Drought Risk Assessment

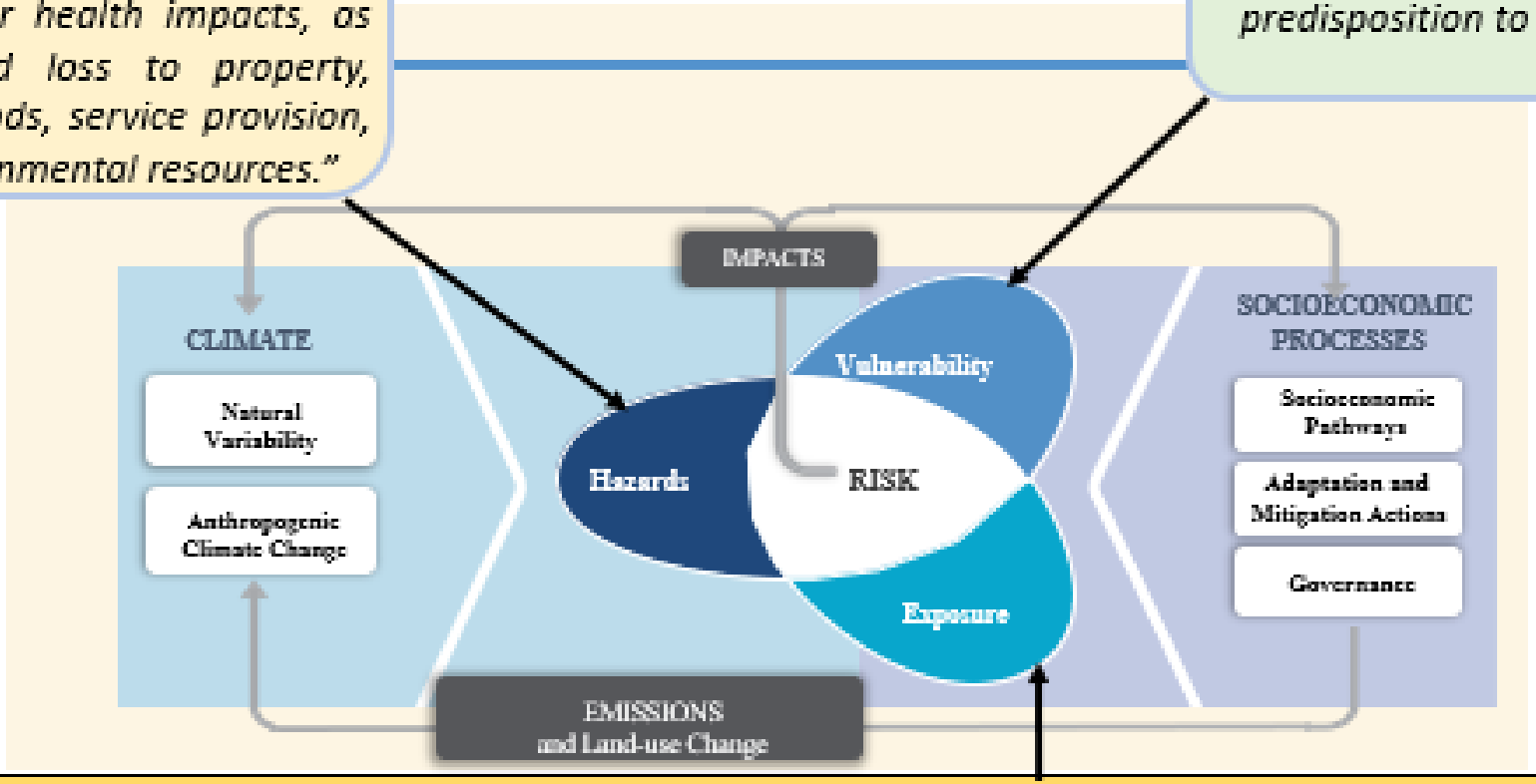
Variability of rainfall leading to rainfall deficiency and water shortage

*'**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".*

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 5.3	Select a method or equation to estimate the selected Hazard Index, Drought, and Flood hazards under current climate scenario	SPI = Standard Precipitation Index (Based on WMO) Geographic Information System (GIS) based flood susceptibility mapping using multi-criteria decision analysis (MCDA) techniques.
Step 5.4	Estimate the Drought Hazard Index and Flood Hazard Index	Drought / Wet events - Low / Moderate / Severe - How many years out of past 30 years - How many years out of projected 30 years Flooded area: - Very low/ Low/ Medium/ High / Very high - How many years out of past 30 years - How many years out of projected 30 years
Step 6	EXPOSURE INDEX ASSESSMENT	Ex; at District scale
Step 6.1	Select Hazard-specific exposure indicators and collect data for selected indicators under current climate.	- Select indicators for selected scale -Estimate current value of exposure indicators
Step 6.2	Normalize, give equal weights and estimate the Exposure Index at the scale selected under historical climate period	- Estimate Exposure Index

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

Drought Hazard

A number of different indices have been developed to quantify a drought

- Palmer drought severity index (PDSI; Palmer 1965)
- Standardized precipitation index (SPI; McKee et al., 1993, 1995),
- Standard Evapotranspiration Index (SPEI)
- Percent of normal precipitation (PNP)
- Rainfall anomaly index (RAI; van Rooy, 1965), deciles (Gibbs and Maher, 1967),
- Crop moisture index (CMI; Palmer, 1968),
- Surface water supply index (SWSI; Shafer and Dezman, 1982),
- Reclamation drought index (RDI; Weghorst, 1996).
- The soil moisture drought index (SMDI; Hollinger et al., 1993) and
- Crop-specific drought index (CSDI; Meyer and Hubbard, 1995)
- Corn drought index (CDI; Meyer and Pulliam, 1992) and
- Soybean drought index (SDI; Meyer and Hubbard, 1995), and
- Vegetation condition index (VCI; Liu and Kogan, 1996).

Droughts are broadly categorized into four major classes:

(1) **Meteorological drought**, as a deficit in precipitation;

(2) **Hydrological drought,** as a deficit in streamflow, groundwater level or water storage;

(3) **Agricultural drought**, as a deficit in soil moisture; and

(4) **Socio-economic drought**, incorporating water supply and demand (Wilhite and Glantz 1985; Anderson et al. 2011).

