Government of Nepal
Ministry of Home Affairs
National Disaster Risk Reduction & Management Authority

ICIMOD

CONSULTATIVE MEETING ON

Development of multi-hazard risk and loss and damage assessment framework for HKH

8–9 December 2022

#HKHmultihazardL&D

Methodological Framework of the Multi-hazard Risk Assessment in the HKH Region

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Background

- Enable sustainable and resilient mountain development for improved and equitable livelihoods through knowledge and regional cooperation.

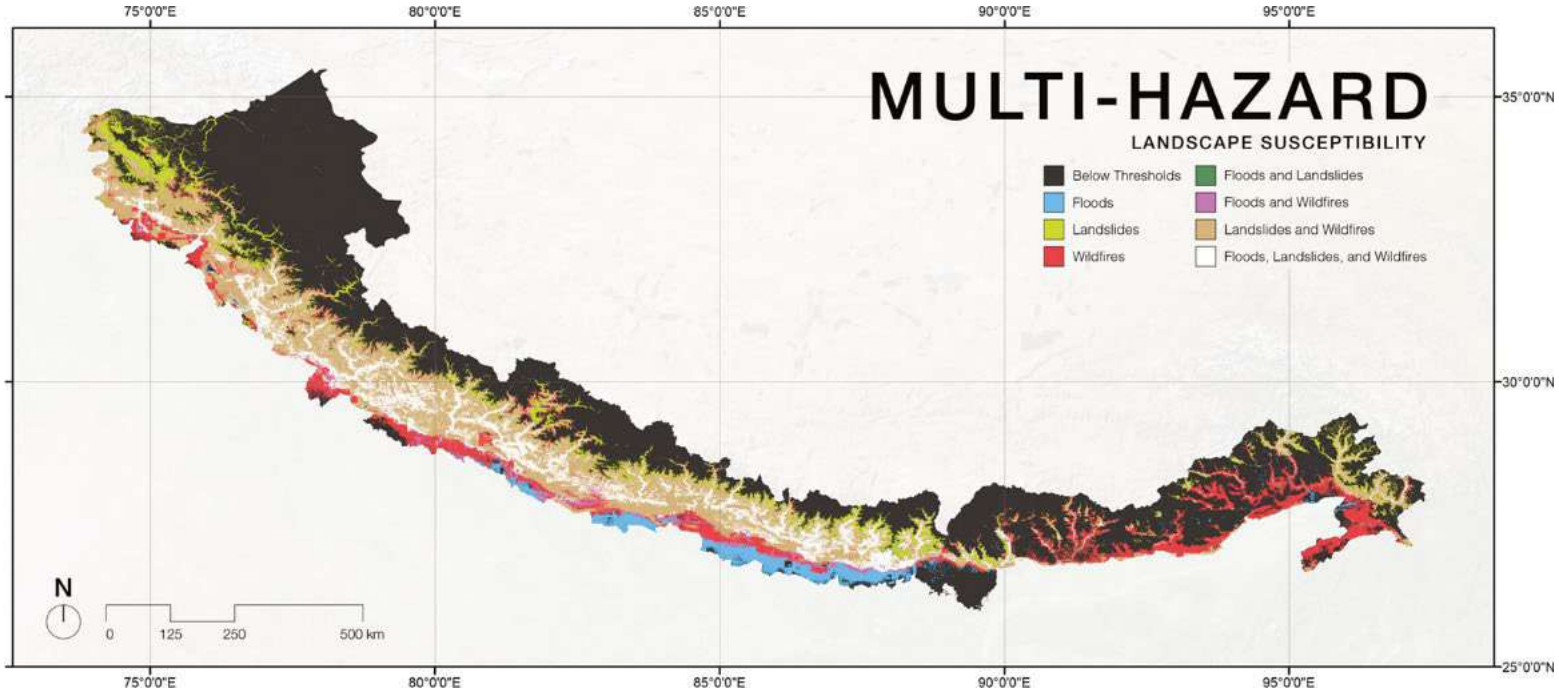
- ICIMOD is a regional intergovernmental learning and knowledge sharing centre serving the eight regional member countries of the Hindu Kush Himalaya (HKH) – Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan.

- Provide a platform for researchers, practitioners, and policy makers from the region and around the globe to generate and share knowledge, support evidence-based decision making, and encourage regional cooperation

Study area

- The Hindu Kush Himalaya (HKH) system stretches around 3500km, covering an area of almost 4.2 million km^2
- The ten major river basins in the HKH had a population around 1.9 billion in the year 2015 with about 240 millions in the mountain and hills (Sharma et al., 2019).
- Region receives intense precipitation in the central and eastern Himalayas between the months of June to September while the western Himalayas receives during winter, resulting into the triggering of a number of natural hazards.

