

Climate Variability and Agricultural Productivity

Case Study of Rice Yields in Northern India

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Structure

- Conceptualizing Vulnerability
- Vulnerability Measurement
- Case Study

Vulnerability – Illustrative Example

Consider a motorcyclist on a narrow, winding mountain road, with the mountain to his left and a deep valley to his right. Unbeknownst to the motorcyclist an oil spill covers the road ahead of him, just behind a left-hand curve.

- Oil spill represents a hazard and motorcyclist is at risk of falling down the cliff and being killed: **Natural language**
- Motorcyclist is vulnerable **to** the oil spill with respect to the prospect of an accident: **Climate change literature**
- Motorcyclist is vulnerable **to** the threat of an accident, possibly caused among other things by the oil spill on the road: **Poverty literature**

Vulnerability – Illustrative Example

Consider four more motorcyclists

- A *second* motorcyclist who drives slowly and/or more carefully than the first one
- A *third* motorcyclist who is aware of the possibility of oil spill on the road and gears up for it (buys new tyres and improves his driving skills)
- A *fourth* motorcyclist who is also aware of the possibility of oil spill but is unable to take actions similar to those taken by the third motorcyclist
- A *fifth* motorcyclist confronted with a speeding truck in the opposite direction, and brake system failure besides the oil spill

Vulnerability – Illustrative Example

Challenges in formalizing vulnerability include

- How to account for comparative statements about same system but different attributes (*first* and *second* motorcyclists)?
- How to compare different systems exposed to *similar* risks (*first* and *second* motorcyclists vs *third* and *fourth* motorcyclists)?
- How to capture the ability of the vulnerable actor to act proactively to remove potential future hazards (for example to work towards relaying of road more frequently to reduce probability of oil spill; *mitigation* in the context of climate change)?
- How to capture the ability of the vulnerable entity to deal with multiple exogenous shocks? (e.g., Use of helmet by the *fifth* motorcyclist could reduce the damage in general independent of cause of damage)

Ionescu et al. (2009) formalizes these in the context of climate change

Features of Vulnerability

	Vulnerability to Poverty	Vulnerability to Climate Change
Typical question	Vulnerability of an entity to the threat of poverty	Vulnerability of an entity to the climate change threat
Focus	Outcome; shocks often not specified – consequentialism	Specific shocks; outcome often not clearly specified – emphasis on ‘process’
Entity of concern	Individual/household	Individual or eco-systems
What is of intrinsic interest	Welfare indicators (consumption, education etc.)	Welfare indicators; health/stability of the eco-systems
Nature of shock	Idiosyncratic and covariant	Largely covariant
Temporal scale	Short scale (e.g., next year)	Long time horizon

Climate Change Vulnerability – Indicators and more..

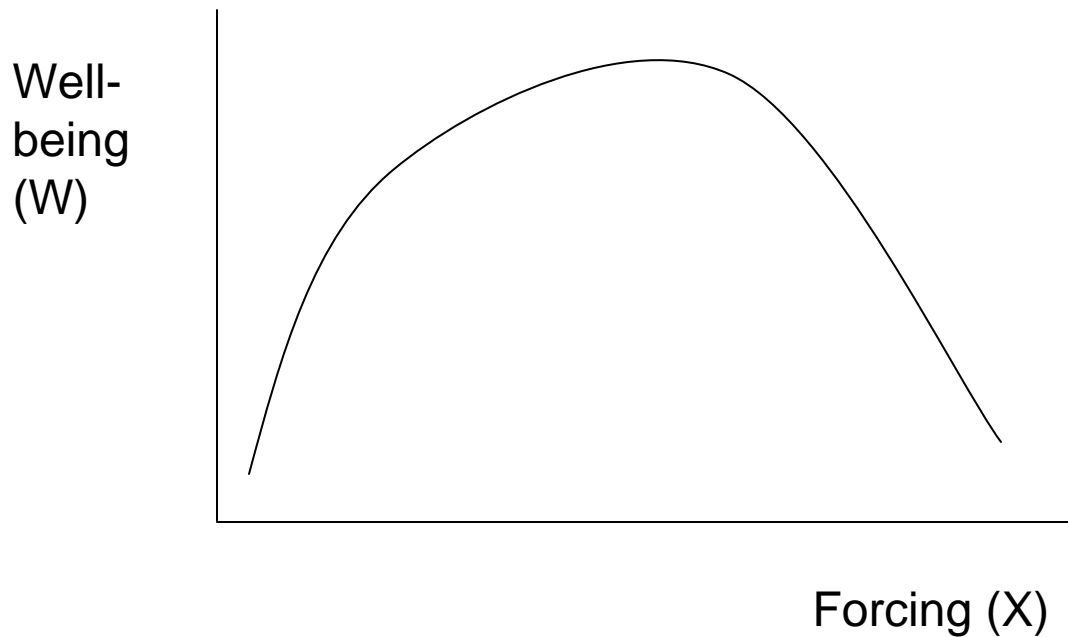
- Vulnerability in the climate change literature is defined as: f (exposure, sensitivity, adaptive capacity)
- Several studies combine indicators to assess vulnerability
- Luers *et al.* (2003, 2005) introduced new approach to measure vulnerability

$$Vulnerability^{CC} = f\left(\frac{sensitivity, exposure}{state\ relative\ to\ threshold}\right)$$

