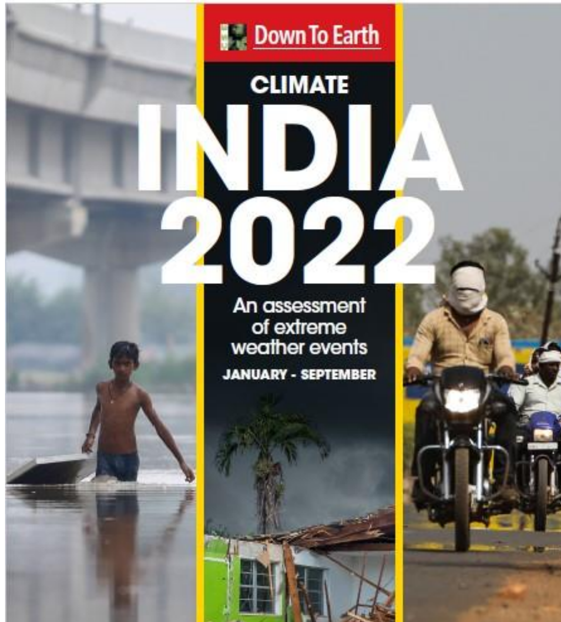
Assessing the “Risks” of Climate Change

13/03/2025

Lecture 19-20

Introduction

- Climate Change (CC) is a reality – effects are complex and widespread
- IPCC AR6 (2021) - Global warming projected to increase by 1 – 1.5 °C (under low GHG emission scenario) and by 5 °C (very high scenario)
    - climate hazards and weather extremes are likely to increase in frequency and severity – serious implications for human and the natural ecosystem
- CC will amplify existing risks and create new risks
- Impacts are unequally distributed; those at most risk are also most exposed and vulnerable



What is climate change risk?

- IPCC defines risk in the context of climate change as “the potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values.

- Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur.

Hypothetical case !

- Which of two regions is at more risk of climate change and its impacts:

  Bangladesh or Canada?”

- Floods or Wildfires or Storms?

“I want to leave early for the airport!”

- Element of risk associated with the action
- There can be consequences of that risk
- Outcome is uncertain –
  - Might face traffic
  - May not reach in time
  - Miss the flight

“Mutual funds are subject to market risks!”

- no way to predict what will happen in the future or whether a given asset will increase or decrease in value
- the market cannot be accurately predicted or completely controlled - no investment is risk-free

- As defined by IPCC, risk in the context of climate change results from dynamic interactions of climate-related hazards with exposure and vulnerability of the affected human or ecological system.

$$\text{Risk} = f\ (\text{H, E, V})$$

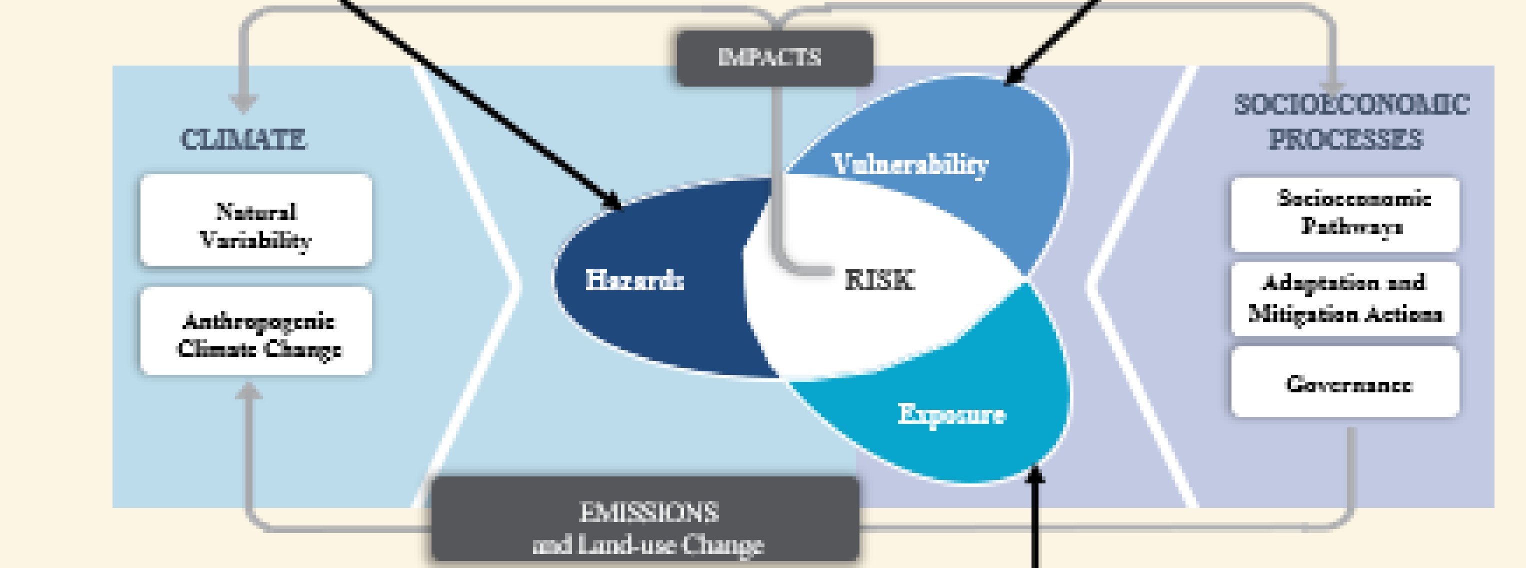
- Hazard (H), Exposure (E), and Vulnerability (V) may each be subject to uncertainty in terms of magnitude and likelihood of occurrence, and each may change over time and space due to socioeconomic development, adaptation responses and human decisions.