Drought Hazard Assessment

Drought Hazard Index (DHI)

Data

- Precipitation ($0.25^o \times 0.25^o$)
- Temperature ($1^o \times 1^o$)

IMD 50-year gridded data from 1970-2019

Method

- Standard Precipitation Evaporation Index (SPEI)

Drought types corresponding to the SPEI value

SPEI	Drought
1.00>SPEI≥-1.00	Normal
-1.00≥SPEI>-1.50	**Moderate drought**
-1.50≥SPEI>-2.00	**Severe drought**
-2.00≥SPEI	**Extreme drought**

Source: Dabanli 2018; Dilawar et al., 2022

Normalization

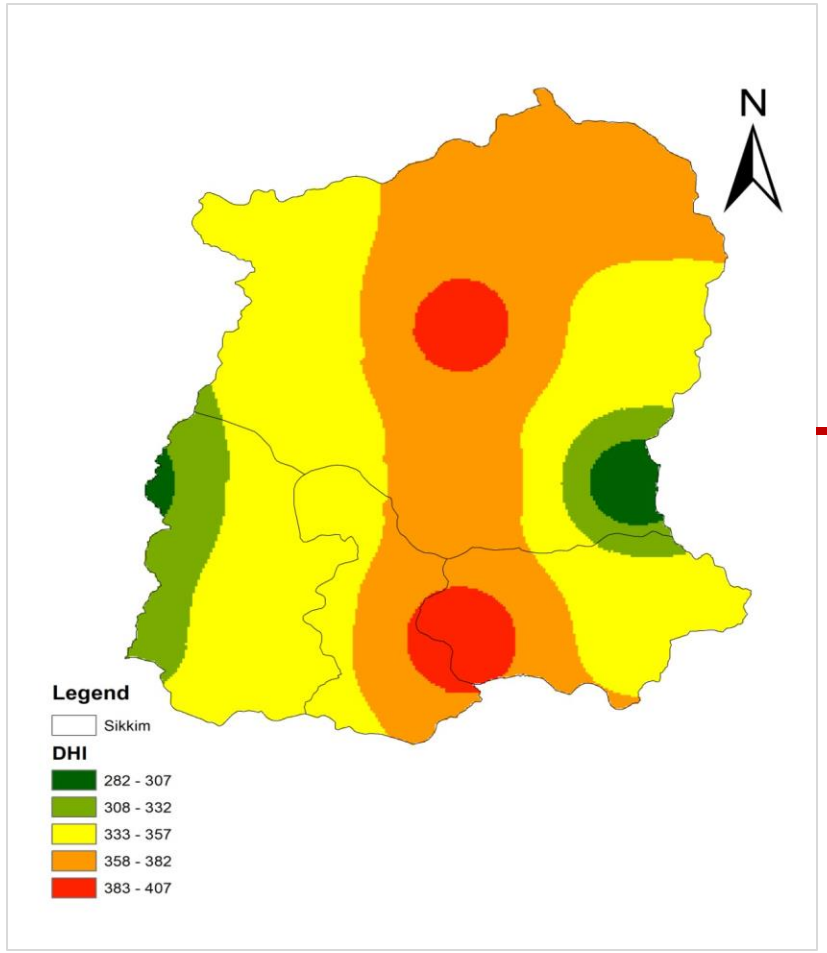
Positive functional relationship	Negative or inverse functional relationship
$x_{ij}^{P} = \frac{Xij - Min\ i\ \{Xij\}}{(Max\ i\ \{Xij\} - Min\ i\ \{Xij\}}$	$NV\ of\ indicator = \frac{Max_i\ (Xij) - Xij}{Max_i\ (Xij) - Mini\ (Xij)}$
• Values will range between 0 and 1 • Normalized value of 1 corresponds to highest value of indicator	• Values will range between 0 and 1 • Normalized value of 1 corresponds to lowest value of indicator

Drought- Positive relationship, number of drought events increases negative impacts will also increases

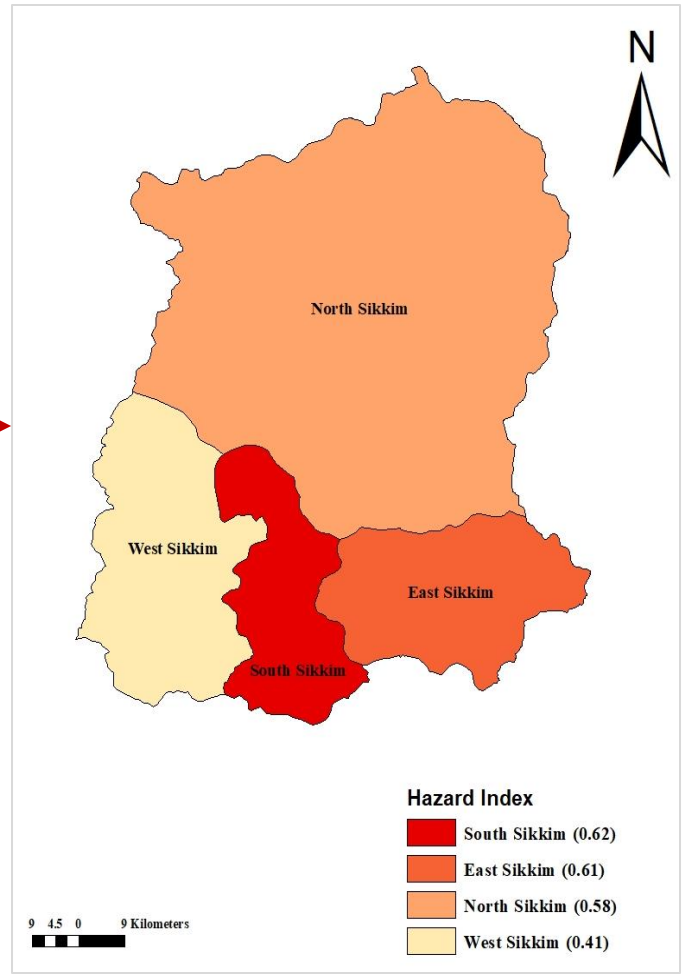
District/State	Drought Hazard	Formula (Drought increases negative impacts increases	DHI
A	330	(Actual value)-(Minimum Value)/(Maximum-Minimum)	0.511628
B	430	(Actual value)-(Minimum Value)/(Maximum-Minimum)	0.744186
C	540	(Actual value)-(Minimum Value)/(Maximum-Minimum)	1
D	110	(Actual value)-(Minimum Value)/(Maximum-Minimum)	0
Min	110		
Max	540		