- Adaptive Capacity – ability to modify above

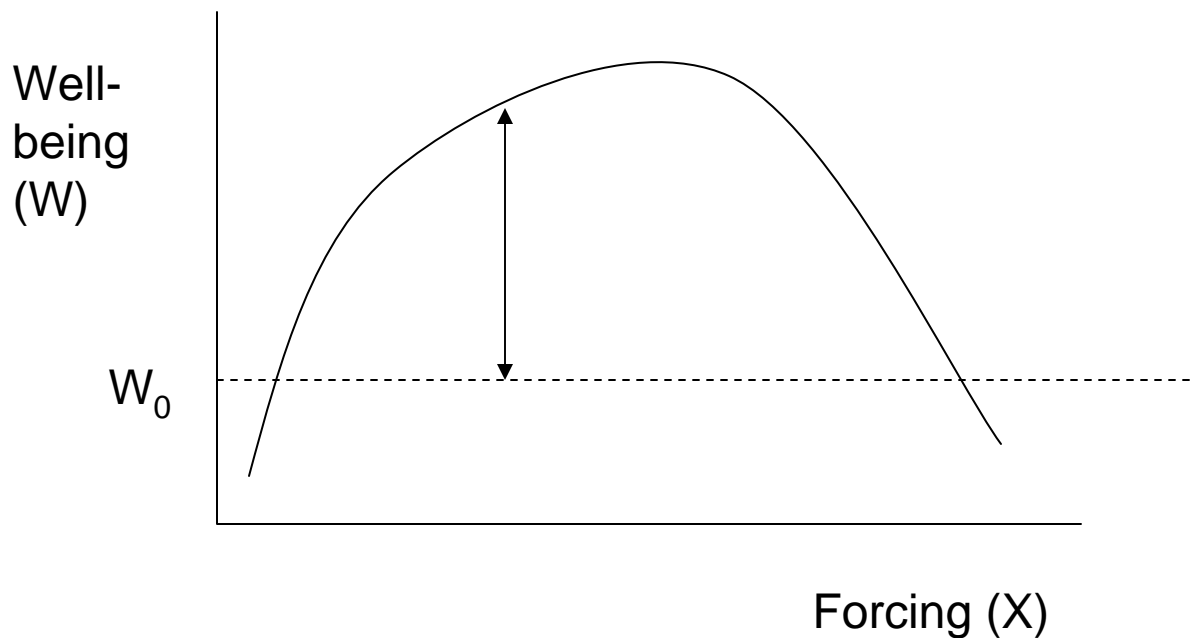
Vulnerability – Beyond Indicators

First define a ‘well-being’ function



Vulnerability – Beyond Indicators

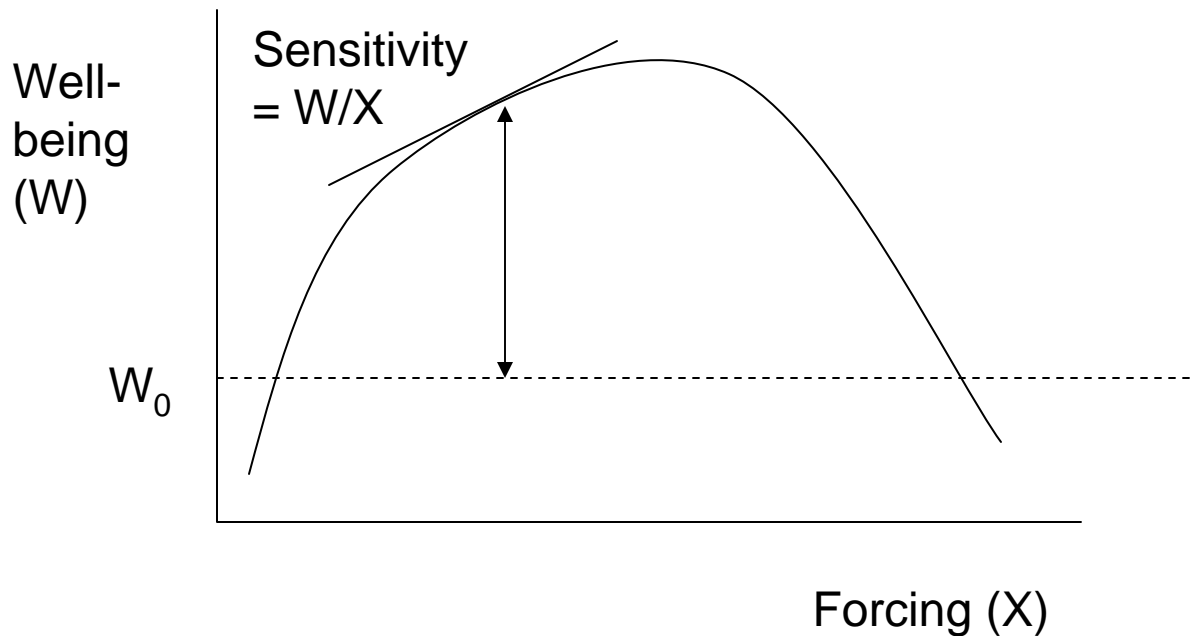
Identify 'state' relative to 'threshold' of damage



Vulnerability is a function of inverse of state relative to the threshold – i.e., better the state (relative to W_0), lower the vulnerability