*'**Hazard**' is "the potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources."*

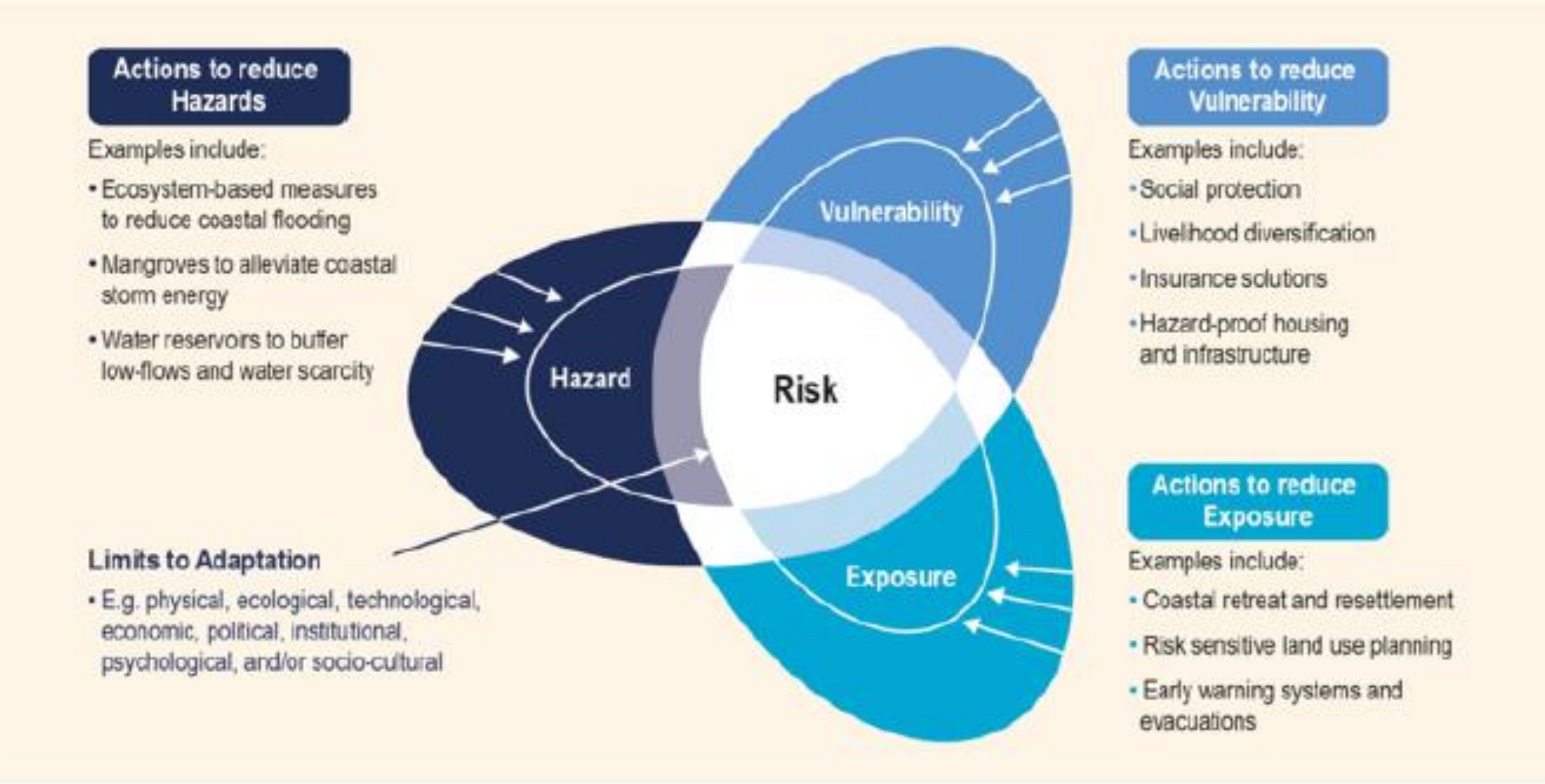
Based on IPCC 2014

'Vulnerability' is considered as a system property representing its "propensity or predisposition to be adversely affected"

