INTRODUCTION

Risk, hazard, vulnerability, elements at risk

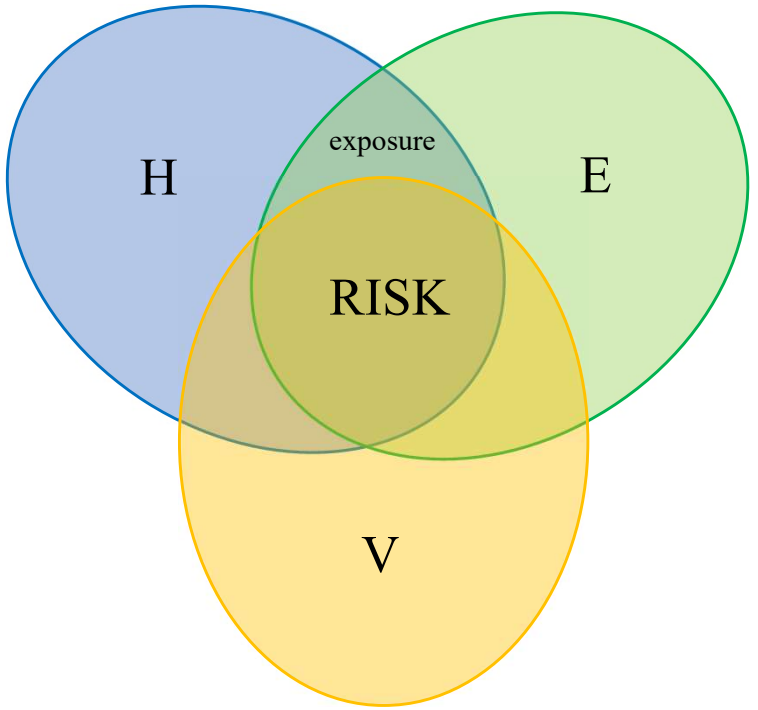
Risk, hazard, vulnerability, elements at risk

- Risk is the effect of uncertainty on objects/elements/events
- The notion of risk implies the possibility that something happens differently than expected (negative/positive)
- It is related to the uncertainty that any event can cause a negative/different impact on what individuals consider valuable (undesirable consequences)

Risk, hazard, vulnerability, elements at risk

$$R = f(H,V,E) = H \times V \times E$$

- R = risk (expected loss)
- H = hazard (probability of occurrence) of a specific type (e.g. debris flow, flash flood, river flood…)
- V = vulnerability (degree of loss)
- E = amounts of Elements at risk (value/quantification)



Risk *is defined as* ***the probability of harmful consequences****, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged)* ***resulting from*** *interactions between natural or human-induced hazards and vulnerable conditions (UN-ISDR, 2009, EC, 2011).*

Burke, L., & Spalding, M. (2022). Shoreline protection by the world's coral reefs: Mapping the benefits to people, assets, and infrastructure. Marine Policy, 146, 105311.

Risk, hazard, vulnerability, elements at risk

$$R_S = f(H, V, E) = H_{T:Hs}\, H_{L:Hs}\, V_{Es|Hs}\, E_{Es}$$

- $H_{(T:Hs)}$ is the temporal (T) probability of occurrence (e.g. annual) of a specific hazard scenario (H_s) with a given return period in an area;
- $H_{(L:Hs)}$ is the locational (L) or spatial probability of occurrence of a specific hazard scenario with a given return period in an area impacting the elements-at-risk;
- $V_{(Es \mid Hs)}$ is the PHYSICAL/SOCIAL/ECONOMIC/ENVIRONMENTAL vulnerability, specified as the degree of damage/loss to a specific element-at-risk E_s given the local intensity caused due to the occurrence of hazard scenario H_S. It is expressed on a scale from 0 (no damage) to 1 (total loss).
- E_{Es} is the quantification of the specific type of element at risk (*Es)* evaluated (e.g. number of building, people, type of infrastructure)

Westen C J Van 2016 Introduction to Exposure, Vulnerability, and Risk Assessment J. Carribean Handb. Risk Inf. Manag