Vulnerability – Beyond Indicators

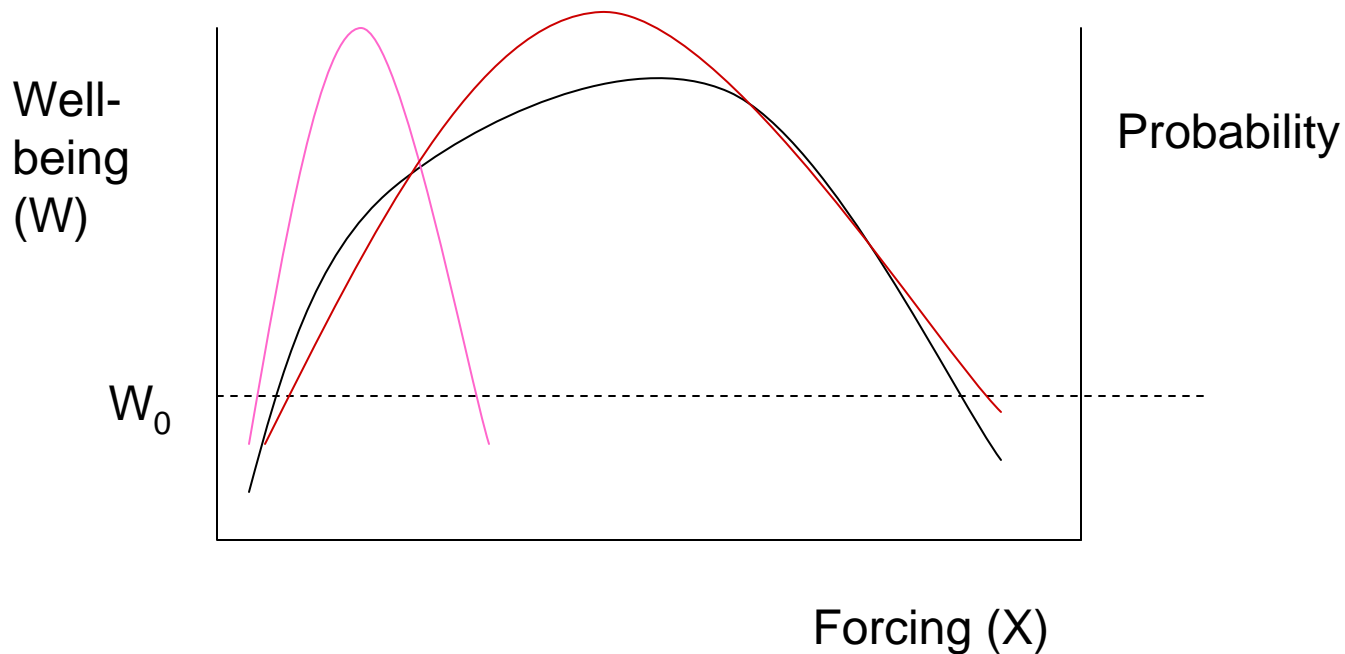
Assess the ‘sensitivity’ of the system



Vulnerability is a function sensitivity – higher the sensitivity, greater the vulnerability

Vulnerability – Beyond Indicators

Identify the distribution of the ‘exposure’



Vulnerability is a function exposure – higher the exposure, greater the vulnerability

Vulnerability Metric

Sensitivity

Exposure

Threshold of Damage

$$V^{CC} = \int \frac{W/x}{W/W_0} p_x dx$$

The diagram illustrates the components of the vulnerability metric equation. The equation is $V^{CC} = \int \frac{W/x}{W/W_0} p_x dx$. Annotations include: 'Sensitivity' pointing to the top part of the fraction W/x ; 'Exposure' pointing to the probability density function $p_x dx$; and 'Threshold of Damage' pointing to the denominator W/W_0 . The terms W/x and W/W_0 are circled, and the integral symbol is also circled.

Measuring Vulnerability

Measures used to assess VP can be summarized as:

$$(1) \quad V^P = \sum_{i=1}^n p_i v(x_i) \quad , \quad x_i = \frac{\hat{y}_i}{z} \quad , \quad \hat{y}_i = \min(y_i, z)$$

where

V^P is the vulnerability measure

$v(x_i)$ is monotonically decreasing and convex

y_i is the outcome of interest (e.g., consumption) in state i

z is the corresponding poverty line

p_i is the probability of occurrence of state i

n represents the number of states of the world

Measuring Vulnerability (contd.)

Crucial input needed in VP assessment is an ex-ante probability distribution of outcomes

This is typically generated through the error-structure of cross-sectional regression model explaining outcomes by household and community characteristics – sensitivity of outcome to the shock is implicitly specified

- This is done mainly due to non-availability of panel data and data with explicit information on shocks in developing countries

Few examples exist that explicitly estimate sensitivity and assess vulnerability through probability distribution of shock(s) – Christiaensen and Subbarao (2005)

Measuring Vulnerability (contd.)

Vulnerability to climate change in its most general form can be represented as:

$$(2) \quad V^{cc} = \sum_i \frac{\beta}{y_i / y_0} p_i$$

where, numerator (β) represents the sensitivity, the denominator represents the outcome of interest relative to a threshold, and p_i is the probability of the i^{th} state

Measuring Vulnerability (contd.)

Alternatively V^{CC} can be assessed similar to V^P by estimating the outcome in future state using entity's sensitivity to shock

Thus V^{CC} can be written as:

(3)

$$V^{CC} = \sum_{i=1}^n p_i [v(\hat{y}_i, \beta_i)] \quad \text{where } \hat{y}_i = \frac{y_i}{y_0}, \beta_i = \frac{\Delta y}{\Delta T}$$

where, y is an indicator of well-being of the entity (e.g., yield of representative farmer)

y_0 is the threshold level of well-being (e.g., break-even level of yield)

T is the exogenous input affecting the entity (e.g., temperature change)

