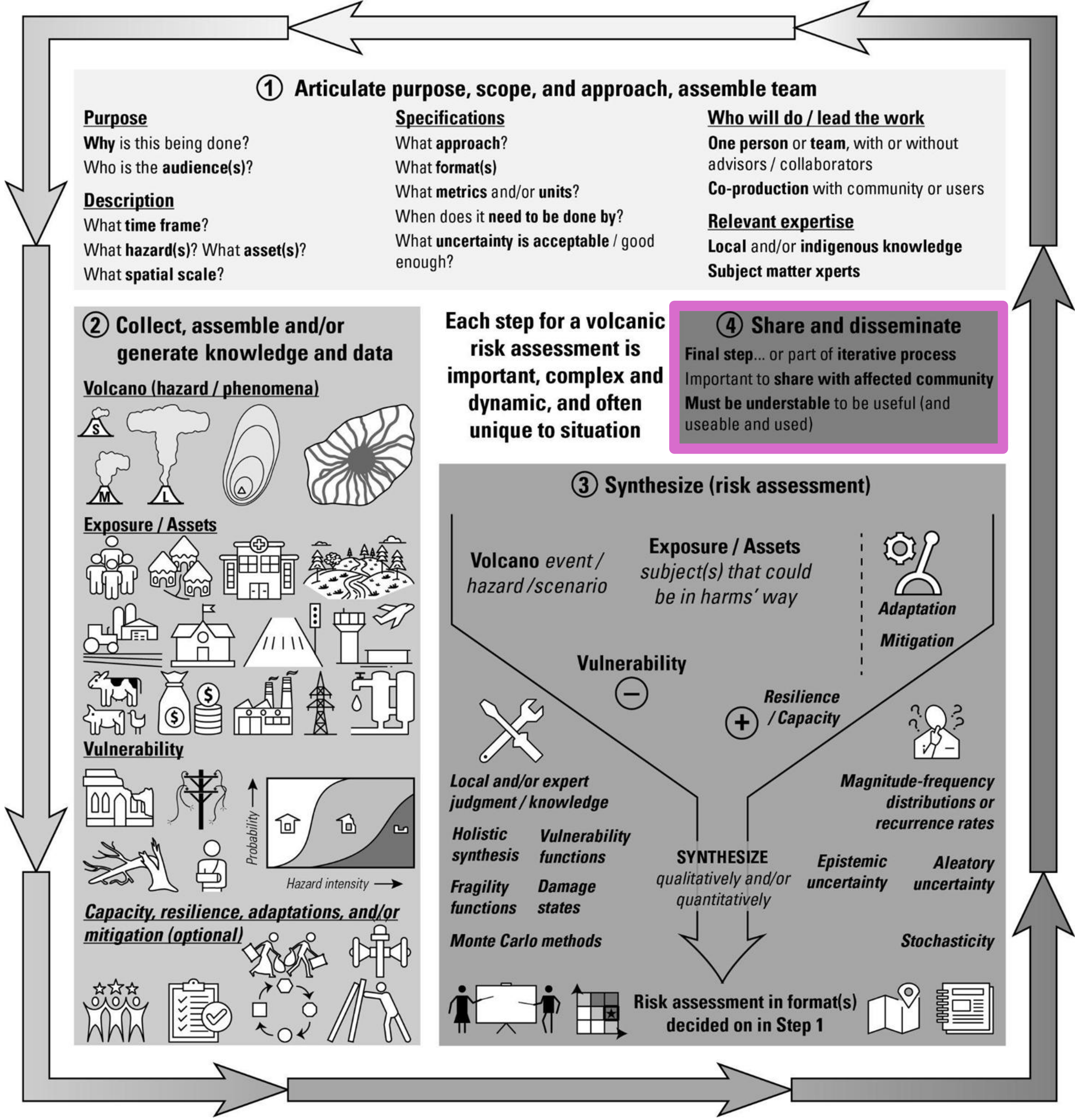
Multi-hazard posters: #20; #26; #44



Challenges

4: Share and disseminate

- Knowing the audience(s)
- Suitable format(s) in evolving expectations and needs
- Being useful, useable, and used - and incorporating feedback as needed



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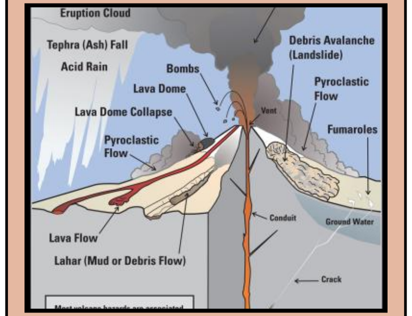
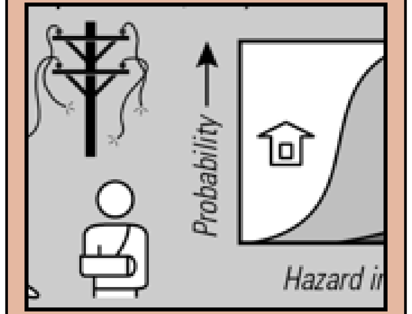
Take home messages and pathway forward

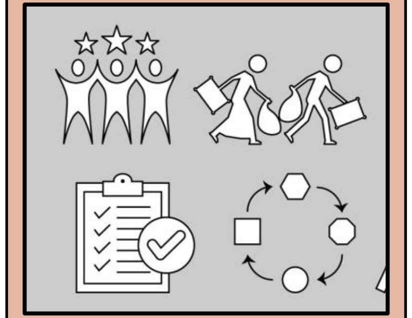


Volcanic hazard

Exposure / Assets



Vulnerability



Capacity / Resilience / Adaptation / Mitigation

- All components of volcanic risk assessment are complex and dynamic
- Volcanic eruptions (and unrest) have multiple hazards occurring (and interacting) over different temporal and spatial scales
- Require collaboration across multi-disciplinary teams and involve communities to understand local context and to address complexities and dynamics of volcanic risk assessment
- Increased prioritization and research interest - we are getting better at synthesizing risk across different contexts
- Pathway forward: need for shared resources (data, methods, tools) across the volcano community to support accessible volcanic risk assessments for all

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Any questions?