Drought Hazard profile of Sikkim

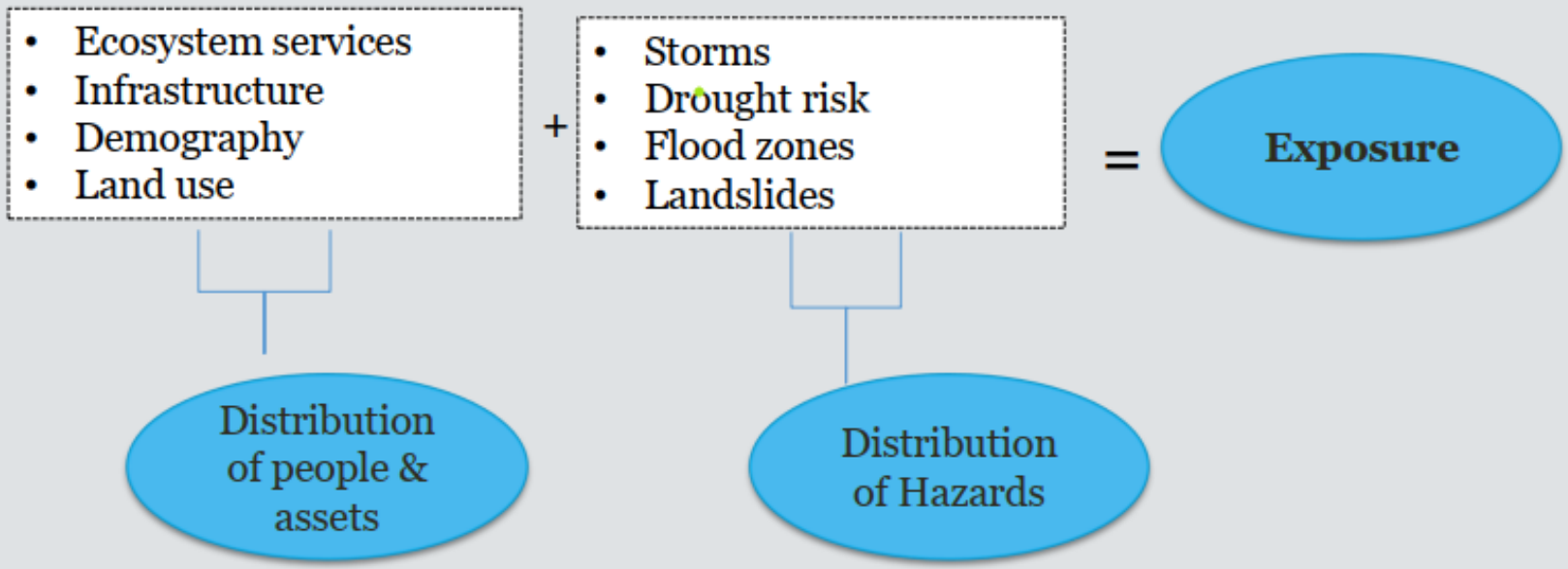
Drought Hazard



Drought Hazard based district ranking



Key elements of exposure



Exposure Indicator

Hazard

Drought Hazard Index

- Current- IMD 50-year gridded rainfall (0.25 ° ×0.25° resolution) and temperature (1 ° ×1° resolution) data 1970-2019.
- Standard Precipitation Evaporation Index (SPEI)

Exposure

- Population exposed
- Proportion of rainfed agriculture

Exposure

Positive relationship, more exposure to drought/hazard more will be the negative impact

(Actual value)-(Minimum Value)/(Maximum-Minimum)

District/ State	Population density (AV)	Population density (NV)	Proportion of land under rainfed agriculture (AV)	Proportion of land under rainfed agriculture (NV)	Formula for calculating Exposure Index	Exposure Index	Exposure Ranking
A	473.13	0.12	0.42	0.17	(Normalised value population density for A+Normalised value of proportion of land under agriculture for A)/ Number of indicators	0.15	3.00
B	853.73	1.00	0.73	1.00	(Normalised value population density for B+Normalised value of proportion of land under agriculture for B)/ Number of indicators	1.00	1.00
C	418.97	0.00	0.36	0.00	(Normalised value population density for C+Normalised value of proportion of land under agriculture for C)/ Number of indicators	0.00	4.00
D	816.60	0.91	0.67	0.84	(Normalised value population density for D+Normalised value of proportion of land under agriculture for D)/ Number of indicators	0.88	2.00
Min	418.97	0.00	0.36	0.00		0.00	1.00
Max	853.73	1.00	0.73	1.00		1.00	4.00

AV= Actual value; NV= Normalized value

Vulnerability Indicators

Indicators	Dimension and functional relationship	Category
% BPL population	Sensitivity/ Lack of adaptive capacity (Positive)	Socioeconomic and livelihood
Income share from natural resources	Sensitivity (Positive)	
Share of horticulture in agriculture	Adaptive Capacity (Negative)	
Marginal and small landholdings	Sensitivity (Positive)	
Women participation in workforce	Adaptive Capacity (Negative)	
Yield variability of food grains	Sensitivity (Positive)	Biophysical
Area under rainfed agriculture	Sensitivity (Positive)	
Forest area per 1,000 rural population	Adaptive Capacity (Negative)	
Vector-borne diseases	Sensitivity (Positive)	
Water-borne diseases	Sensitivity (Positive)	
Area covered under crop insurance	Adaptive Capacity (Negative)	Institution and infrastructure
MGNREGA	Adaptive Capacity (Negative)	
Road and rail density	Adaptive Capacity (Negative)	
Density of Health Care Workers	Adaptive Capacity (Negative)	

Vulnerability

Normalization

Case I: The indicator that has a + relationship with vulnerability. (Example: number of marginal landholding)

$$Normalized\ value = \frac{(Actual\ \ indicator\ value - Min\ indicator\ value)}{(Max\ indicator\ value - Min\ indicator\ value)}$$

Case II: The indicator that has a - relationship with vulnerability. (Example: MGNREGA)

$$Normalized\ value = \frac{(Max\ indicator\ value - Actual\ \ indicator\ value)}{(Max\ indicator\ value - Min\ indicator\ value)}$$

	Marginal farmers (+)		MGNREGA (-)	
District	Actual Value	Normalized	Actual Value	Normalized
A	20	(20-20)/(50-20)= 0	80	(80-80)/(80-40)=0
B	30	(30-20)/(50-20)= 1/3	40	(80-40)/(80-40)=1
C	40	(40-20)/(50-20)= 2/3	50	(80-50)/(80-40)=3/4
D	50	(50-20)/(50-20)= 1	60	(80-60)/(80-40)=2/4

Vulnerability Index is the arithmetic mean of all normalized scores.