- **Sensitivity**
- **Adaptive Capacity**

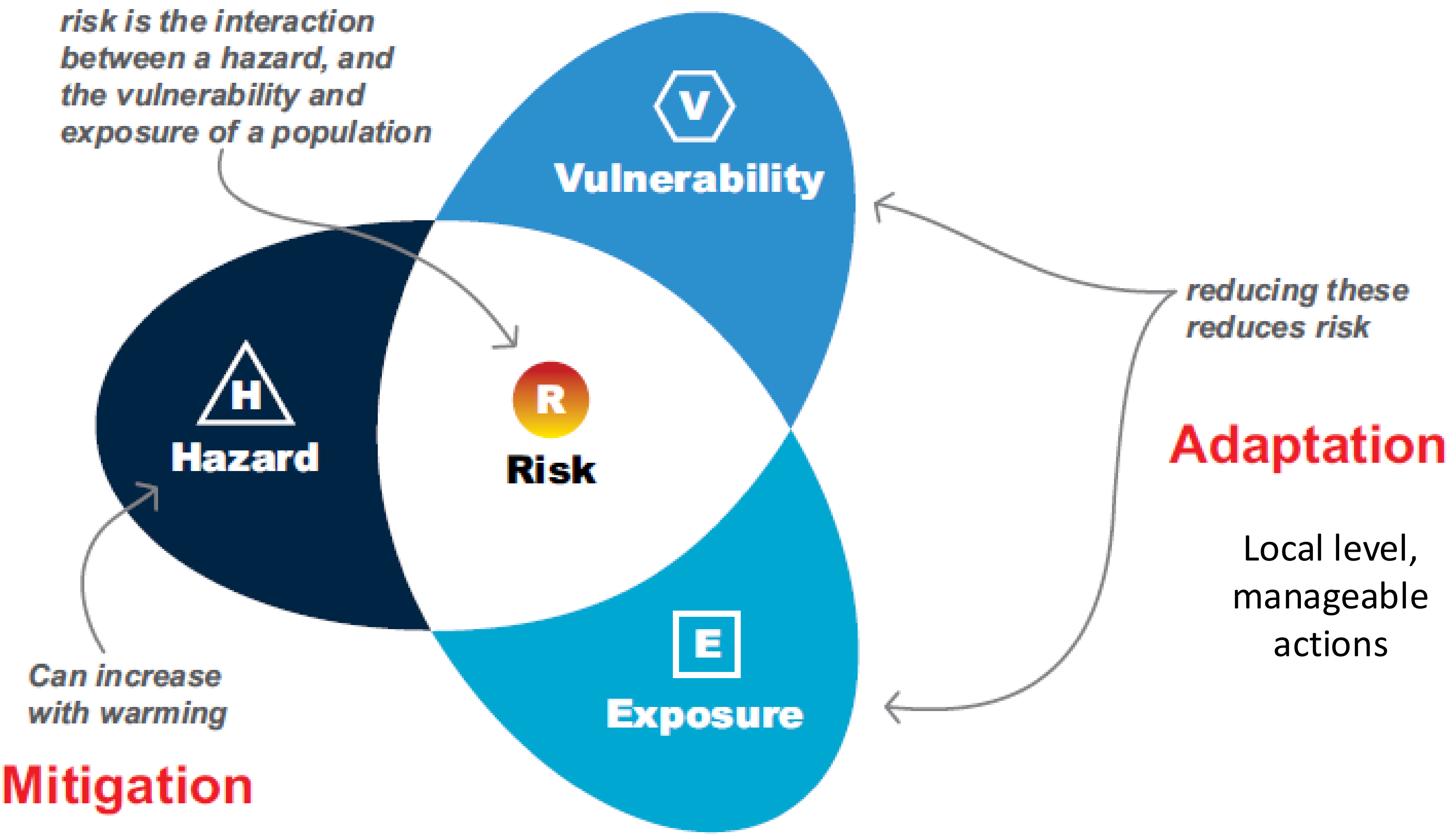


*"**Exposure**" is "the presence of people, livelihoods, species or ecosystems, environmental functions, services and resources, infrastructure, or economic, social or cultural assets in places and settings that could be adversely affected".*



Reducing vulnerability is the first step towards reducing and managing overall risks under current climate variability as well as building resilience in the long run

Takes
collective
effort across
nations



Risks arising from climate change impacts resulting from dynamic interactions (adapted from IPCC Risk Framework (IPCC, 2014))

Definitions and Components of Risk

Risk (R)	Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard.
Hazard (H)	The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. • climate-related physical events such as droughts, floods, hurricanes, heatwaves etc.
Exposure (E)	The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.
Vulnerability (V)	The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

Understanding Exposure and Vulnerability

- Can hazard alone pose a risk?
- Not all hazards pose a risk; it is the exposure of systems that makes hazard a risk; severity of impact depends on the level of exposure.
- Possible to be exposed, but not vulnerable (*floodplain building structure*). Yet necessary to be exposed to be vulnerable to an extreme event.
- Exposure represents the extrinsic property of a system, while vulnerability is intrinsic.