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H

$H_{T:Hs}$ $H_{L:Hs}$

HAZARD

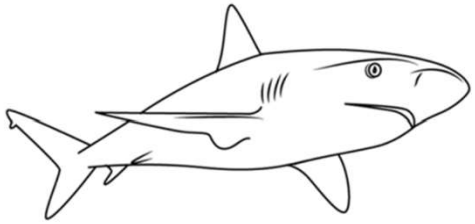
Exposure

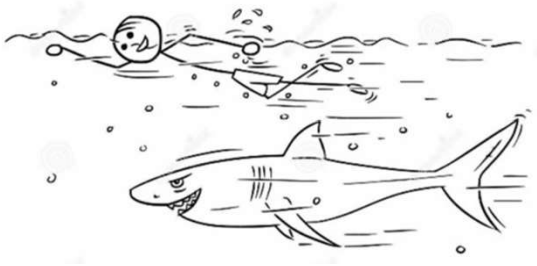
RISK

R_S

Any **source** of potential damage or effect on a target

The fact that a **target** suffers a certain level of damage/change if **exposed** to the hazard





UNDRR
UN Office for Disaster Risk Reduction

*"**A dangerous phenomenon**, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage. This event has **a probability of occurrence within a specified period of time and within a given area and has a given intensity.**" (UN-ISDR, 2009)*

The expected losses in a given area and period of time (e.g. annual) for a specific set of elements-at-risk as a consequence of a specific hazard scenario with a specific return period.

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H

$H_{T:Hs}$ $H_{L:Hs}$

HAZARD
potentially damaging physical event, phenomenon and/or human activity, which may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation.

NATURAL HAZARDS
Natural processes or phenomena occurring in the biosphere that may constitute a damaging event.
Natural hazards can be classified by origin in: geological, hydrometeorological or biological.

ORIGIN	PHENOMENA / EXAMPLES
Geological hazards Natural earth processes or phenomena in the biosphere, which include geological, neotectonic, geophysical, geomorphological, geotechnical and hydrogeological nature.	• Earthquakes, tsunamis; • Volcanic activity and emissions; • Mass movements i.e.: landslides, rockslides, rockfall, liquefaction, submarine slides; • Subsidence, surface collapse, geological fault activity.
Hydrometeorological hazards Natural processes or phenomena of atmospheric, hydrological or oceanographic nature.	• Floods, debris and mud flows; • Tropical cyclones, storm surges, thunder/hailstorms, rain and wind storms, blizzards and other severe storms; • Drought, desertification, wildland fires, heat waves, sand or dust storms; • Permafrost, snow avalanches.
Biological hazards Processes of organic origin or those conveyed by biological vectors, including exposure to pathogenic micro-organisms, toxins and bioactive substances	Outbreaks of epidemic diseases, plant or animal contagion, and extensive infestations.