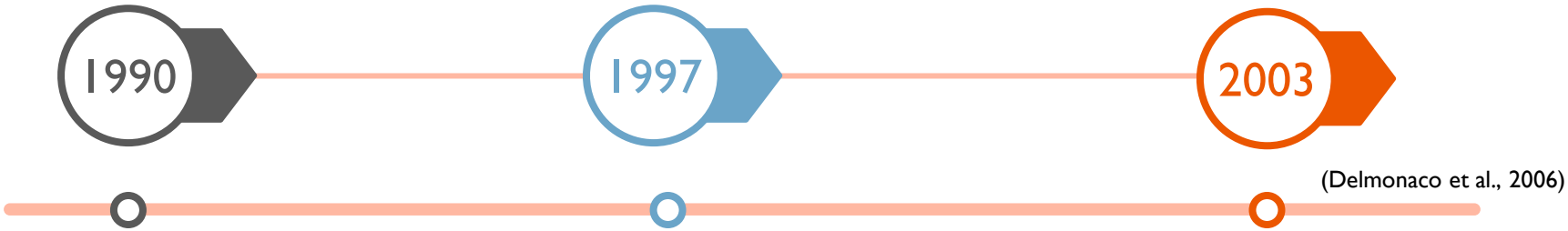
Study area



Rusk, J., Maharjan, A., Tiwari, P., Chen, T. H. K., Shneiderman, S., Turin, M., & Seto, K. C. (2022). Multi-hazard susceptibility and exposure assessment of the Hindu Kush Himalaya. *Science of The Total Environment*, *804*, 150039. https://doi.org/10.1016/J.SCITOTENV.2021.150039

Evolution of Multi-hazard risk Assessment

Evolution of Multi-hazard risk Assessment



(Delmonaco et al., 2006)

DDRM (France) multi-risk approach
Délégation aux Risques Majeurs (DDRM)

- multi risk procedure: seven classes of risk
- components of exposed elements and vulnerability were ignored
- no attention to exposed elements and vulnerability as fundamental parameters

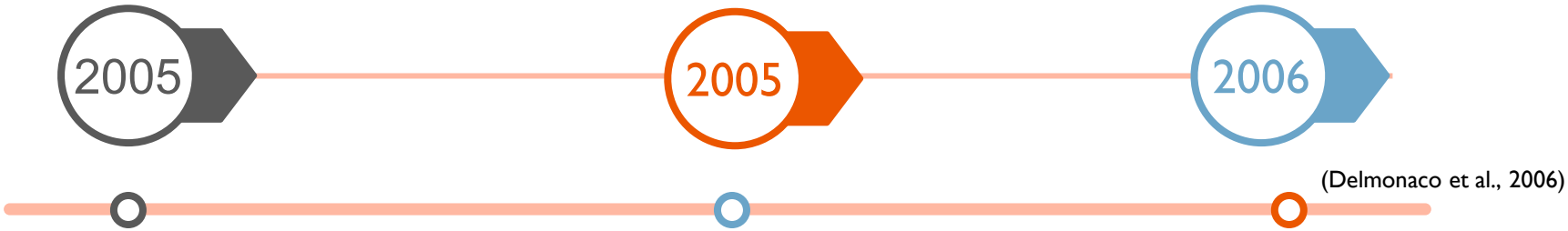
TIGRA Project
The Integrated Geological Risk Assessment

- a feasibility project for understanding the possibility to realize tools and procedures for a successful land planning and management of territory
- MHRA: by means of economic indexes reporting the expected economic losses resulting from each hazards

TEMRAP
The European Multi-Hazard Risk Assessment Project

- Comprehensive investigation on the environment and human structures and infrastructures
- Exposure & Vulnerability assessment procedures were limited
- Expected Potential = Prob.of occurrence * composed vulnerability *Coeff of exposure

Evolution of Multi-hazard risk Assessment



ESPON multi-hazard approach
European Spatial Planning and Observation Network

- The risk of hazards is a result of the hazard potential and the vulnerability.
- Delphi method: Based on a weighted combination of population, GDP (national and regional) and fragmented natural areas.
- Tool to define preliminary strategies and policies at European level.