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			

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			

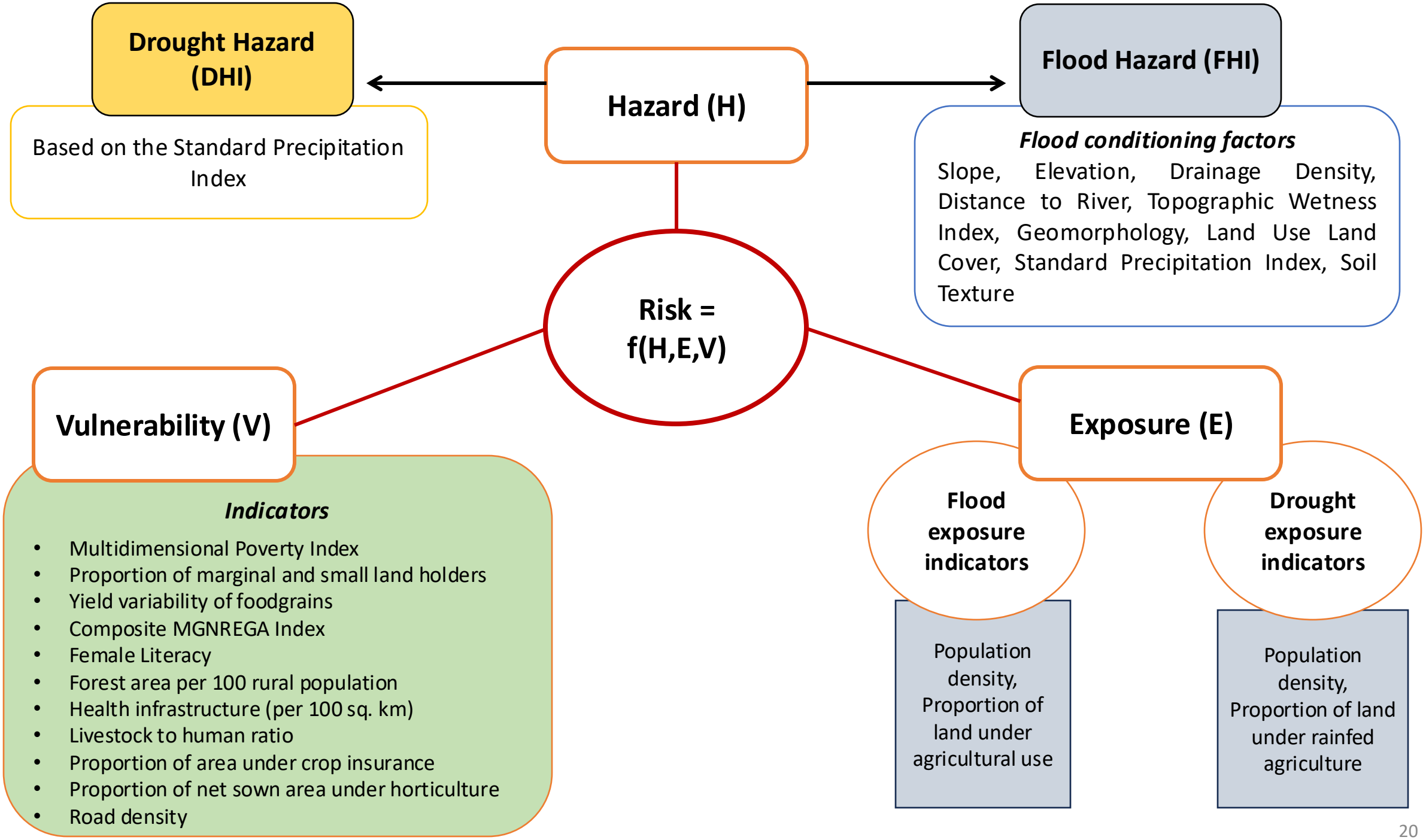
Example showing calculation of Risk

Drought Hazard Index (DHI)	Exposure Index (EI)	Vulnerability Index (VI)	*Drought Risk Index (DRI)*
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	

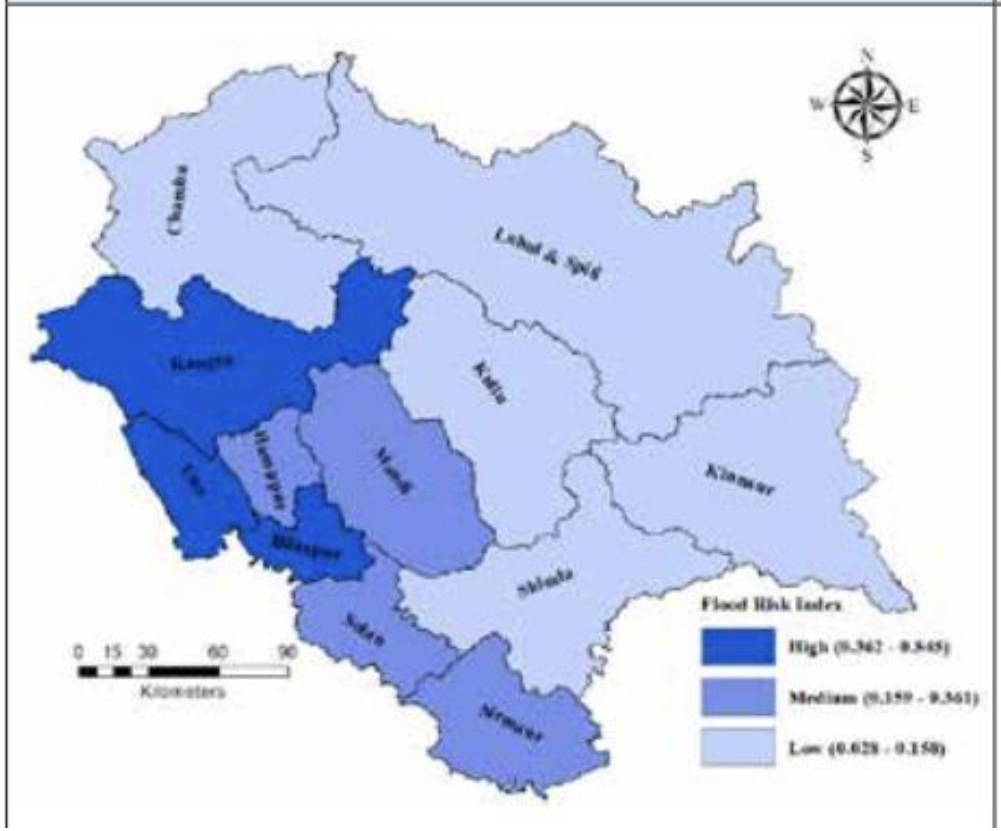
Equation for Risk, *DRI* = $\sqrt[3]{DHI * EI * VI}$