Equally exposed; but least vulnerable dwelling

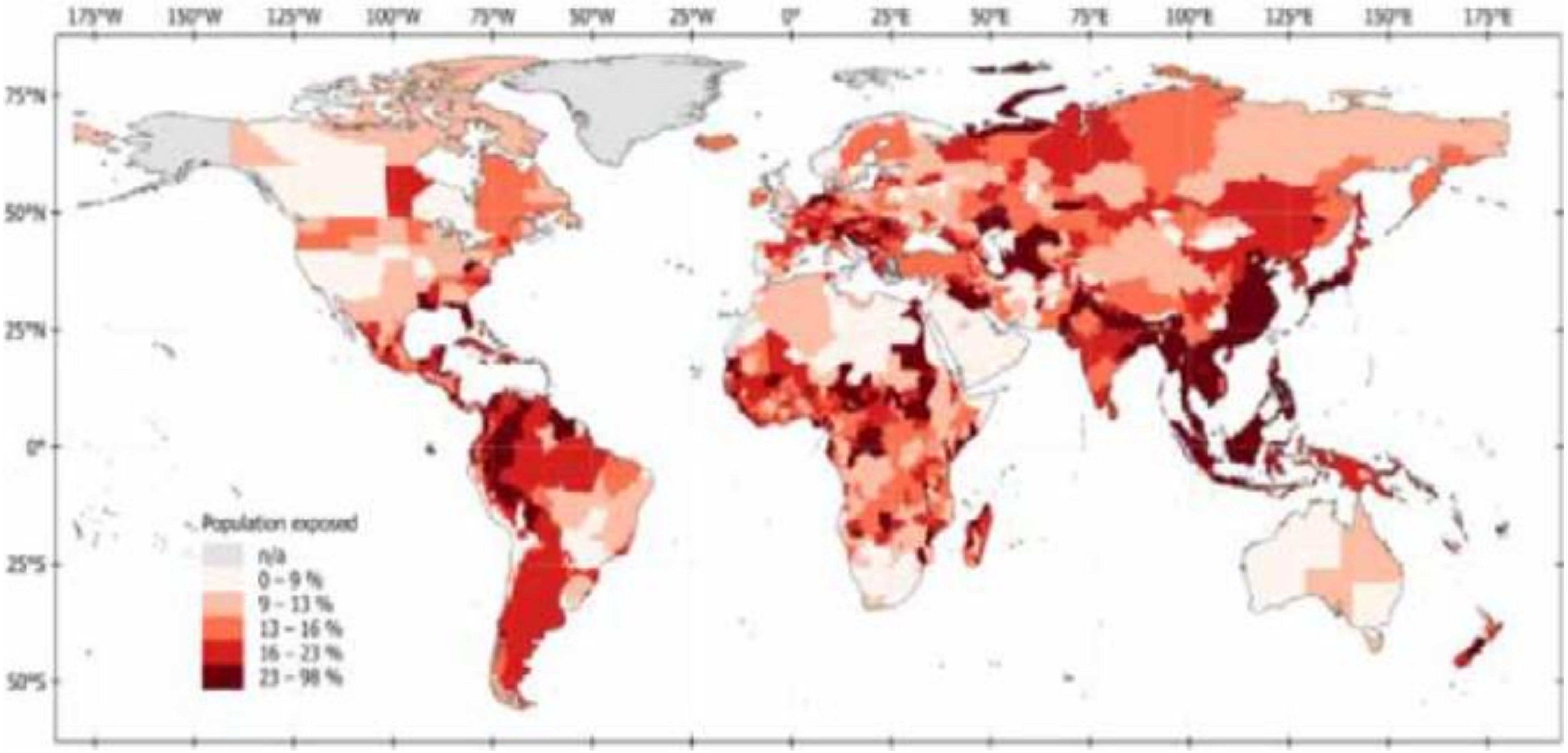
Type of Exposure

Biophysical: related to the topography, geomorphology, landscape etc.

- Exposure of coastal ecosystems to cyclones and tsunamis.

Socio-economic: A region may not be biophysically exposed due to its location but may still be exposed to climate change risks due to lack of adequate capacity to withstand the impacts of climate change.

- Population density, Economic density, Infrastructure



Population exposed to Flood (Source: Rentschler, Salhab and Jafino, 2022)

Exposure continued…

Temporal:

- **Current** - risk assessed considering the current extent of exposure indicators. *Population density for the year 2020.*
- **Climate change projection scenarios** – selected indicators are projected for future periods such as 2030 or 2100 (medium to long-term change). *Population density in the year 2030 or 2100.*

Spatial: location of the system at a place where hazard occurs and causes adverse impacts. *Rural or urban, coastal or plains or mountains*

Vulnerability

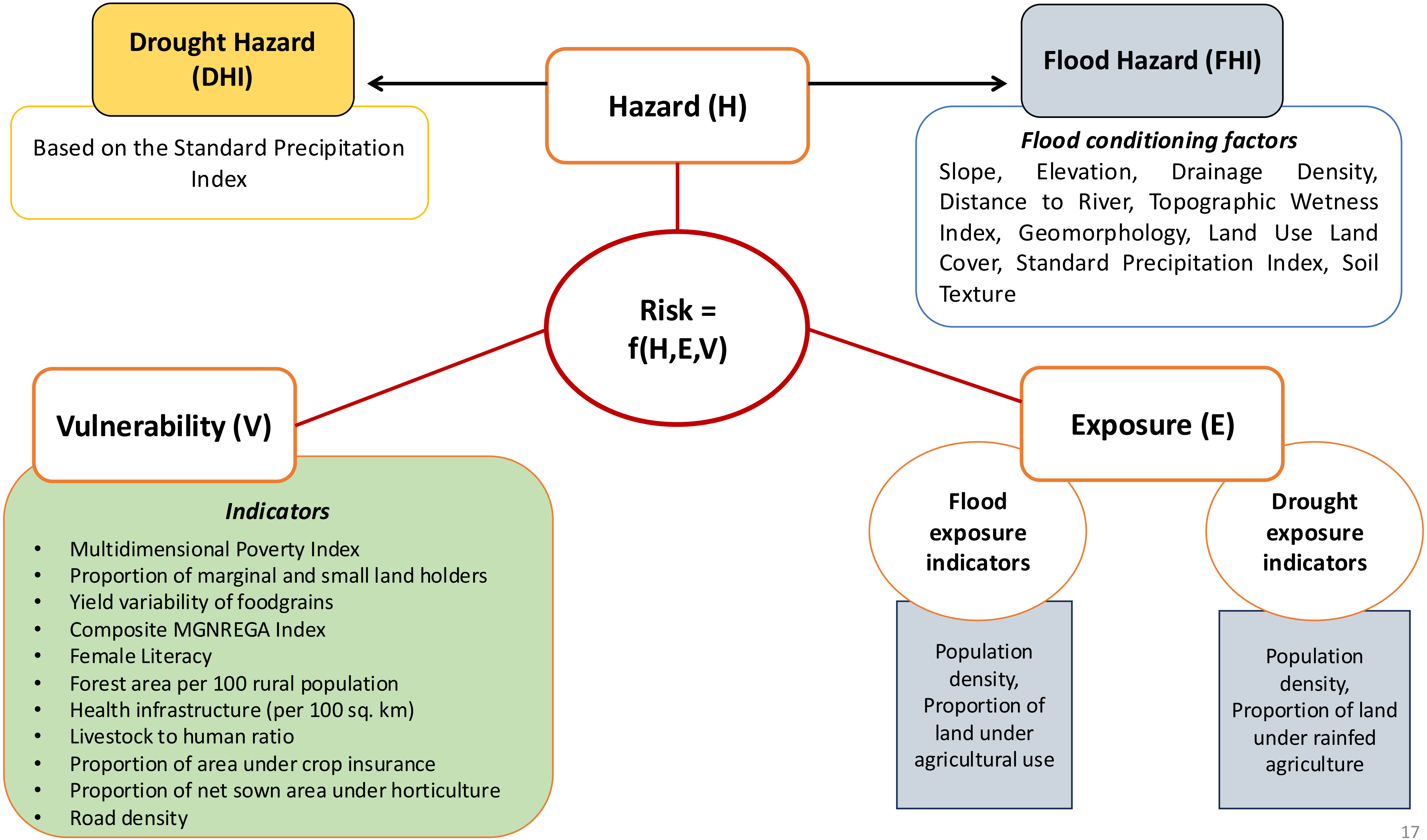
- Unlike exposure and hazard – difficult to quantify or measure vulnerability – no generally agreed metric
- Does not denote an observable phenomenon *(Hinkel 2011)*
- Multiple elements/contextual mechanisms interact to generate vulnerability
- “relative measure” – place-based and context-specific
- Reducing it to single metric may undermine the underlying processes or factors or its complexity
- Assessed using proxy indicators that represent vulnerability – easy comprehension and effective communication with policy makers and for analysing the overall risk of climate change