World Bank Methodology - Natural Disaster Hotspots

- Impact-weighted multi-hazard disaster hotspot index.
- Global scale and makes the basis of grid GIS environment of spatial representation of dataset
- Rather than one single indicator, build up a series of indexes of increasing complexity

ARMONIA
Applied multi-risk mapping of natural hazards for impact assessment

- Harmonized and innovative methodological approach
- Fundamental tool to reduce losses from natural disasters through correct land-use planning and management of rural areas of further development, rural areas with infrastructures and urban areas

Evolution of Multi-hazard risk Assessment

- The European Multi-Hazard Risk Assessment Project
- Risk is defined as a function of severity and probability,
- Severity = f (Exposure, Vulnerability (intensity)
- Probability = f (Frequency, Time)
- Total Risk Index = (Risk Score/Maxm Risk Score) * Community Vulnerability Index

(Delmonaco et al., 2006)

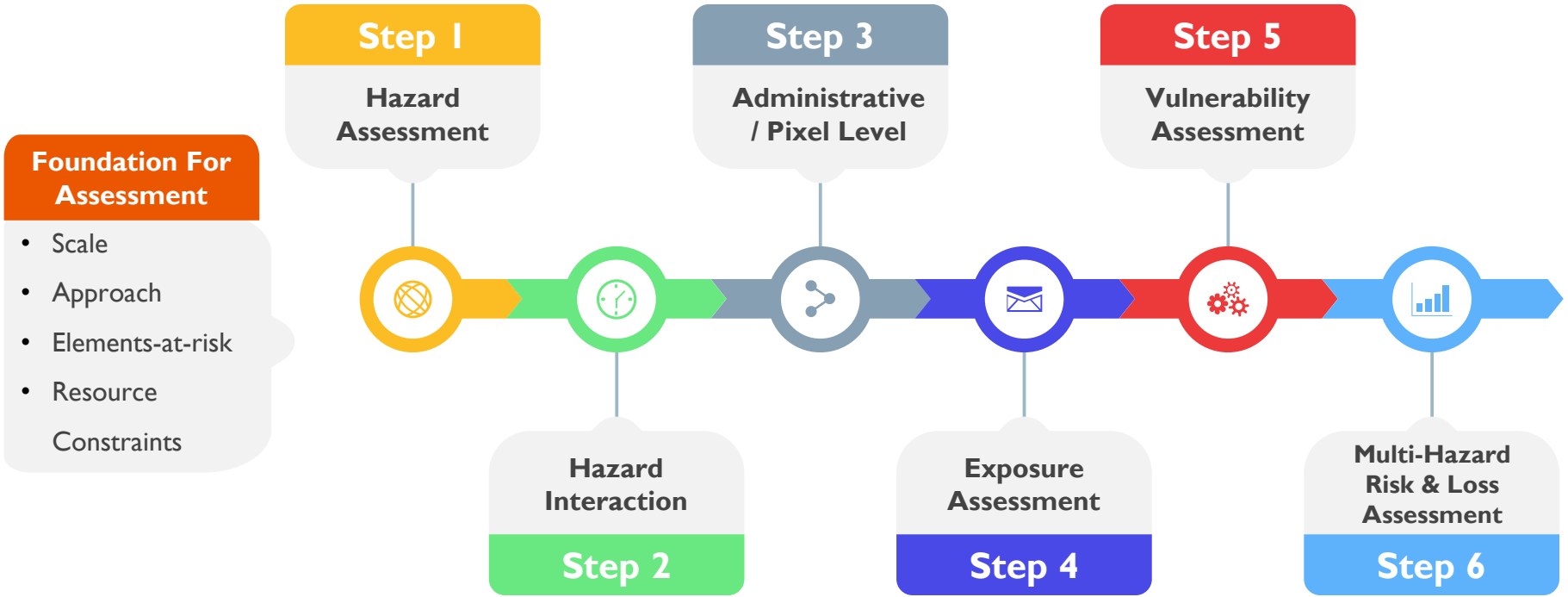
- an integrated approach
- Risk is the function of Hazard, Vulnerability and Amount .
- Frequency Class, Exposure Analysis, Physical Vulnerability and Risk Analysis was carried out.
- Hazard Interaction

C. J. Westen, 2019)

Multi-hazard risk Assessment Tools

Approaches	Details
HAZUS MH	• Initially Developed by FEMA focusing the US Continent, Adopted by different emergency management organizations in Singapore, Canada, Australia, Pakistan, Taiwan • Multi-hazard tool: Estimating potential losses from EQ, floods, and hurricanes. • Environment to estimate physical, social and economic impacts of disasters. • Large quantity of the input data and needs adaptation for use at different levels of details
CAPRA	• Central American Probabilistic Risk Assessment and is an open source platform for the risk assessment • **Modules:** Hazard, Exposure, Physical Vulnerability**,** Loss, Additional • ERN Flood, ERN-Landslide, ERN-Vulnerability
RISK CHANGE	• By Geoinformatics Centre, Asian Institute of Technology (AIT) and ITC University of Twente. • Open-source tool for multi-hazard risk assessment and decision making which allows the end-users and stakeholders to assess and evaluate the prevailing risks in a designated area and decide the best available risk reduction alternatives.