https://www.adrc.asia/publications/LWR/LWR_pdf/Chapter%202%20Section%202_1.pdf

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VULNERABILITY

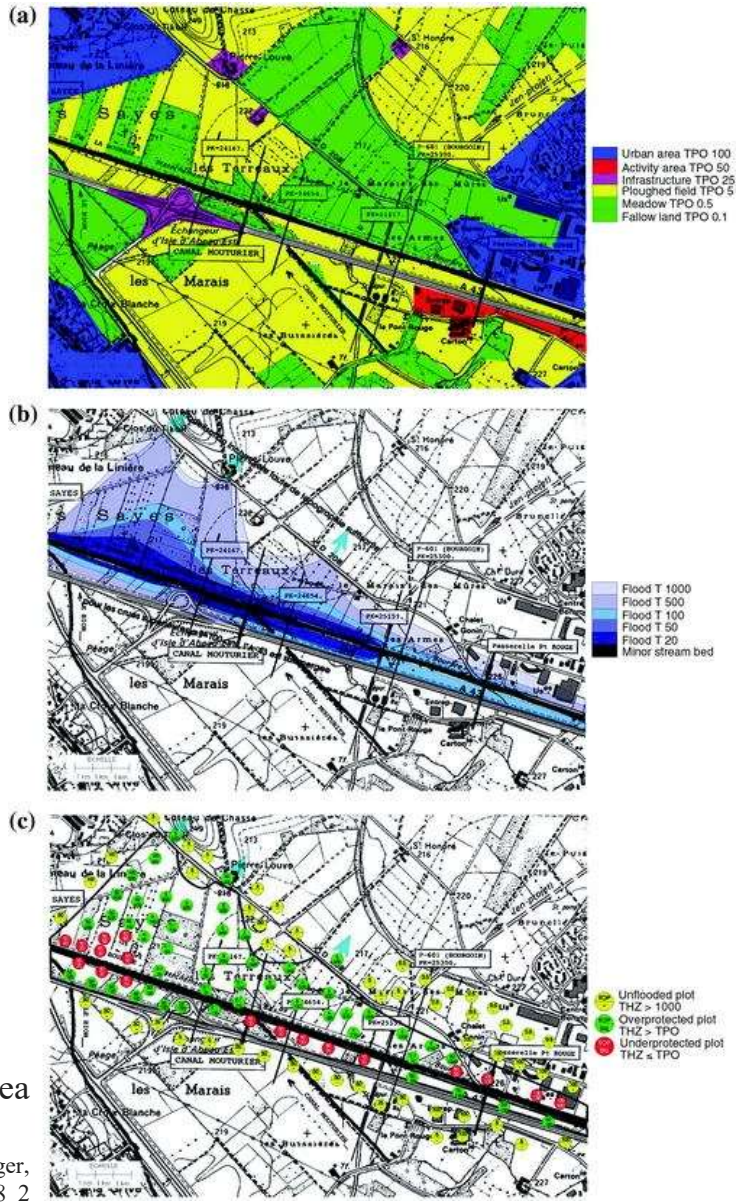
V

$V_{Es|Hs}$

- To define a full set of economic, social, cultural, psychological, etc., factors have to be taken into consideration

- It involves individual to political perceptions, determining the operational choices made by a country or society to ensure protection from foreseen risks

- The conditions determined by **physical, social, economic and environmental** factors or processes, which increase the susceptibility of a community to the impact of hazards.



Vulnerability (a), hazards (b) and risk (c) maps for the same area

Gilard, O. (2016). Hazards, Vulnerability and Risk. In: Torquebiau, E. (eds) Climate Change and Agriculture Worldwide. Springer, Dordrecht. https://doi.org/10.1007/978-94-017-7462-8_2

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VULNERABILITY

•**Physical Vulnerability**: meaning the potential for physical impact on the physical environment - which can be expressed as elements-at-risk (E). The degree of loss to a given E from the occurrence of a natural phenomenon of a given magnitude and expressed on a scale from 0 (no damage) to 1 (total damage)".

•**Economic vulnerability**: the potential impacts of hazards on economic assets and processes (i.e. business interruption, secondary effects such as increased poverty and job loss) Vulnerability of different economic sectors.

	Human - social	Physical	Economic	Cultural Environmental
Direct losses	• Fatalities • Injuries • Loss of income or employment • Homelessness	• Structural damage or collapse to buildings • Non-structural damage and damage to contents • Structural damage infrastructure	• Interruption of business due to damage to buildings and infrastructure • Loss of productive workforce through fatalities, injuries and relief efforts • Capital costs of response and relief	• Sedimentation • Pollution • Endangered species • Destruction of ecological zones • Destruction of cultural heritage
Indirect losses	• Diseases • Permanent disability • Psychological impact • Loss of social cohesion due to disruption of community • Political unrest	• Progressive deterioration of damaged buildings and infrastructure which are not repaired	• Economic losses due to short term disruption of activities • Long term economic losses • insurance losses weaken-ing the insurance market • Less investments • Capital costs of repair • Reduction in tourism	• Loss of biodiversity • Loss of cultural diversity

•**Social vulnerability**: the potential impacts of events on groups such as the poor, single parent households, pregnant or lactating women, the disabled, children, minorities, and elderly; consider public awareness of risk, ability of groups to self-cope with catastrophes, and status of institutional structures designed to help them cope.

•**Environmental vulnerability**: the potential impacts of events on the environment(flora, fauna, ecosystems, biodiversity).

Table: Types of losses associated with different types of vulnerabilities (highlighted the most frequent ones)

https://www.cdema.org/virtuallibrary/index.php/charim-hbook/methodology/5-risk-assessment/5-3-vulnerability

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ELEMENT AT RISK E_{ES}

Elements at risk encompass everything exposed to a hazard that could be damaged or affected. This includes:

•**People**: Lives, health, and social well-being.

•**Property**: Infrastructure, homes, businesses, and crops.

•**Ecosystems**: Wetlands, forests, and biodiversity.

•**Economy**: Livelihoods, industries, and services that could face disruptions.

Identifying the elements at risk is crucial for conducting comprehensive vulnerability assessments and prioritizing risk reduction measures.