Common indicators

- Multidimensional Poverty Index
- Proportion of marginal and small land holders
- Yield variability of foodgrains
- Female Literacy
- Health infrastructure (per 100 sq. km)
- Livestock to human ratio
- Proportion of area under crop insurance
- Proportion of net sown area under horticulture
- Road infrastructure etc.

Differentiating between exposure and vulnerability indicators

- **An important distinction -**
  - **Exposure** can be reduced only in the **medium to long-term**; **vulnerability** can be reduced in the **short to medium-term** through relevant policies.
  - If an indicator can be controlled in the short-term through policies and programmes, then it is considered to represent vulnerability and not exposure.
- Exposure is extrinsic; vulnerability - intrinsic (Jones et al., 2017).
- Exposure – non-climatic locational driver, low manageability
- Vulnerability – non-climatic, high manageable socio-economic driver (Tapia et al. 2017).


Drought Hazard (DHI)
Based on the Standard Precipitation Index
Hazard (H)
Flood Hazard (FHI)
Flood conditioning factors
Slope, Elevation, Drainage Density, Distance to River, Topographic Wetness Index, Geomorphology, Land Use Land Cover, Standard Precipitation Index, Soil Texture
Risk = f(H,E,V)
Vulnerability (V)
Indicators
• Multidimensional Poverty Index
• Proportion of marginal and small land holders
• Yield variability of foodgrains
• Composite MGNREGA Index
• Female Literacy
• Forest area per 100 rural population
• Health infrastructure (per 100 sq. km)
• Livestock to human ratio
• Proportion of area under crop insurance
• Proportion of net sown area under horticulture
• Road density
Exposure (E)
Flood exposure indicators
Population density, Proportion of land under agricultural use
Drought exposure indicators
Population density, Proportion of land under rainfed agriculture

Why assess climate risks?

- The impact of climate change is determined by not just hazards, but exposure and even more importantly vulnerability. In fact, exposure and vulnerability are bigger contributors of loss and damage due to climate change, than the hazards itself.
  - e.g., Hazard may be high but Exposure may be low or Vulnerability may very low?

- Help quantify the extent of risk and the key drivers
    - Hazard, exposure or vulnerability or combination
    - Within each what are the key contributing factors

- Understand how risks will change in the future – under different climate scenarios

- Will help identify and rank regions, districts, cropping systems, communities who are at risk of climate change Hazard linked damage and losses.

- Assist adaptation doners, bankers and funding agencies to identify areas/sectors of targeted interventions
  - Prioritize and optimize resource allocation

- Ex-ante approach of risk reduction and management

Steps for Climate Risk Assessment

Step 1	Define the objectives of risk assessment: Current Risk assessment	1. Assist in adaptation planning 2. Prioritising adaptation investment
Step 2	Define the type of risks to be assessed: Hazard-specific risk assessment under current climate	1. Drought hazard 2. Flood hazard 3. Others
Step 3	Define the region / scale for risk assessment and define the boundary for risk assessment; District, State and Country	1. State & district 2. Cropping systems
Step 4	Define the risk framework Hazard, Exposure, Vulnerability based framework	IPCC, 2014 Risk Framework
Step 5	HAZARD INDEX ASSESSMENT	
Step 5.1	Hazards for risk assessment under historical climate data	1. Drought hazard 2. Flood hazard
Step 5.2	Obtains historical climate data for the selected hazard: Daily / Monthly Rainfall data in mm at the district level or 0.25 x 0.25-degree gridded data.	1. Drought data 2. Flood data 3. Period: 30 to 50 years