Example showing calculation of Risk

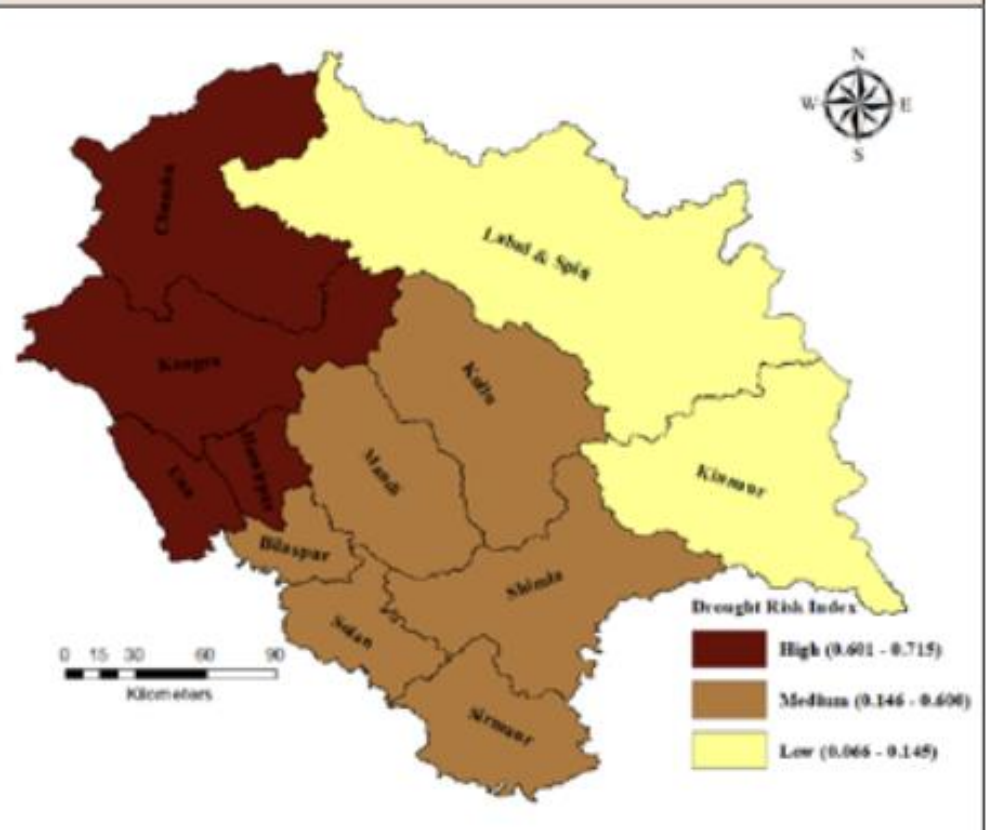
Drought Hazard Index	Exposure Index	Vulnerability Index	Drought Risk Index
0.43	0.58	0.46	0.49
0.35	0.5	0.25	0.35
0.49	0.9	1	0.76
0.28	0.3	0.49	0.35
0.55	0.8	0.25	0.48