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EXAMPLE: Risk of Urban Flooding

$$R_S = f(H, V, E) = H_{T:Hs}\, H_{L:Hs}\, V_{Es|Hs}\, E_{Es}$$

- $H_{(T:Hs)}$ and $H_{(L:Hs)}$: ……
- $V_{(Es\ |\ Hs\ )}$: ……
- E_{Es} : ……

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RISK	UNCERTAINTY
Relates to **known** and **measurable** probabilities	Involves **unknown** probabilities and **unpredictable** outcomes
Can be quantified and assessed objectively	**Difficult to quantify or assess** due to lack of information
Arises from **identifiable** events or situations	Arises from **ambiguity and lack** of information
Involves known potential outcomes and their likelihoods	Involves unknown potential outcomes and their probabilities
Allows for calculation of expected values and probabilities	Does not allow for precise calculations or predictions
Can be managed and mitigated **through risk management strategies**	Cannot be fully managed or eliminated
Provides a basis for decision-making and planning	Requires adaptive and flexible approaches
Involves both positive and negative consequences	Can lead to both opportunities and threats
Associated with potential losses or gains	Associated with ambiguity and limited information

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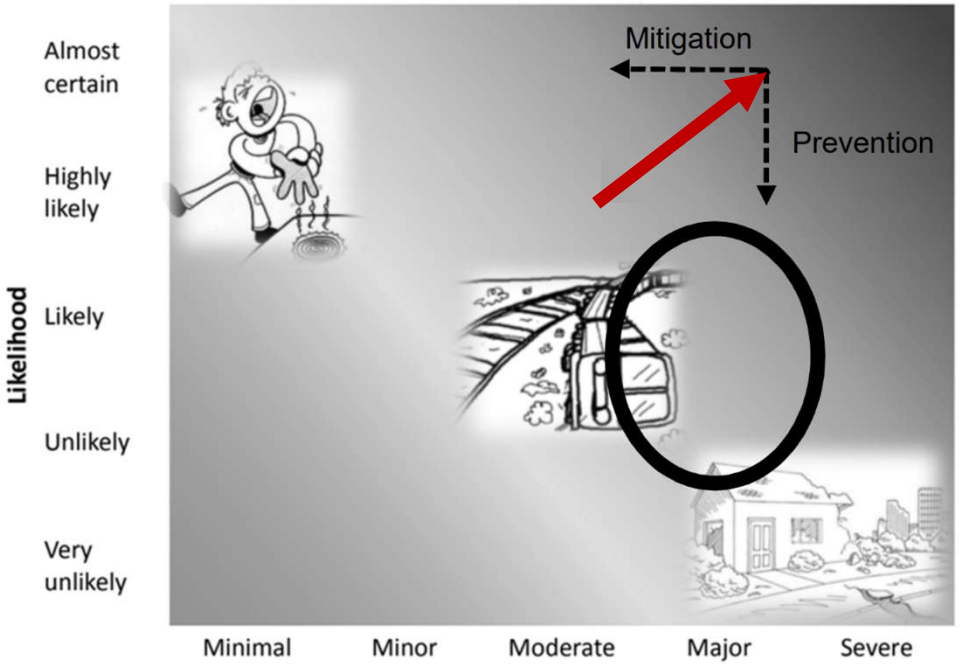
Two components determine the risk:

1. **Probability** of occurrence

2. **Consequences** or **magnitude**



Risk can be reduced with via:

1. PREVENTIVE strategies → likelihood

2. MITIGATIVE strategies → consequences

3. RIST TRANSFER strategies (PRIVATE) → transfer costs

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- Understanding the values and concerns arising in a specific context is fundamental because individuals rarely consider all things equal
- **Decision-makers** require **information about the preferences and priorities** of potentially affected individuals or groups of individuals toward the **relevant set of risks, benefits, and costs**
- Values may affect how we feel about a source of risk and the priority we place on its management

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- Relative importance of risks and related risks (cascade)
- Perception of deriving benefits and costs
- Timing of the expected impacts
- Uncertainties on hazard occurrence, vulnerability, set of exposed elements
- Understanding of realistic alternatives
- ……