Steps for Multi-hazard risk Assessment



Multi-hazard risk Assessment Framework

Hazard Interaction

Hazard Interaction	Explanation
Independence	Pure coincidence, Triggering event do not interact Both spatial and temporal overlay of the impacts of two hazards, but no triggering or dependence relationship. Eg: Flood and Landslide
Compounding Events	For the independent events happening close Eg: Landslide and floods
Coupled Events	There will be the same trigger. Same area might be affected. (Eg: Flash floods and Debris Flows)
Domino or cascading	Primary and a secondary hazard. Any hazard might trigger zero, one or more hazards. The second hazard might be the same or different. Eg: First Rainfall, then Landslide Damming and followed by flood
Conditional	One hazard changing the condition for the next hazard for eg: Forest Fire and Landslide

Multi-hazard risk Assessment Framework

Hazard Interaction

	River Flooding	GLOF	Landslides	Debris Flow	Forest Fire
River Flooding		Caused by	Coupled	Coupled	Independent
GLOF			Chain	Chain	Independent
Landslides				Chain	Independent/ Conditional
Debris Flow					Independent/ Conditional
Forest Fire					

relationship should be read starting from the left and reading horizontally.

Foundation for Assessment

Working in the data scarce region

- Scale
  - National/Regional
  - Local
- Approach
- Elements-at-risk
- Resource Constraints

Multi-hazard risk Assessment Approach

A. Qualitative Method

- Combines hazard map with the elements-at-risk at the GIS environment
- Development of simple-risk matrix.
- Initial screening process to identify hazards and risks.
- Data scarce situation or the quantitative variables are not available.

- **Community Perception Model (CPM):**
  - intuitive judgement of the individual and groups subjected to risk
  - Assesses Social, Physical, Economic and Environmental vulnerabilities in consultation with the main stakeholders in the community.
  - **Risk, R** = H x (V x cp), where
    H is Hazard or likelihood (or probability), V is the vulnerability/impact/severity; and cp is community perception of the impact of disasters (Ferrier & Haque, 2003).