p_i is probability of occurrence of state i

β is the sensitivity of the entity

$v(\cdot)$ is monotonically decreasing in y and increasing in β

Comparison of Vulnerability Metrics

Vulnerability to Expected Poverty

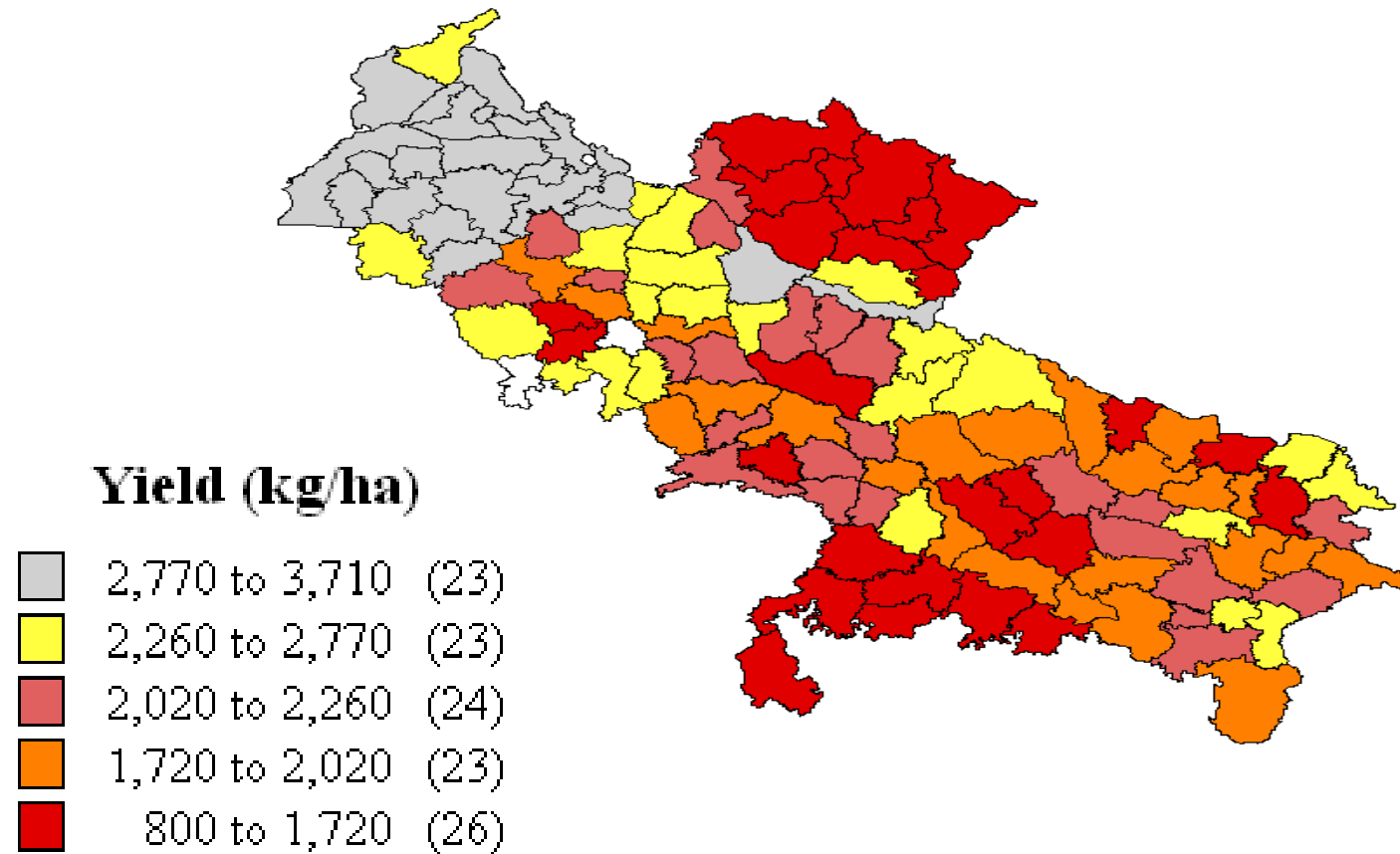
Vulnerability to Climate Change

$V^P = \sum_{i=1}^n p_i v(x_i), x_i = \frac{\hat{y}_i}{z}, \hat{y}_i = \min(y_i, z)$	$V^{CC} = \sum_{i=1}^n p_i [v(\hat{y}_i, \beta_i)], \hat{y}_i = \frac{y_i}{y_0}, \beta_i = \frac{\Delta y}{\Delta T}$
Vulnerability as expected value.	Vulnerability as expected value.
Future states of the world are referred on the basis of outcome of concern	Future states of the world referred on the basis of shock causing vulnerability
Outcome is censored with all values above the threshold having no influence on the vulnerability	Outcome is typically not censored and hence higher outcome values in 'good' states can bring down the vulnerability of an entity – violates 'focus' axiom
Higher value of outcome (after censoring) leads to lower vulnerability	Higher value of outcome results in lower vulnerability
Sensitivity of outcome to the shock is often implicitly captured, but few studies explicitly account for this	Sensitivity is explicitly specified along with the information on shock distribution
Non-availability of panel data for long time series requires the analyst to infer outcome distribution based on either cross-sectional data or short panel data	Distribution of shock is typically generated through historic data

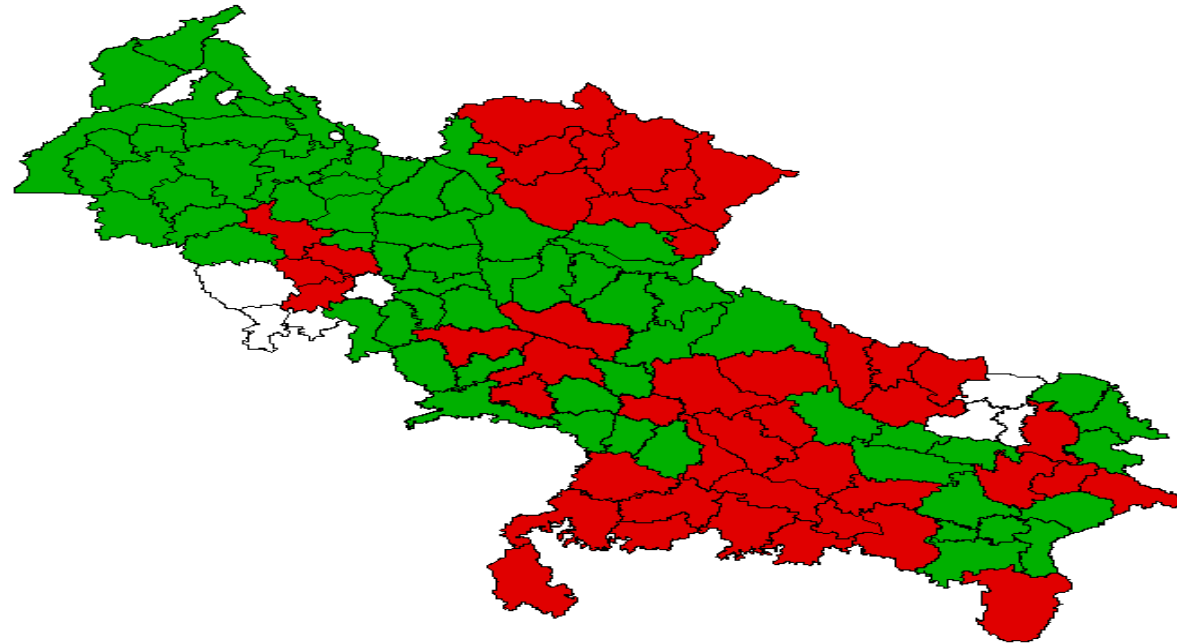
Vulnerability to Climate Variability

- Vulnerability of rice yields to climate variability in the Northern India (Punjab, Haryana, Uttar Pradesh, and Uttaranchal)
- Unit of analysis – districts
- Variability in – temperature and precipitation
- Methodology – Luers et al. (2003, 2005) and expected poverty (or, low yield)

