State-Level Vulnerability Assessment

1. Introduction:

The Climate Vulnerability Index helps us see how different regions are affected by climate change—not just by extreme weather, but also by how prepared they are to handle it. This study looks at five Indian states—**Bihar, Gujarat, Tamil Nadu, Odisha, and West Bengal**—to understand their risks.

We examine:

Exposure: How much they face extreme heat and unpredictable rainfall.

Sensitivity: How their people and economies are affected by these changes (like poverty or weak infrastructure).

Adaptive Capacity: How well they can respond, based on factors like education, farming methods, and government support.

By comparing these states, we can see which areas need the most help to cope with a changing climate.

2. Data and Methods:

2.1 Data

Exposure:
Exposure was assessed using key climate variables, including precipitation and temperature. The analysis incorporated the following data sources and processing steps:

Climate Data Sources :
Gridded NetCDF datasets (precipitation.nc, tmax.nc, tmin.nc) provided daily values spanning multiple decades.

Geospatial Processing :
The datasets were spatially clipped to state boundaries using shapefiles from the Indian administrative boundary dataset.

Temporal Scope :
The baseline reference period was set as 1901–2020.

The latest available year was used for anomaly comparison to assess deviations from the baseline.
This approach ensures a robust evaluation of climate exposure by integrating long-term trends and recent variations.

Sensitivity and Adaptive Capacity:

Sensitivity: Assessed using net agricultural land use data from data.desagri.gov.in.

Adaptive Capacity: Evaluated based on state-level literacy rates from state_level_Data.xlsx.

2.2 Methods

The vulnerability index is computed using the **IPCC framework**:

Vulnerability = (Exposure − Adaptive Capacity) × Sensitivity
Each component is normalized to a common scale before integration.

1. Exposure Calculation
Exposure to climate extremes was quantified using the **Z-score method** for simplicity and efficiency. The steps involved:

Precipitation Extremes:
Very Dry Days: Days with precipitation below the 5th percentile of the reference period.
Very Wet Days: Days with precipitation above the 95th percentile.
Temperature Extremes:
Very Cool Days: Days with minimum temperature (*tmin*) below the 5th percentile.
Very Hot Days: Days with maximum temperature (*tmax*) above the 95th percentile.
Percentage Calculation:
The frequency of extreme days was converted into percentages:
Percentage=(No. of extreme daysTotal valid days)×100Percentage=(Total valid daysNo. of extreme days)×100
Z-Score Standardization:
Extreme events were identified using: $Z = (X - \mu) / \sigma$
where X = daily value, μ = mean, σ = standard deviation.
Days with $Z < -2$ or $Z > 2$ were counted as extreme exposure events.
Exposure Index:
The average percentage of extreme hot/cold and wet/dry days was computed for each state and normalized using:
$X_{ij}' = (X_{ij}) - \min(X_{ij}) / \max(X_{ij}) - \min(X_{ij}))$

2. Sensitivity & Adaptive Capacity :

Sensitivity: Measured as the total agricultural land use per state (sourced from data.desagri.gov.in).
Adaptive Capacity: Derived from state-level literacy rates (*state_level_Data.xlsx*):
Adaptive Capacity=Total literate population/total population

Normalization & Aggregation: Both indicators were normalized (using the same formula as exposure) and combined with equal weights.

This structured approach ensures a standardized and comparable vulnerability assessment across states.

2.3 Study area

This study evaluates climate vulnerability across five Indian states - Odisha, Bihar, West Bengal, Gujarat, and Tamil Nadu - through a comprehensive index derived from climate patterns and socioeconomic indicators. The composite vulnerability score incorporates three key dimensions: Exposure (to climate hazards), Sensitivity (of populations and systems), and Adaptive Capacity (to respond to changes). The framework systematically assesses each state's relative vulnerability by integrating these measurable components.

3. RESULTS

States	Precipitation(no. of days %)		Temperature(no. of days %)		Exposure	Exposure	Adaptive Capacity	Adaptive Capacity	Sensititvity(Norm	Vulnerability
	>mean + 2*std	< mean - 2*std	tmax>mean + 2*std	tmin< mean - 2*std	Average frequency of	Normalised	Literacy	Normalised	normalised	
Odisha	3.88	0	4.89	1.05	2.455	0.9719101124	0.63	0.5909090909	0.24	0.09144024515
Bihar	5.17	0	2.49	0.7	2.09	0.5617977528	0.5	0	0.51	0.2865168539
Tamil Nadu	3.96	0	1.14	4.82	2.48	1	0.72	1	0	0
Gujarat	3.81	0	0.66	1.89	1.59	0	0.68	0.8181818182	1	-0.8181818182
West Bengal	4.5	0	3.64	0.74	2.22	0.7078651685	0.67	0.7727272727	0.01	-0.00064862104

4. Interpretation:

Based on the table provided by the IPCC and the results derived from our data analysis, the following observations can be made:

Tamil Nadu demonstrates low vulnerability despite having the highest level of exposure among the states. This is primarily attributed to its high adaptive capacity and low sensitivity.

Bihar exhibits high vulnerability, driven mainly by its low adaptive capacity, even though its exposure level remains moderate.

IPCC (2007)	Range
Very less	(-0.61)- (-1)
Less	(-0.2)-(-0.6)
Moderate	0.2- (-0.19)
High	0.21-0.6
Very high	0.61-1.0

Gujarat shows very low vulnerability, owing to its minimal exposure and strong adaptive capacity. The moderating influence of its coastal regions likely contributes to this outcome

West Bengal, with a normalized agricultural land value of 0.01—just above the minimum—experiences comparatively lower vulnerability than many other states.

Odisha lies near the mid-range across most indicators, suggesting a need for balanced and targeted intervention strategies.

5. Conclusion:

Our analysis reveals striking differences in climate vulnerability among Odisha, Bihar, West Bengal, Gujarat, and Tamil Nadu. These variations stem from distinct combinations of climate risks, socioeconomic conditions, and adaptation capabilities.

High-Vulnerability States (e.g., Bihar)

- Face greater climate extremes
- Lag in adaptive capacity
- Require urgent government intervention

More Resilient States (e.g., Tamil Nadu, Gujarat)

- Benefit from stronger education systems
- Possess better infrastructure
- Serve as models for vulnerable regions

Critical Policy Recommendations

1. Boost education and climate awareness
2. Develop climate-proof infrastructure
3. Promote sustainable farming practices
4. Strengthen local disaster response systems

Core Insight: Vulnerability depends more on preparedness than just climate exposure. Enhancing adaptive capacity through targeted measures can significantly reduce risks, with lessons applicable across India.

This framework enables tailored adaptation strategies for different regional contexts, supporting India's climate resilience efforts.