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

Flood Risk Map - Himachal Pradesh

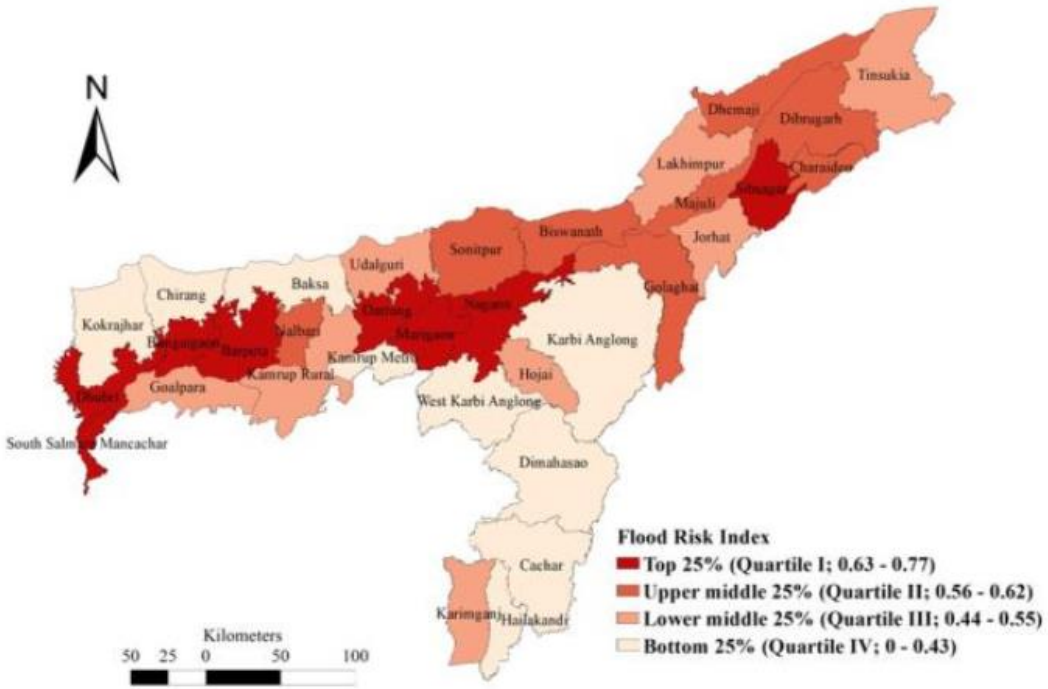


Drought Risk Map - Himachal Pradesh



Categorisation

	A	B	C	D	E	F	G	H	I	J	K	L
1	**State/District**	**DRI/FRI**								**State/District**	**DRI/FRI**	**Category**
2	A	0.73		**Number of categories= 3**						A	0.73	High Risk
3	B	0.64		**Max**	0.73					B	0.64	High Risk
4	C	0.56	Chart Area	**Min**	0.41					C	0.56	Moderate Risk
5	D	0.53		**Range**	0.108672	**(Maximum value-Minimum value)/number of categories**				D	0.53	Moderate Risk
6	E	0.48								E	0.48	Low Risk
7	F	0.45								F	0.45	Low Risk
8	G	0.42		**Maximum value**	0.73	0.63	**Maximum value - Range**	**High**		G	0.42	Low Risk
9	H	0.41		**F8**	0.63	0.52	**F8-Range**	**Moderate**		H	0.41	Low Risk
10	I	0.41		**F9**	0.52	0.41	**F9-Range**	**Low**		I	0.41	Low Risk
11												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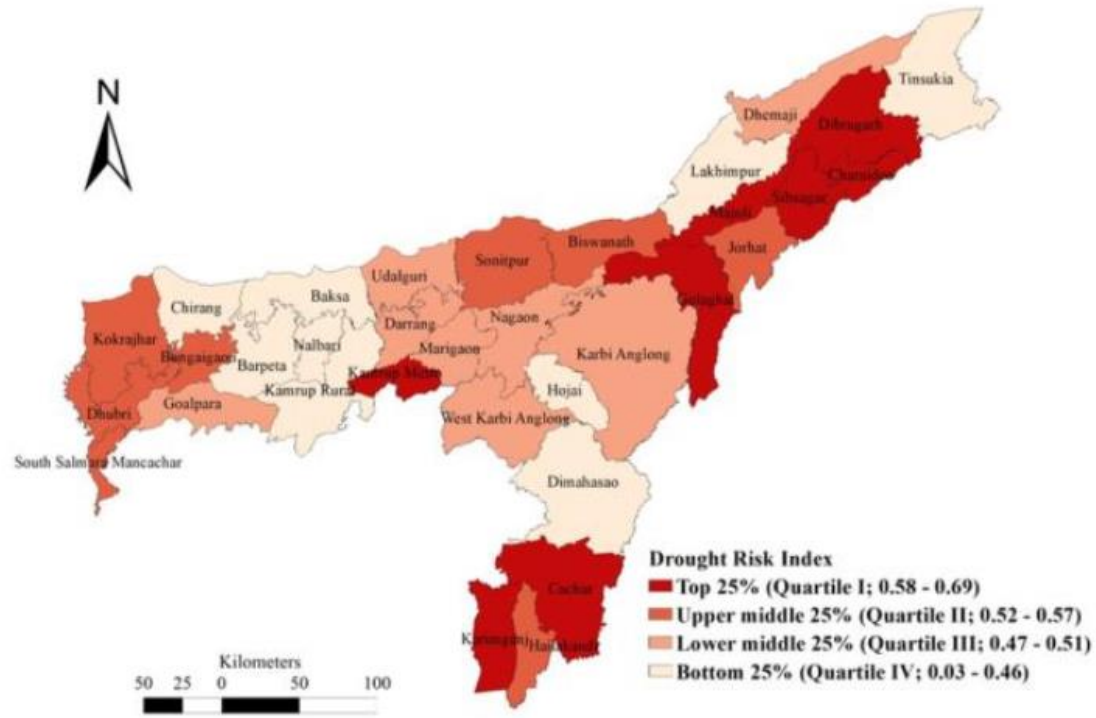
Sivasagar
Majuli
Jorhat
Golaghat
Biswanath
Sonitpur
Udalguri
Baksa
Chirang
Kokrajhar
Nagaon
Karbi Anglong
Hojai
Kamrup Metro
Kamrup Rural
Goalpara
West Karbi Anglong
Dimahasao
Cachar
Karimganj
Hailakandi
Kilometers
50 25 0 50 100
Flood Risk Index
Top 25% (Quartile I; 0.63 - 0.77)
Upper middle 25% (Quartile II; 0.56 - 0.62)
Lower middle 25% (Quartile III; 0.44 - 0.55)
Bottom 25% (Quartile IV; 0 - 0.43)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Dibrugarh
Lakhimpur
Sivasagar
Jorhat
Golaghat
Biswanath
Sonitpur
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Chirang
Kokrajhar
Darrang
Nagaon
Nalbari
Marigaon
Karbi Anglong
Barpeta
Kamrup Rural
Hojai
Goalpara
Dhubri
West Karbi Anglong
Dimahasao
Cachar
Kilometers
50 25 0 50 100
Drought Risk Index
Top 25% (Quartile I; 0.58 - 0.69)
Upper middle 25% (Quartile II; 0.52 - 0.57)
Lower middle 25% (Quartile III; 0.47 - 0.51)
Bottom 25% (Quartile IV; 0.03 - 0.46)

