Climate Change and Indian Agriculture

Impacts, Vulnerability and Adaptation Assessment

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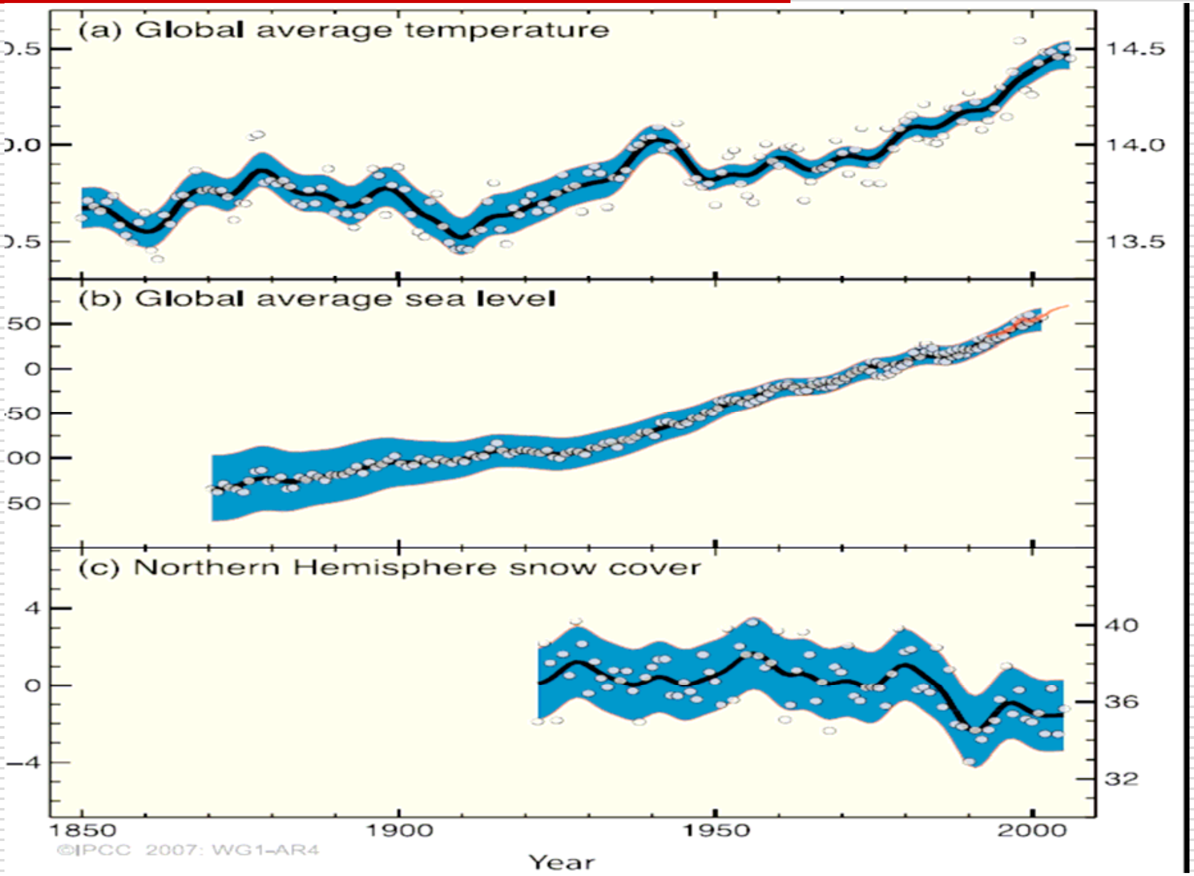
Structure of Presentation

- Introduction
- Assessing Impacts
- Vulnerability Assessment
- Adaptation Assessment
- Research Directions