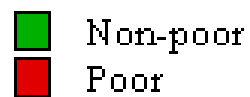
Rice Yields – Base Scenario



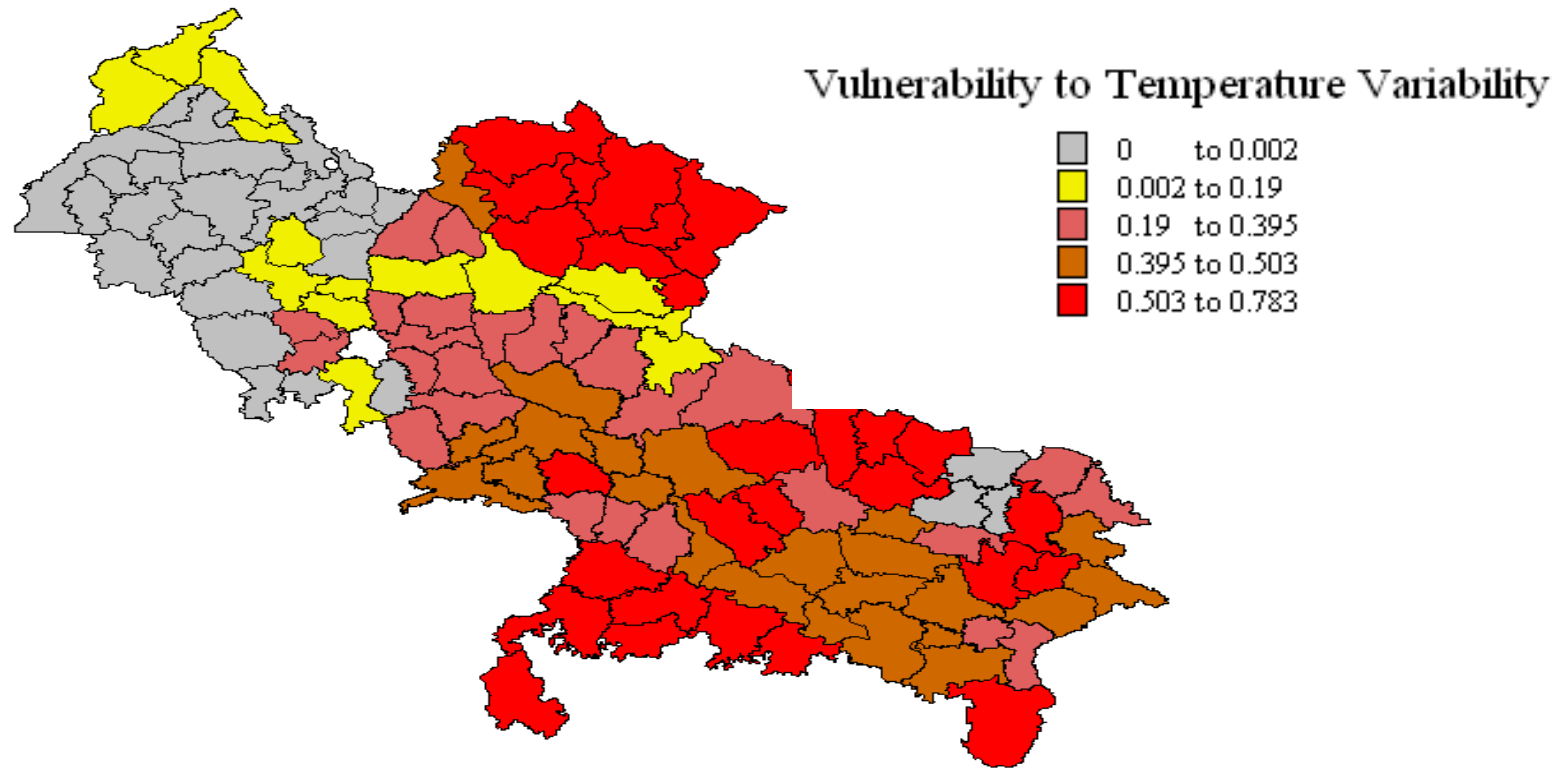
Poor-Non-poor: Current Status



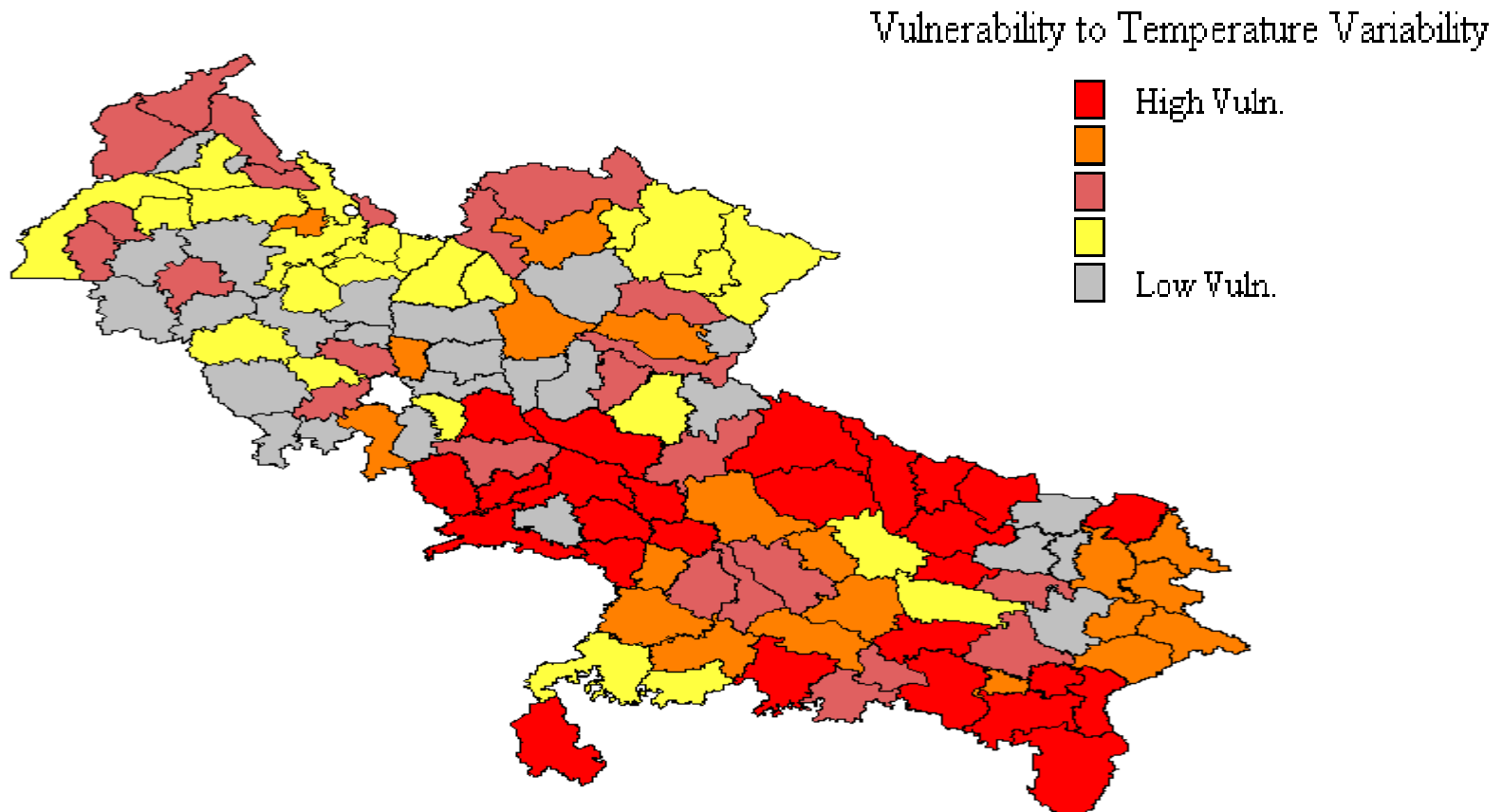