District level flood and drought risk maps – All India level

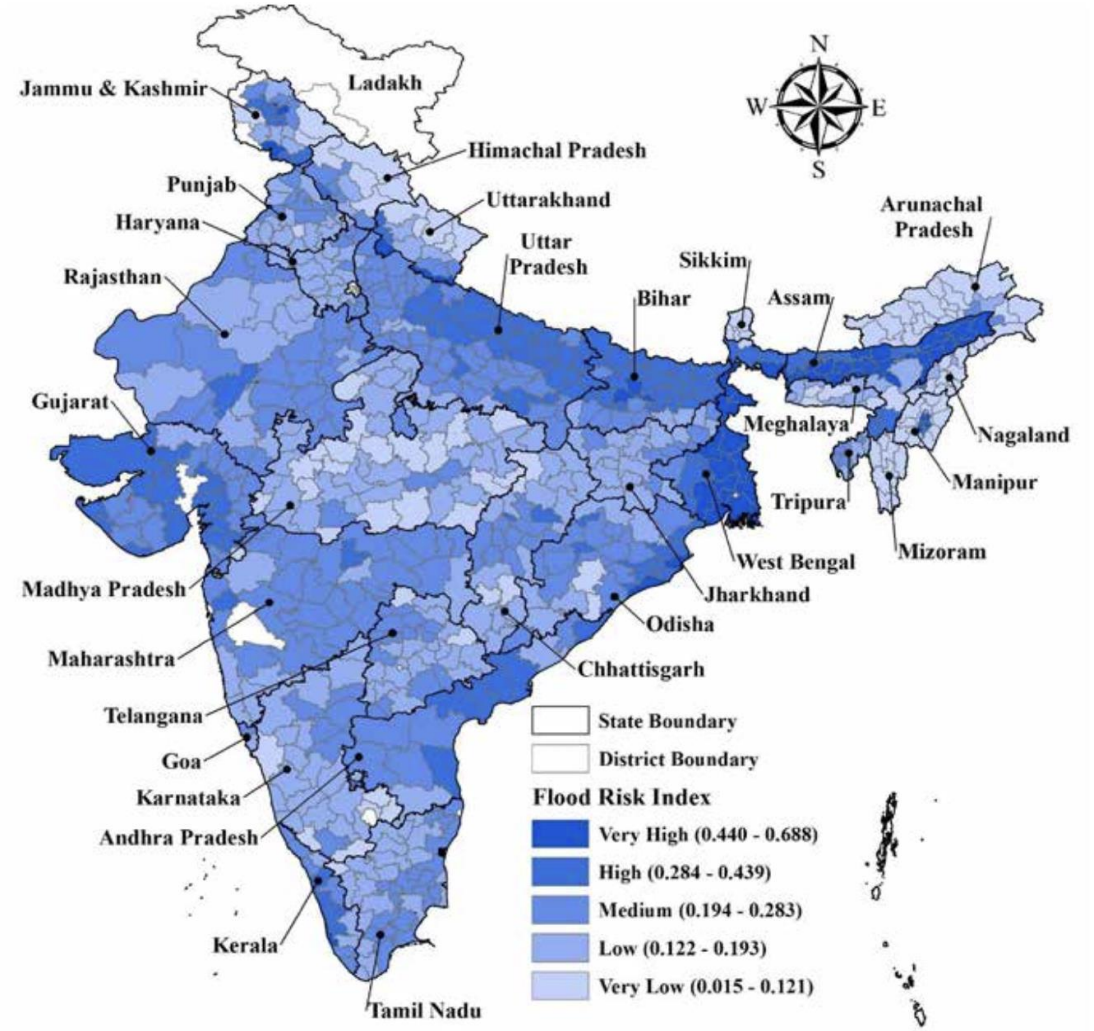


Figure 3.6: District-level Flood Risk Map of India (for the period 1970–2019)