Multi-hazard risk Assessment Approach

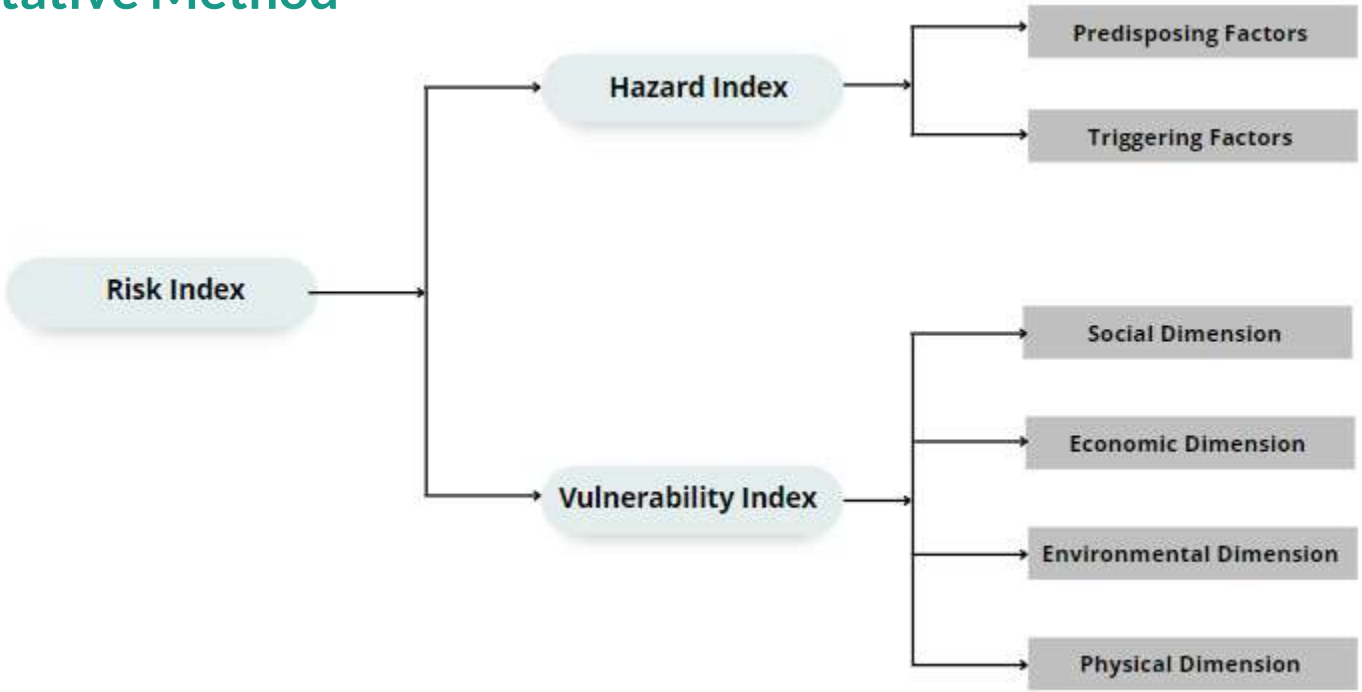
A. Qualitative Method

- **Pressure and Release (PAR) Model**
  - Assess the disaster risk considering the hazards, identification of the root causes, dynamic pressures (that translate root causes into unsafe conditions), and unsafe conditions (Birkmann, 2006).

- **Spatial Multi-Criteria Evaluation (SMCE)**
  - Uses matrices to calculate a vulnerability index and give qualitative classes (H, M & L)
  - Hazard index combined with the vulnerability index.
  - **Indicators,** processed, analyzed, normalized and standardized according to its contribution to the hazard and vulnerability.
  - Indicators weighed using pair-wise comparison matrix or Analytical Hierarchical Process (AHP) controlled through the consistency index, combined to obtain the final risk map.

Multi-hazard risk Assessment Approach

A. Qualitative Method



Multi-hazard risk Assessment Approach

B. Quantitative Method

- Assessment of risk in the quantitative terms either as probabilities, or expected losses.
- **Engineering Approach** and focuses on the evaluation of the direct physical losses resulting from the impact of the hazards.
- The quantitative approach of multi-hazard risk assessment is also based on vulnerability surface and joint return period of hazards to assess the risk
- **Risk** a function of the probability of the hazard occurrence, the probability of the spatial impact, vulnerability and the economic value of the exposure elements Wei et al. (2022)