Steps continued…

Step 7	VULNERABILITY INDEX ASSESSMENT	
Step 7.1	Select hazard-specific indicators for vulnerability assessment at the scale selected and compile data for the indicators under historical climate period.	- District scale - Current value of vulnerability indicators
Step 7.2	Normalize, give equal weights, and estimate the vulnerability Index at the scale for historical climate period.	
Step 8	RISK INDEX DEVELOPMENT	
Step 8.1	Estimate Risk Index using the equation: $$Risk = \sqrt[3]{H \times V \times E}$$ Where, H is Hazard, V is Vulnerability, and E is Exposure	Ex. At district/state scale
Step 8.2	Rank the districts / blocks / communities; based on the risk index values	- High / Moderate / Low Risk - Very high / High / Moderate / low / Very low
Step 8.3	Identify key drivers of risk.	- Hazard indicator - Exposure indicator - Vulnerability indicator
Step 8.4	Prepare Risk maps and classify and rank districts using a scale; High Risk – Moderate risk – low risk	- Hazard map, Exposure map, - Vulnerability map, Risk map

- Risk Index = H * E * V?

- Risk Index = H + E + V?

Risk Index = $\sqrt[3]{H * E * V}$

Hypothetical case! - Vulnerability

District	MDPI		Proportion of marginal and small landholders		Female literacy (%)		Road density (km/100 sq. km)		VI	VI Rank
	AV	NV	AV	NV	AV	NV	AV	NV		
A	0.08		0.80		74.80		56.67			
B	0.06		0.87		81.50		82.94			
C	0.12		0.88		69.50		52.81			
D	0.07		0.85		78.80		57.97			
E	0.06		0.83		83.40		64.48			
Max	0.12		0.88		83.4		82.94			
Min	0.06		0.8		69.5		52.81			
Max - min	0.06		0.08		13.9		30.13			

Equations for normalizing indicators

➢ Sensitivity Indicators (positive functional relationship with vulnerability)

$$x_{ij}^{P} = \frac{Xij - Min\ i\ \{Xij\}}{(Max\ i\ \{Xij\} - Min\ i\ \{Xij\}}$$

- Values will range between 0 and 1
- Normalized value of 1 corresponds to highest value of indicator
- Highest sensitivity
- Highest vulnerability

Equations for normalizing indicators

- Adaptive capacity Indicators (negative or inverse functional relationship with vulnerability)

$$NV\ of\ indicator = \frac{Max_i\,(Xij) - Xij}{Max_i\,(Xij) - Mini\,(Xij)}$$

- Values will range between 0 and 1
- Normalized value of 1 corresponds to lowest value of indicator
- Lowest adaptive capacity
- Highest vulnerability

- 0 always means lowest vulnerability; 1 means highest vulnerability

Hypothetical case! - Vulnerability

District	MDPI		Proportion of marginal and small landholders		Female literacy (%)		Road density (km/100 sq. km)		VI	VI Rank
	AV	NV	AV	NV	AV	NV	AV	NV		
A	0.08	0.33	0.80	0.00	74.80	0.62	56.67	0.87	0.46	3
B	0.06	0.00	0.87	0.88	81.50	0.14	82.94	0.00	0.25	4
C	0.12	1.00	0.88	1.00	69.50	1.00	52.81	1.00	1.00	1
D	0.07	0.17	0.85	0.62	78.80	0.33	57.97	0.83	0.49	2
E	0.06	0.00	0.83	0.37	83.40	0.00	64.48	0.61	0.25	5
Max	0.12		0.88		83.4		82.94			
Min	0.06		0.8		69.5		52.81			
Max - min	0.06		0.08		13.9		30.13			

Example showing calculation of Risk

Flood Hazard Index (FHI)	Exposure Index (EI)	Vulnerability Index (VI)	*Flood Risk Index (FRI)*
0.43	0.58	0.46	
0.35	0.5	0.25	
0.49	0.9	1	
0.28	0.3	0.49	
0.55	0.8	0.25	