Poor-Non-poor Status



Vulnerability to Temp. Variability – Poverty Approach

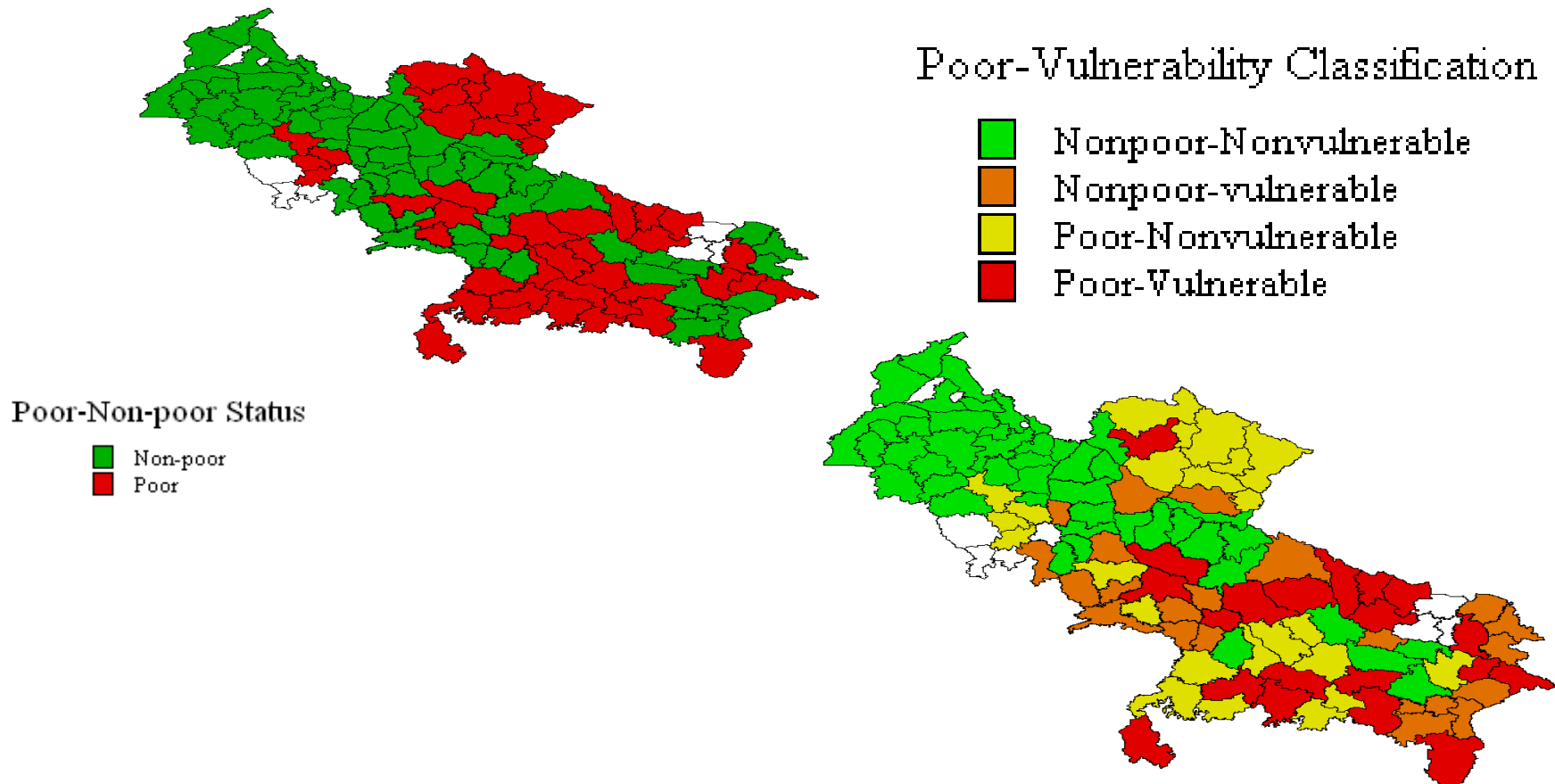


Vulnerability to Temperature Variability – Luers Approach