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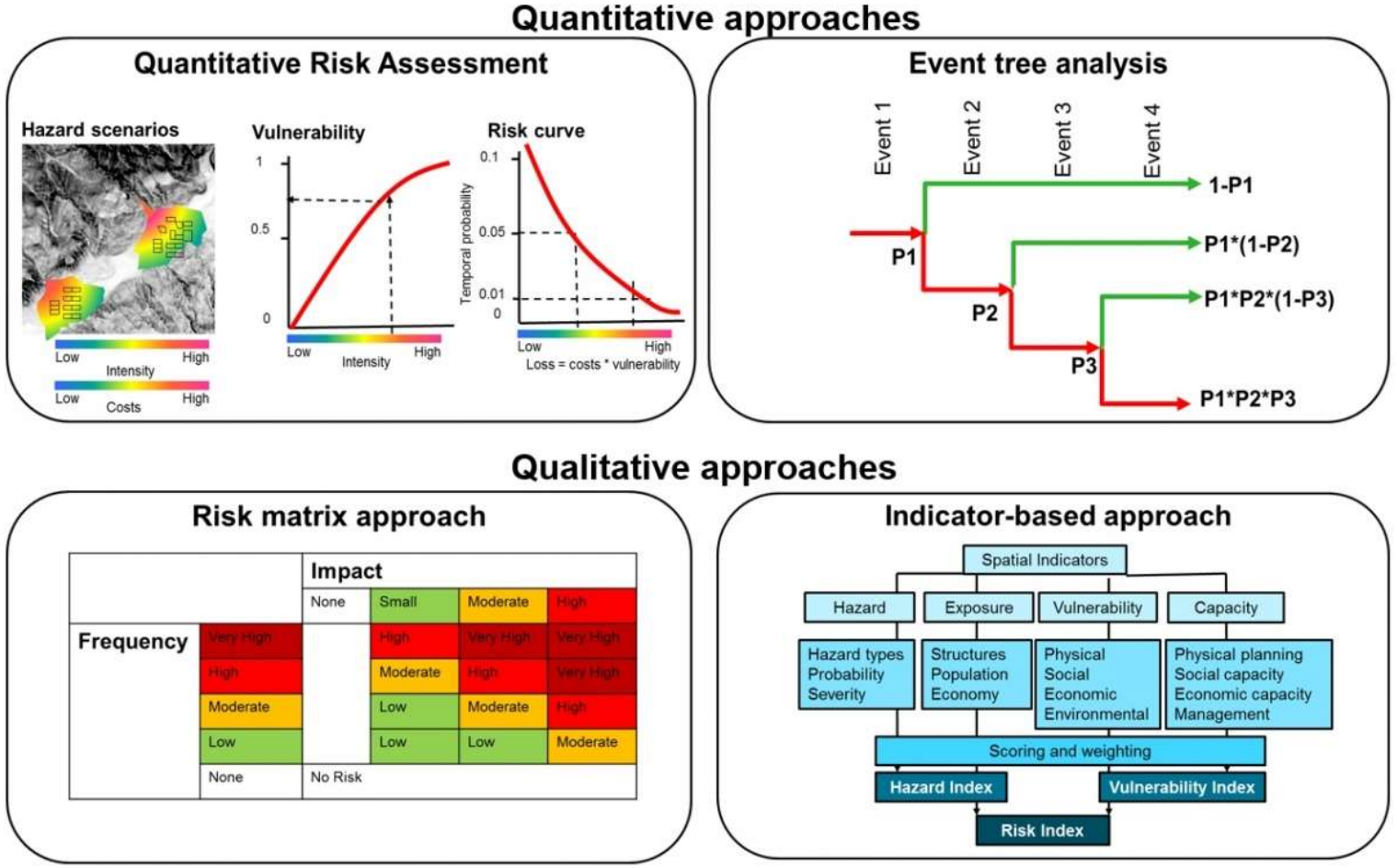
RISK ASSESSMENT AND MAPPING

QRA = Quantitative risk assessment, ETA = Event-Tree Analysis, RMA = Risk matrix approach, IBA = Indicator-based approach



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RISK ASSESSMENT AND MAPPING

METHOD	ADVANTAGES	DISADVANTAGES
Quantitative risk assessment (QRA)	Provides quantitative risk information that can be used in Cost-benefit analysis of risk reduction measures.	Very data demanding. Difficult to quantify temporal probability, hazard intensity and vulnerability.
Event-tree analysis	Allow modelling of a sequence of events, and works well for domino effects	The probabilities for the different nodes are difficult to assess, and spatial implementation is very difficult due to lack of data.
Risk matrix approach	Allows to express risk using classes instead of exact values, and is a good basis for discussing risk reduction measures.	The method doesn't give quantitative values that can be used in cost-benefit analysis of risk reduction measures. The assessment of impacts and frequencies is difficult, and one area might have different combinations of impacts and frequencies.
Indicator-based approach	Only method that allows to carry out a holistic risk assessment, including social, economic and environmental vulnerability and capacity.	The resulting risk is relative and doesn't provide information on actual expected losses.

https://www.cdema.org/virtuallibrary/index.php/charim-hbook/methodology/5-risk-assessment/5-5-risk-assessment-methods

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- Price vs Value of the element at risk
- What is value?
- How can values be ‘measured’?
- Value of what, for whom, for what, ….
- Private costs and benefits vs social costs and benefits

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