Equation for Risk, *FRI* = $\sqrt[3]{FHI \ * EI \ * VI}$

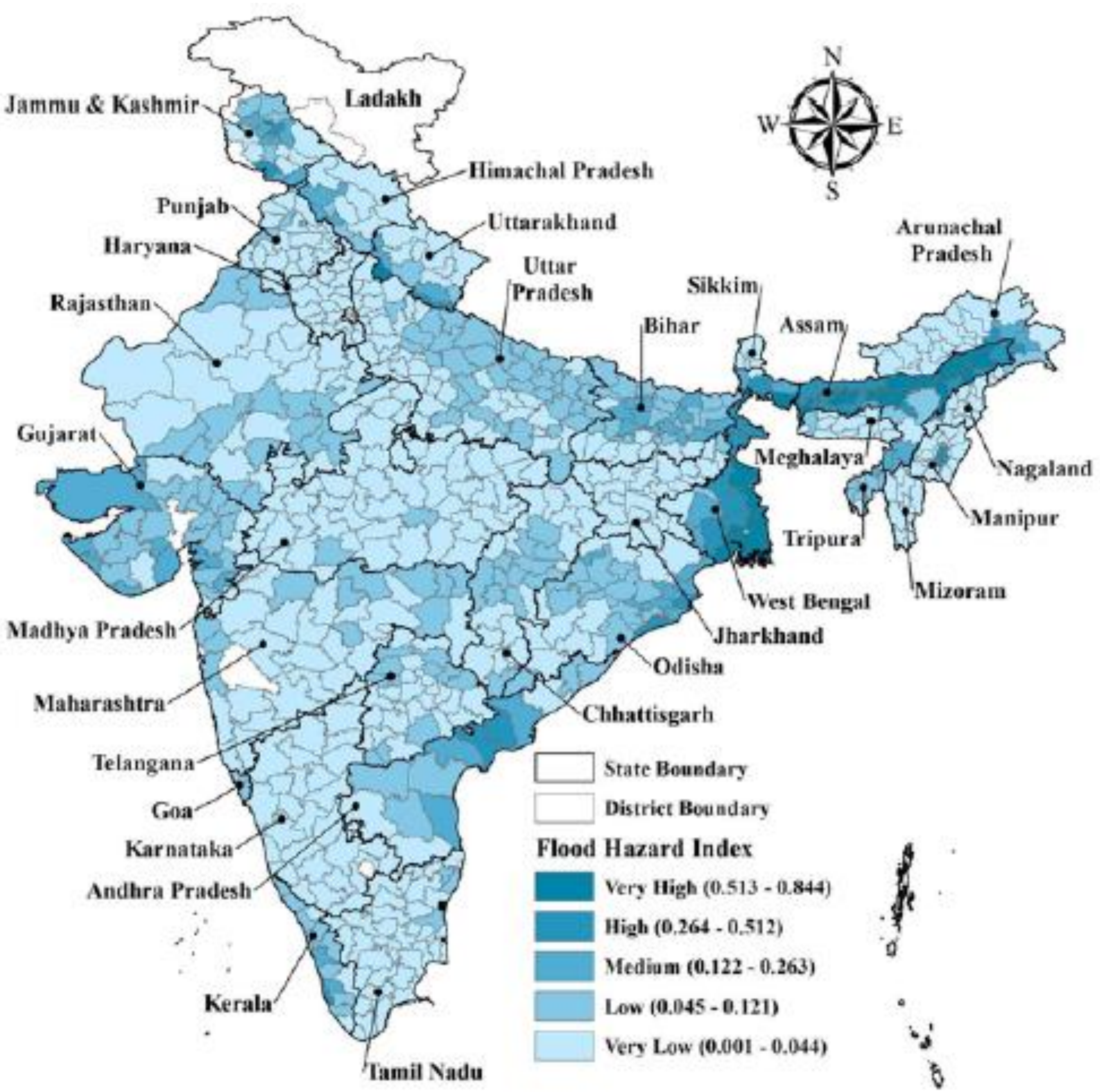
Example showing calculation of Risk

Flood Hazard Index	Exposure Index	Vulnerability Index	Flood Risk Index
0.43	0.58	0.46	0.49
0.35	0.5	0.25	0.35
0.49	0.9	1	0.76
0.28	0.3	0.49	0.35
0.55	0.8	0.25	0.48

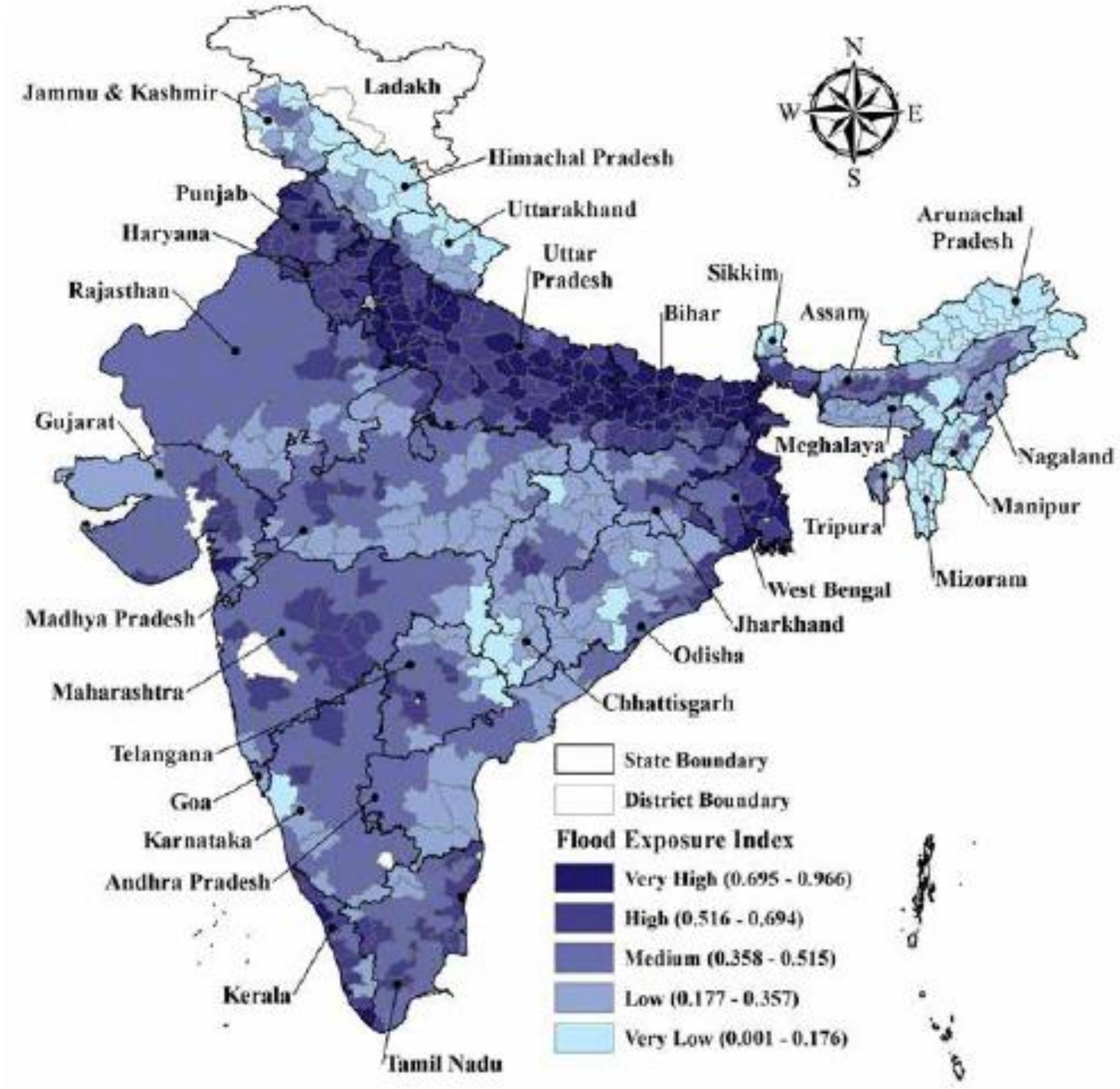
Identify the drivers – hazard is not the only determinant of the impacts of climate change