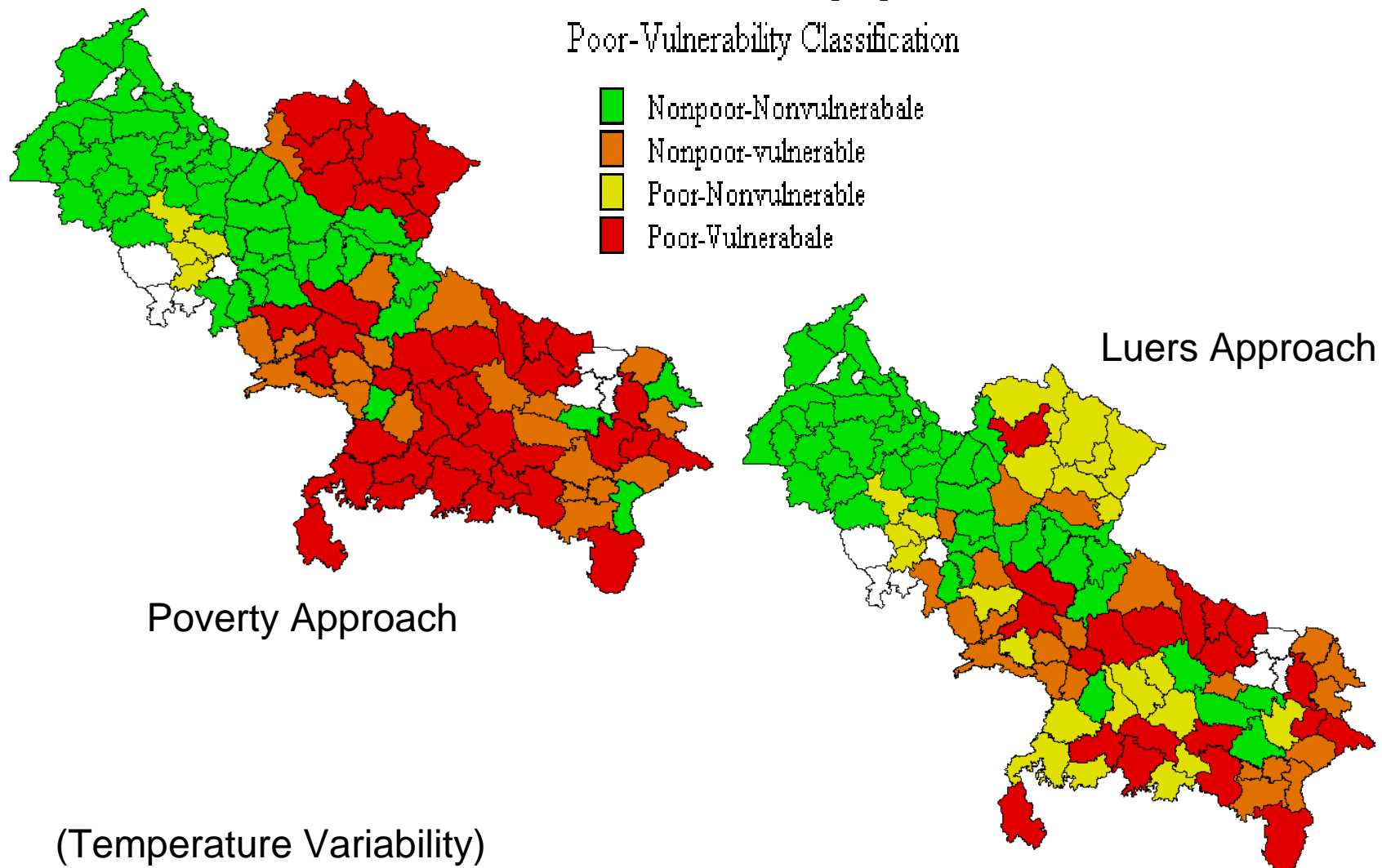
Inclusion of all states of the world in Luers approach results in lower incidence of vulnerability compared to the poverty approach