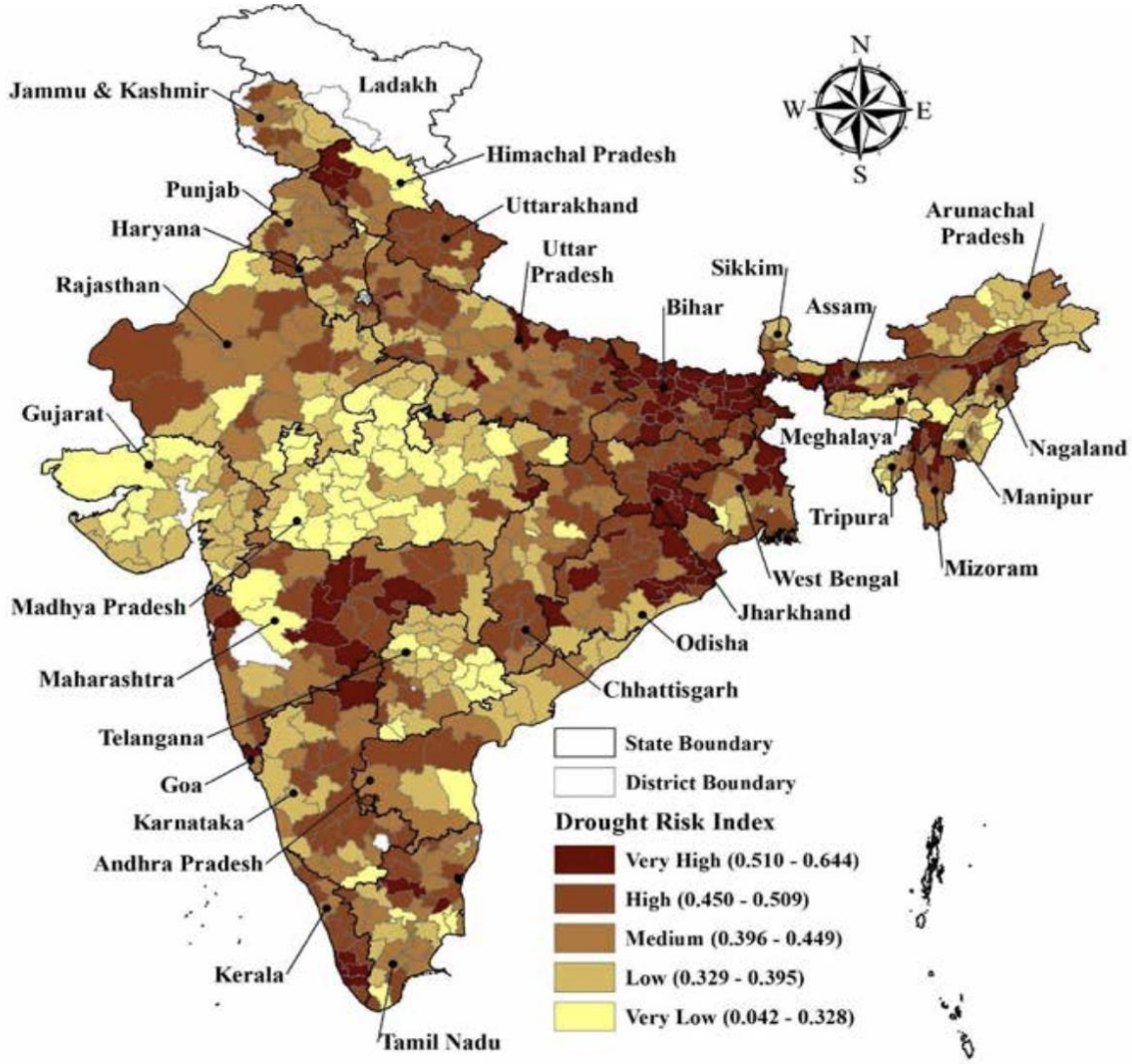
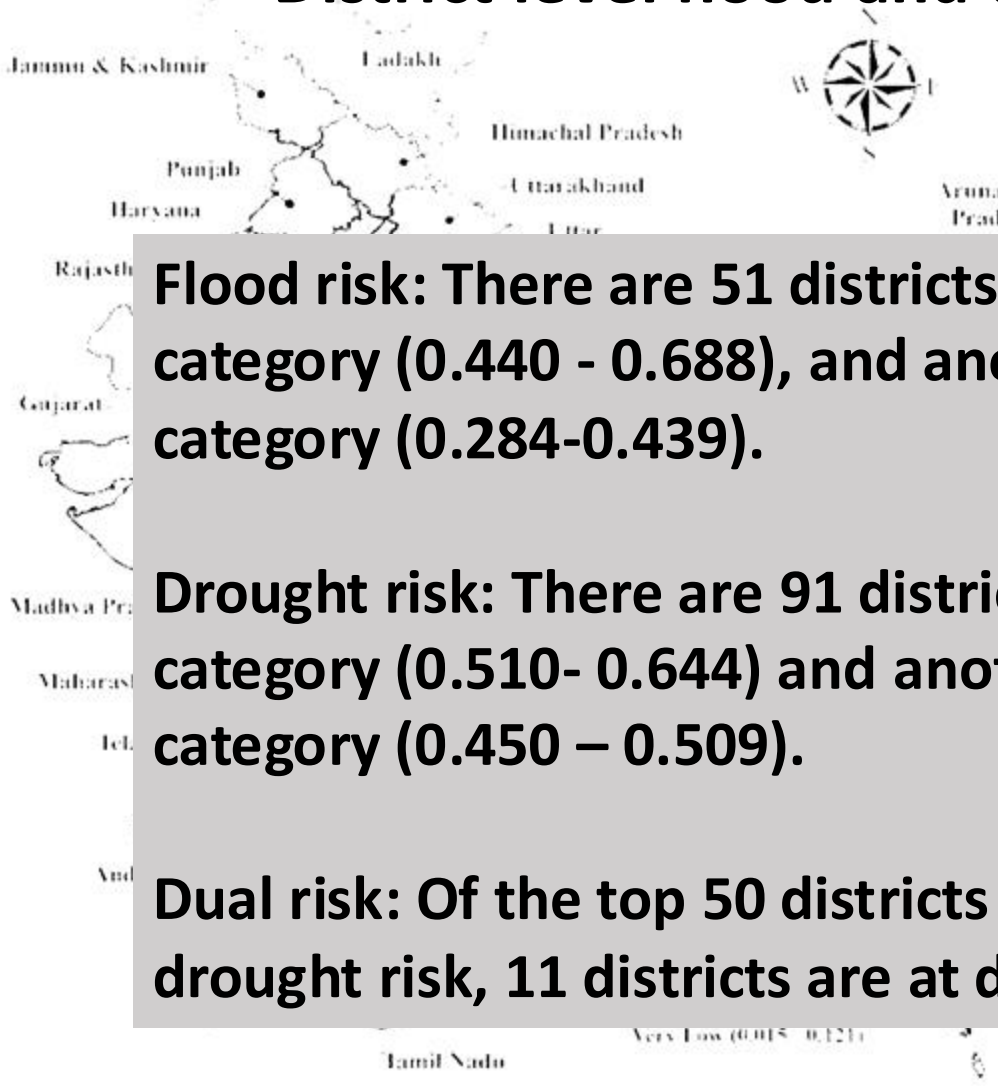
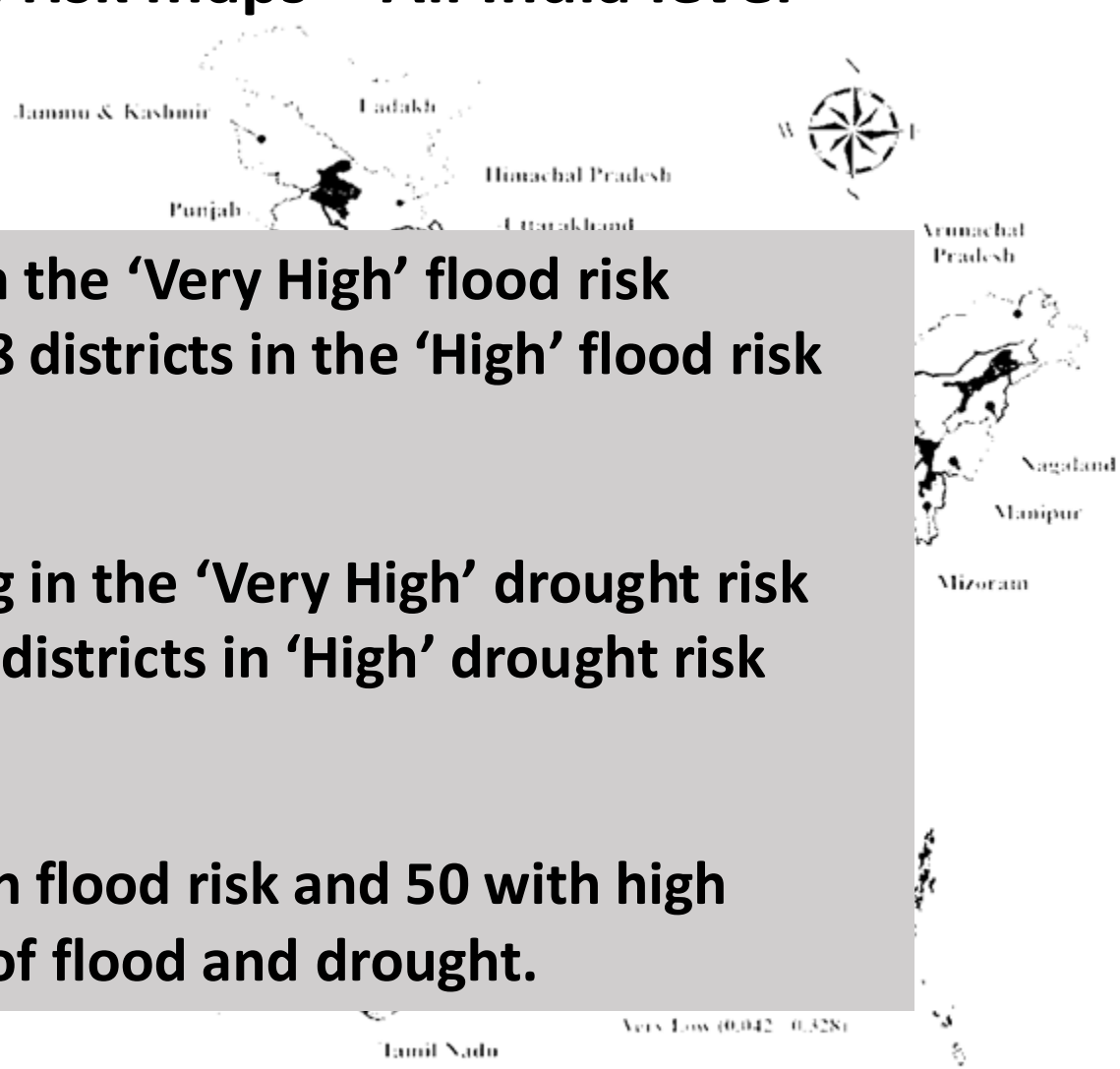


Figure 3.7: District-level Drought Risk Map of India (for the period 1970–2019)

District level flood and drought risk maps – All India level



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



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

Flood risk: There are 51 districts falling in the 'Very High' flood risk category (0.440 - 0.688), and another 118 districts in the 'High' flood risk category (0.284-0.439).

Drought risk: There are 91 districts falling in the 'Very High' drought risk category (0.510- 0.644) and another 188 districts in 'High' drought risk category (0.450 – 0.509).

Dual risk: Of the top 50 districts with high flood risk and 50 with high drought risk, 11 districts are at dual risk of flood and drought.