- Exposure and Vulnerability may be bigger contributors to the loss and damage

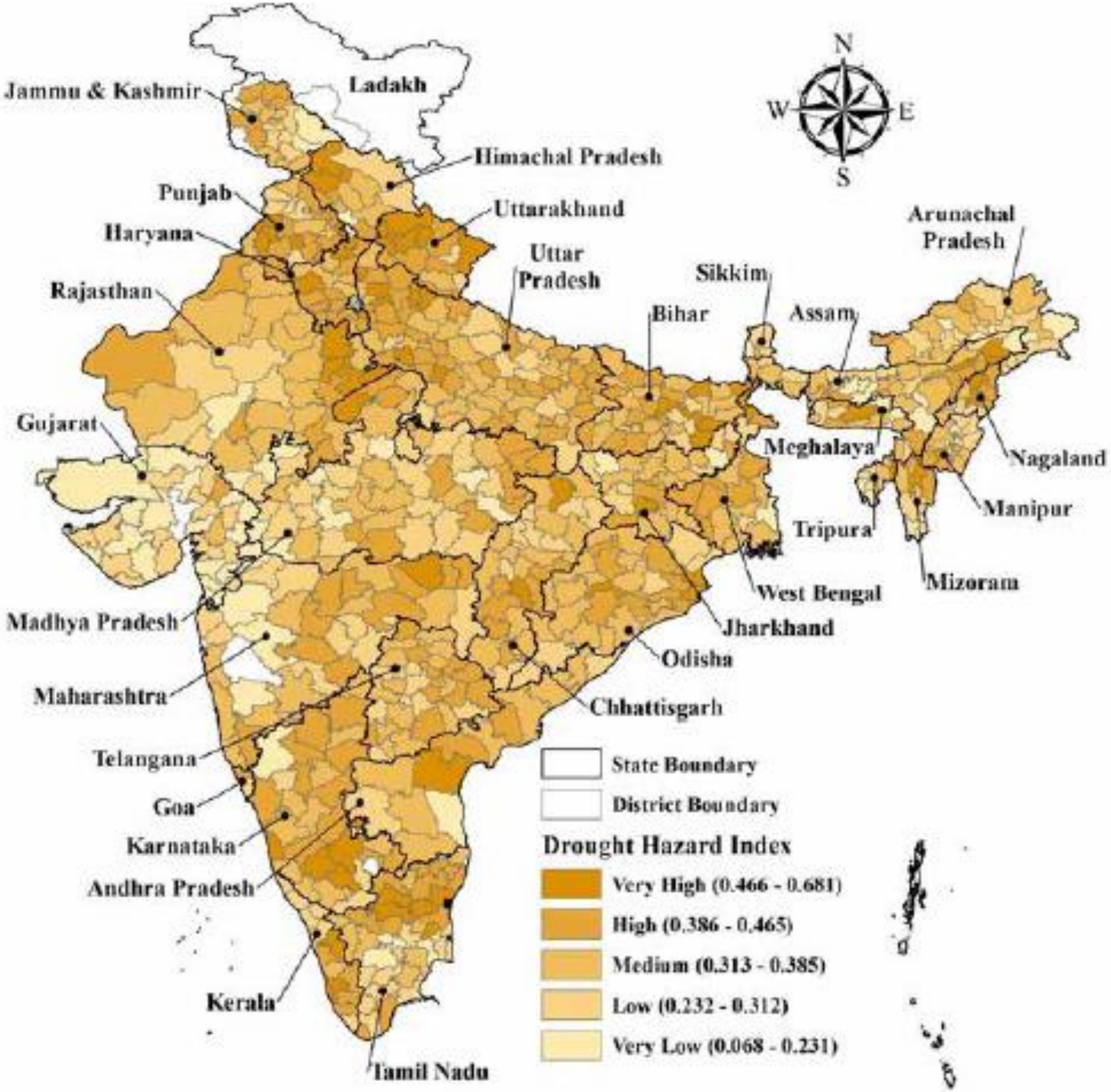
District-level Flood Hazard Map of India (for the period 1970–2019)



District-level Flood Exposure Map of India (for the period 1970–2019)



District-level Vulnerability Map of India



District-level Flood Risk Map of India (for the period 1970–2019)