Poor vs. Vulnerable

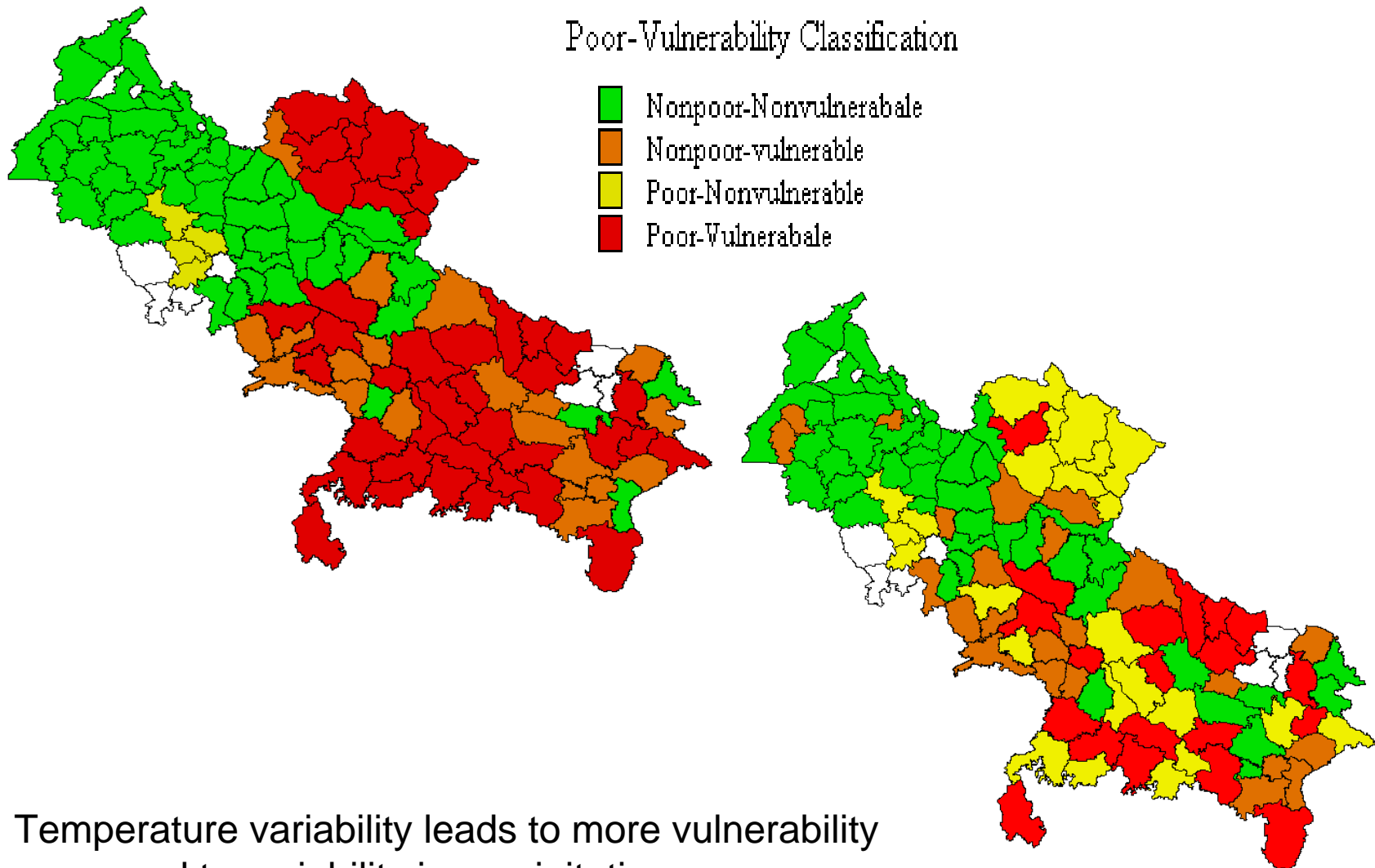


Districts that are presently 'poor' need not become 'vulnerable' – important for resource allocation

Poor-Vulnerable Classification: Comparison of Approaches

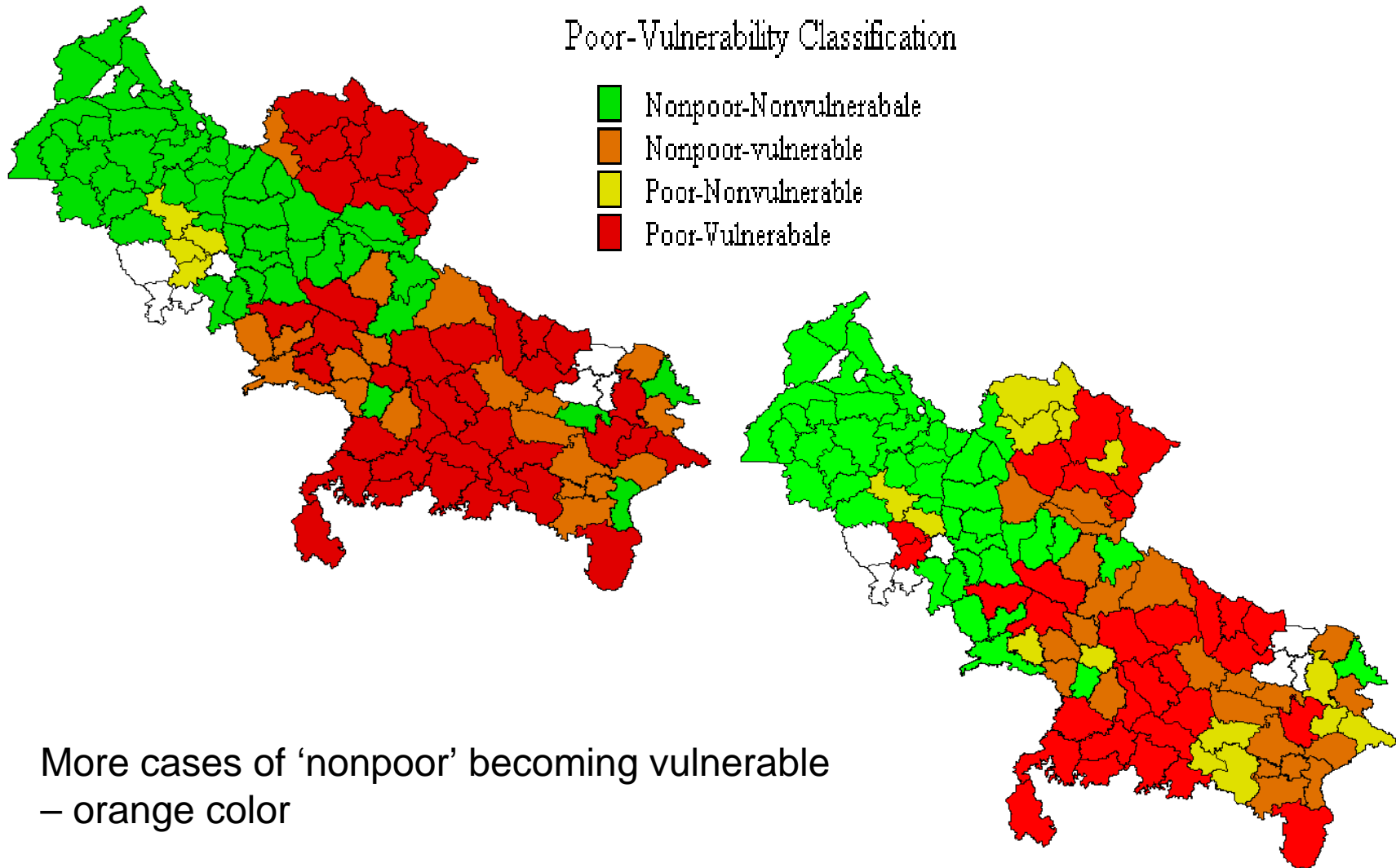


Poor-Vulnerable Classification: Comparison of Stimulus



Temperature variability leads to more vulnerability compared to variability in precipitation

Poor-Vulnerable Classification: Present vs Future Variability



Conclusions

- Several studies over the past two decades have analyzed the impacts of climate change and have used the word ‘vulnerability’ without necessarily providing careful definition to it
 - Janssen *et al.* (2005) note that more than seven hundred articles in the global change literature have used the term ‘vulnerability’ as key word over this period
- Broad interpretation of the term resulted in use of several indicators/measures for vulnerability estimation, raising concerns about the associated subjectivity in the choice of indicators/measures and the aggregation procedure adopted by the analyst

Conclusions (contd.)

- Adoption of the estimation procedure from development economics literature could provide scope for 'objective' assessment of vulnerability and bring-in more specificity into the analysis
 - However, it may rob the pluralistic perspective that vulnerability in CC literature aims to capture

Thank you!