Multi-hazard risk Assessment Approach

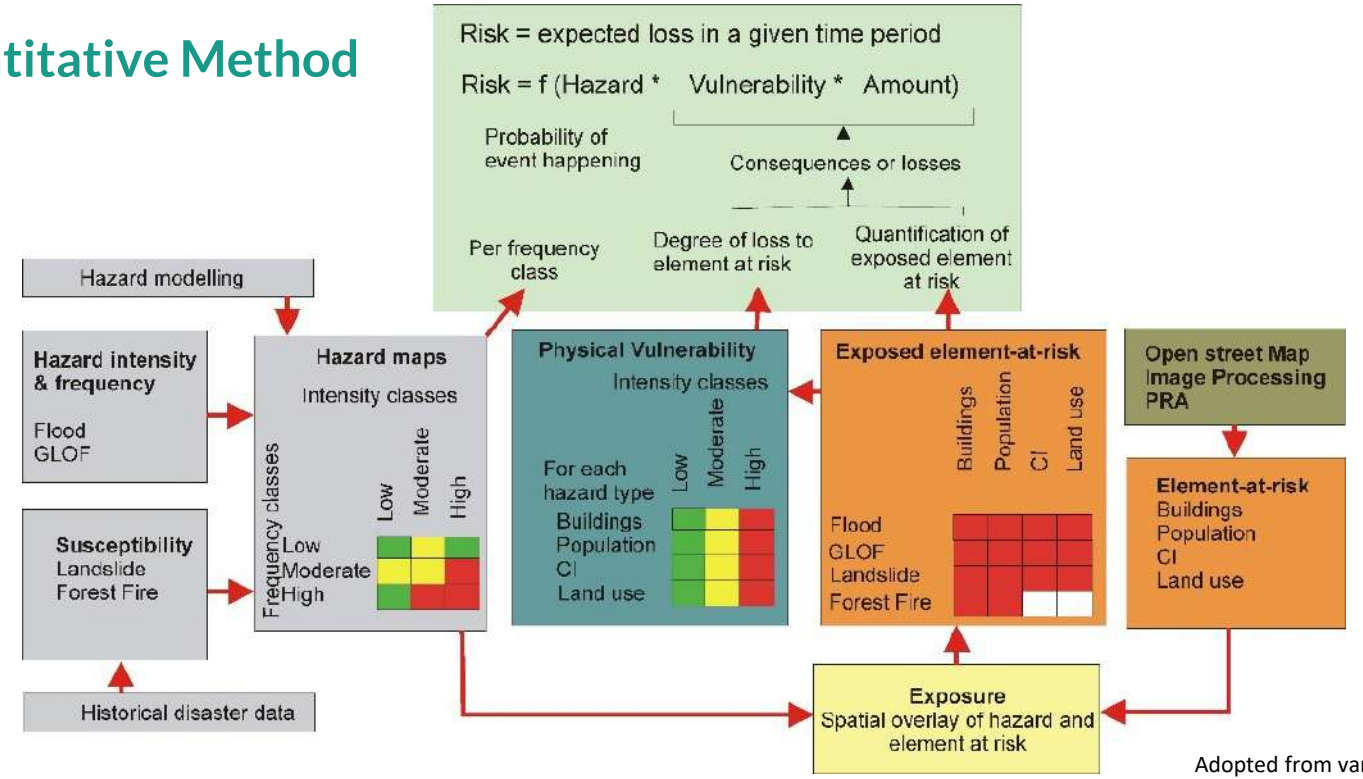
B. Quantitative Method

- **Probabilistic modelling**
  - (taking into account the effect of all possible scenarios):
  - Scenario of damage and losses due to the multiple sources of hazards
  - Probability distribution of hazard magnitudes and different return periods for hazards like floods

- **Deterministic/Scenario Modelling** :
  - **Hazard scenarios:** Under similar conditions or regular recurrence intervals, the impacts of each hazards under similar conditions can be assessed.

Multi-hazard risk Assessment Approach

B. Quantitative Method



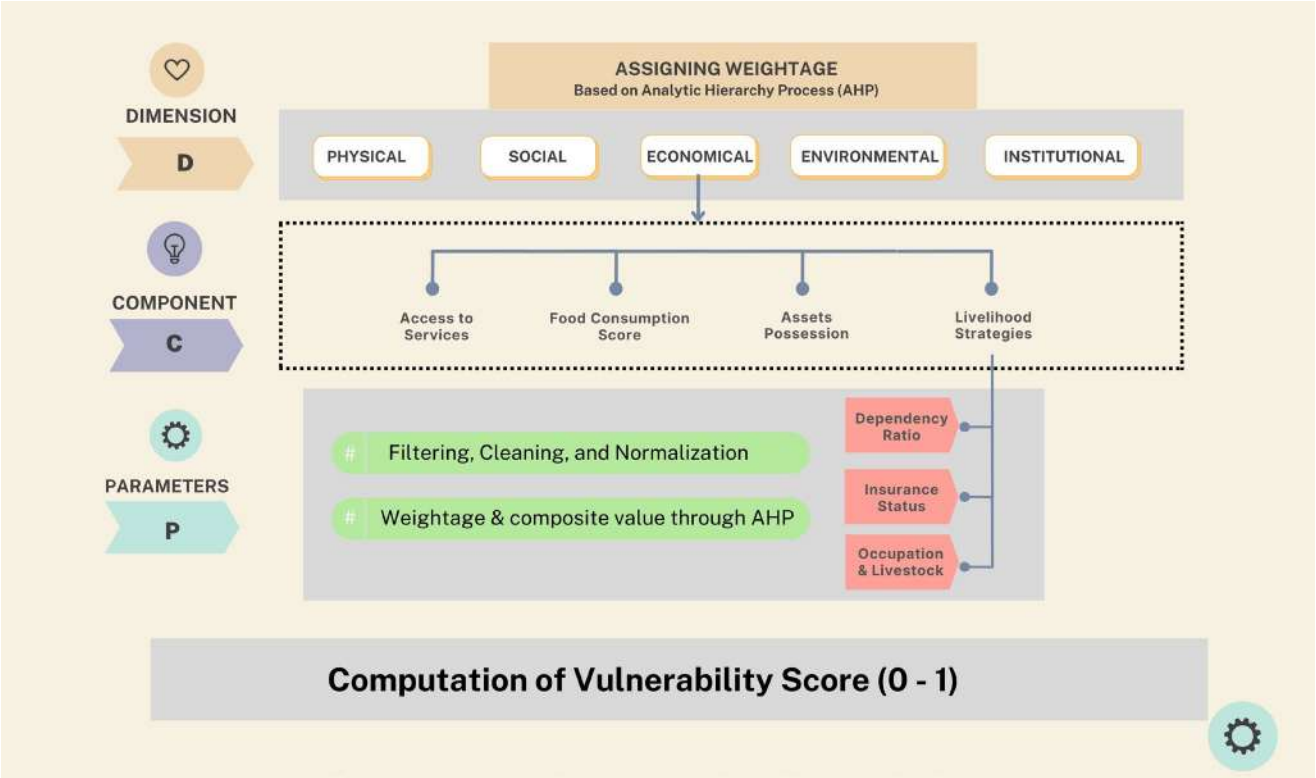
Adopted from van Westen, 2019

Multi-hazard risk Assessment Scale

Elements-at-risk

Population		
Scale	Attributes	Sources
National/Regional Scale	• Population Count • Spatial Location, • Population Density	National Census Data, Global Human Settlement Layer GHSL
Local Scale [Higher attributes of data]	• Population Count • Population Distribution in space and time • Age distribution • Gender Distribution • Ethnic Groups and Marginalized Community • Person with Disability • Income Distribution	Household Survey, Municipality/Local Unit Profile

Multi-hazard risk Assessment Scale



Multi-hazard risk Assessment Scale

Elements-at-risk

Building Footprints		
Scale	Attributes	Sources
National/Regional Scale	• Building Counts, • Spatial Location, • Typology of Buildings	National Census Data, Open Street Map, Cadastral Data
Local Scale [Higher attributes of data]	• Spatial Location, • Construction Typology, • Construction materials, • Roof Types, • Number of floors, • Occupancy in House, • Functional Use of Buildings • Replacement Cost of Structure	Household Survey, Structural Assessment Surveys, Municipal/Digital Profiles, 3D Building Maps, Street View Maps

Multi-hazard risk Assessment Scale

Elements-at-risk

Agricultural Area		
Scale	Attributes	Source
National/Regional Scale	Agriculture area	LULC
Local Scale [Higher attributes of data]	• Type of agricultural crops, • Status or stage of the crop production, • Classification of crops (Food/Cash) • Availability of Crop Insurance, • Livestock fertilizer consumption, • Irrigation status • No of. Tube Wells,	Household Survey, Municipal / Local Digital Profiles

Multi-hazard risk Assessment Scale

Elements-at-risk

Transportation		
Scale	Attributes	Source
National Scale	Roads in km Railways/metro in km Harbor facilities Airport facilities	National Census Data, Digitization over Satellite images, Transportation Network Profile
Local Scale [Higher attributes of data]	• Type of Roads [Strategic, Materials], • Distance in km, • Status of Completion	Municipality Transport Master Plan (MTMP), Surveys

Multi-hazard risk Assessment Scale

Elements-at-risk

Other Critical Infrastructures

Hydropower,

Water Supply Lines,

Electricity Lines,

Telecommunication Lines,

Communication Tower,

Sewerage Lines,

Emergency Shelters,

Schools,

Hospitals,

Police Station,

Ware House, etc.

DATA TYPE

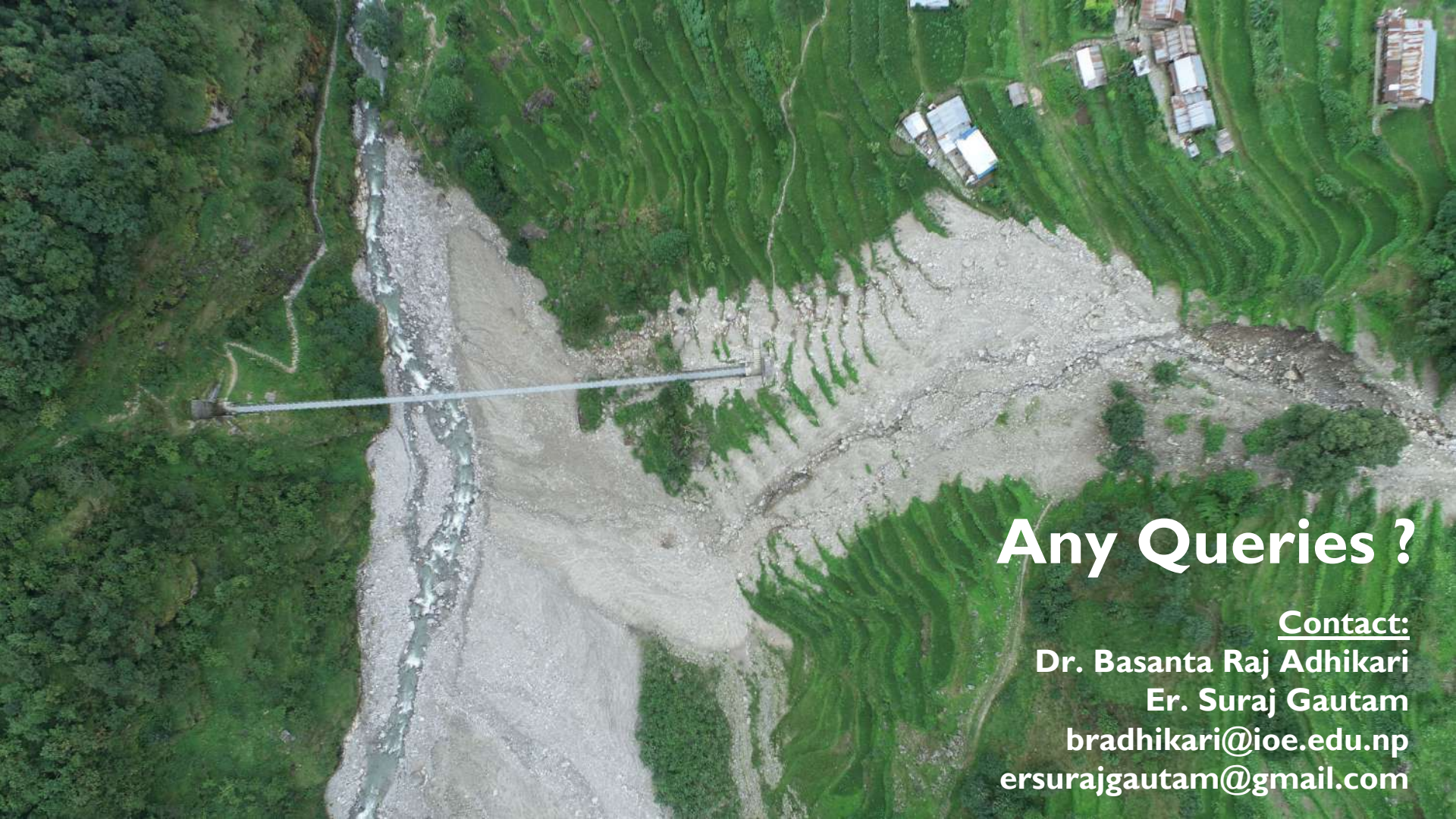
Data Type: Digital Elevation Model		
Copernicus Global 30m	(DSM) representing the surface of the Earth including buildings, infrastructure and vegetation. flattening of water bodies and consistent flow of rivers has been included.	OpenTopography - Copernicus GLO-30 Digital Elevation Model https://portal.opentopography.org/raster?opentopoID=OTSDEM.032021.4326.3 European Space Agency, Sinergise (2021). Copernicus Global Digital Elevation Model. Distributed by
SRTM 30m (1 arcsecond)	SRTM uses radar observations to construct DEM. void filled data at a resolution of 1 arc-second (30 meters)	https://earthexplorer.usgs.gov/
ASTER	Created by stereo correlation of more than 1.2 million individual ASTER stereo scenes contained in the archive.	https://search.earthdata.nasa.gov/search/ (ASTER Global Digital Elevation Model V002) or https://www.jspacesystems.or.jp/ersdac/GDEM/E/
ALOS PALSAR 12.5m	ALOS (Advanced Land Observing Satellite) mission PALSAR (Phased Array L-band Synthetic Aperture Radar) instrument from 2006 to 2011	https://search.asf.alaska.edu/#/
ALOS Palsar 30m merged with SRTM	Global digital surface model (DSM) with horizontal resolution of approximately 30 meters (basically 1 arcsecond) by PRISM)	ALOS Global Digital Surface Model "ALOS World 3D - 30m (AW3D30)" https://www.eorc.jaxa.jp/ALOS/en/dataset/aw3d30/aw3d30_e.htm

DATA TYPE

Land Cover		
World Cover 20m	Sentinel Asia	https://sentinel-asia.org/EO/EmergencyObservation.html
Worldwide land cover mapping	Global land cover products for 2020 and 2021 at 10 m resolution, developed and validated in near-real time based on Sentinel-1 and Sentinel-2 data.	https://viewer.esa-worldcover.org/worldcover/
Using NDVI	With LANDSAT/SENTINEL	
ESRI Land Cover	10-meter resolution land cover using Sentinel-2	https://www.arcgis.com/home/item.html?id=d6642f8a4f6d4685a24ae2dc0c73d4ac
Land Cover of HKH Region	Consolidated and standardized land cover maps for the Hindu Kush Himalayan region (2000–2021) at the regional level. ICIMOD. (2022)	http://rds.icimod.org/Home/DataDetail?metadataId=197251 1
Regional Land Cover Monitoring System (RLCMS)	Generates spatially seamless and temporally consistent annual land cover maps of the whole HKH region using broad land use categories recommended by the IPCC	http://geoapps.icimod.org/RLCMS

DATA TYPE

Historical Disaster Data		
EM-DAT	• Centre for Research on the Epidemiology of Disasters (CRED) Emergency Events Database (EM-DAT) • contains essential core data on the occurrence and effects of over 22,000 mass disasters in the world from 1900 to the present day	http://www.emdat.be/
DesInventar	Methodological tool for the generation of National Disaster Inventories and the construction of databases of damage, losses and in general the effects of disasters.	https://www.desinventar.net/



Any Queries ?

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