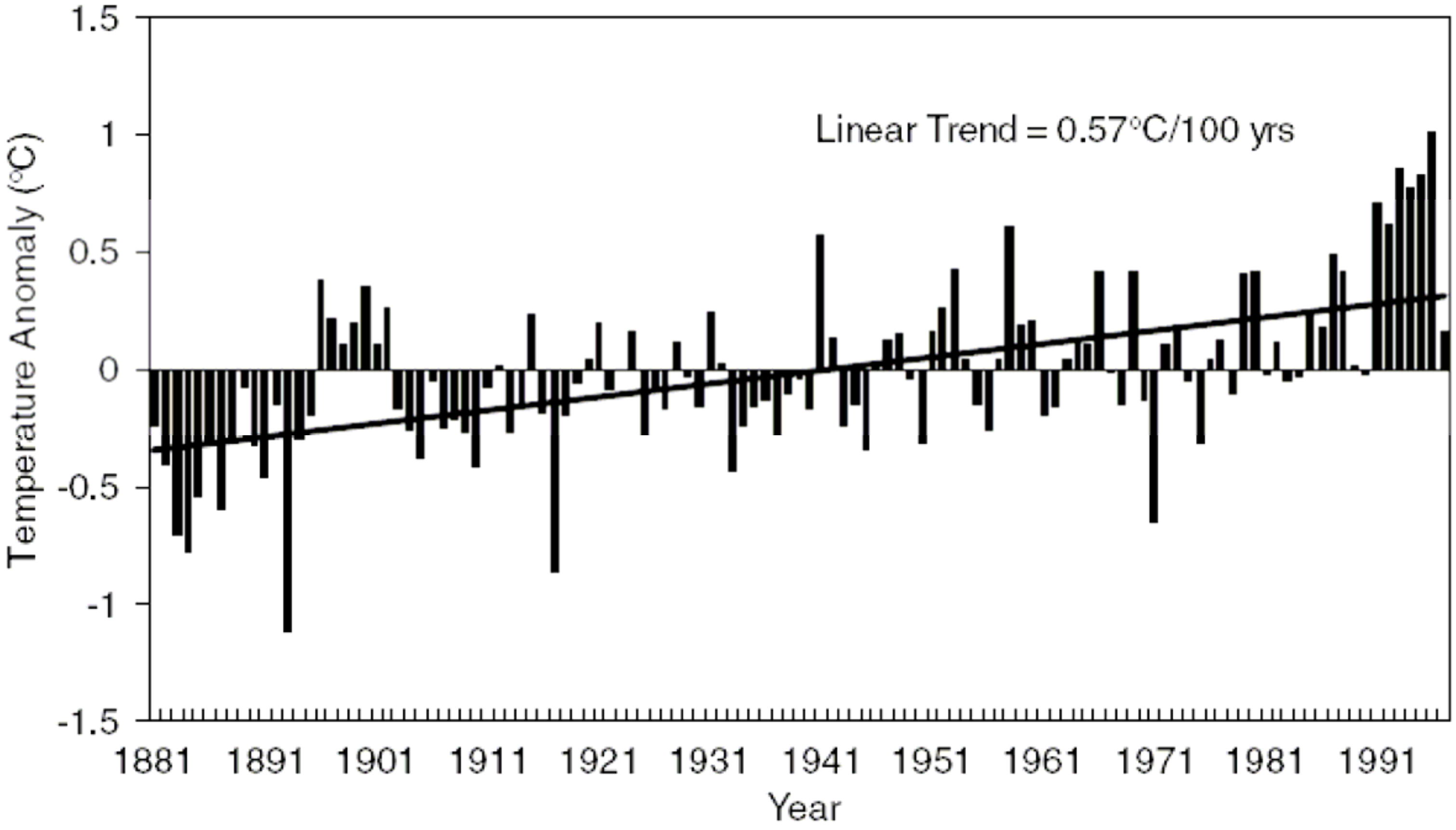
Changes in Global Temperature, Sea Level, NH Snow Cover (IPCC-WG1, 2007)



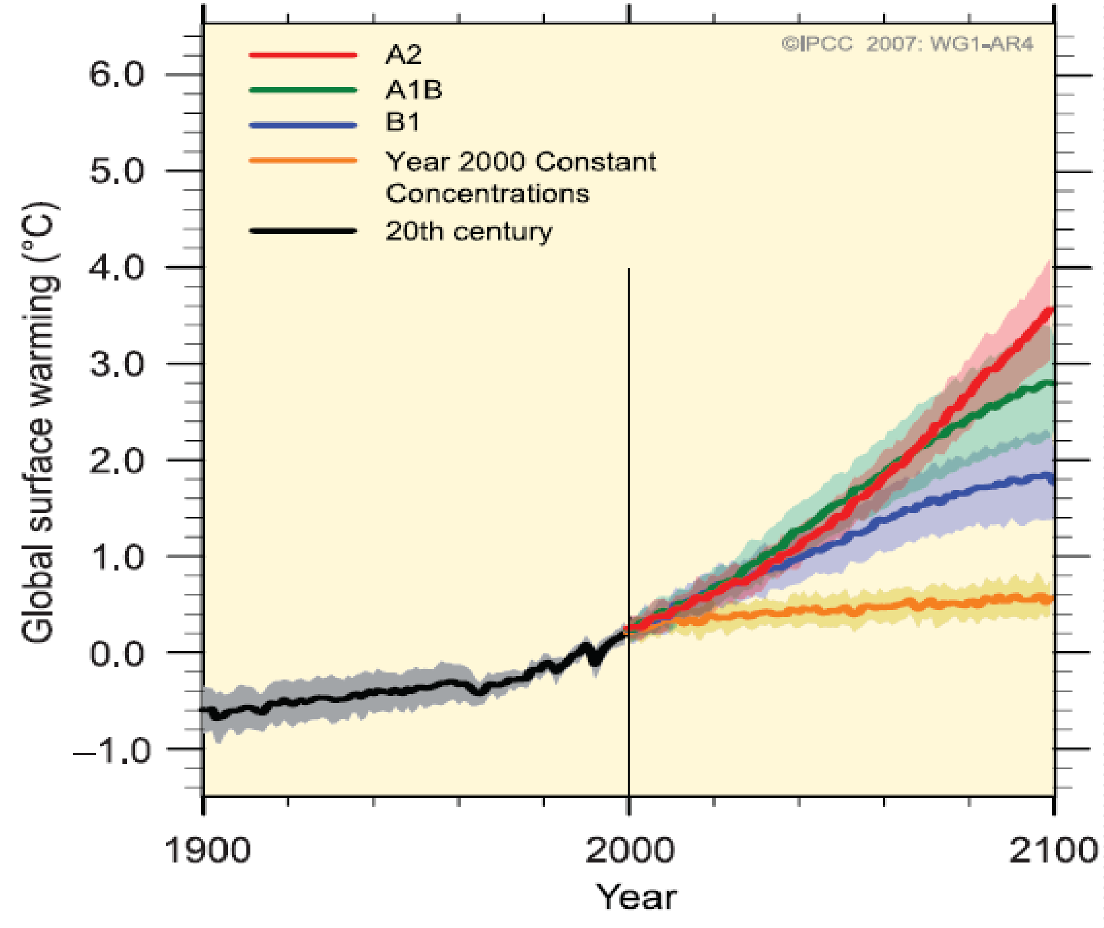
All changes relative to 1961-90 average

Annual Surface Air Temperature Anomalies, India: 1881-1997

(Pant & Rupakumar, 1997)



Climate Change Projections (IPCC-WG1, 2007)



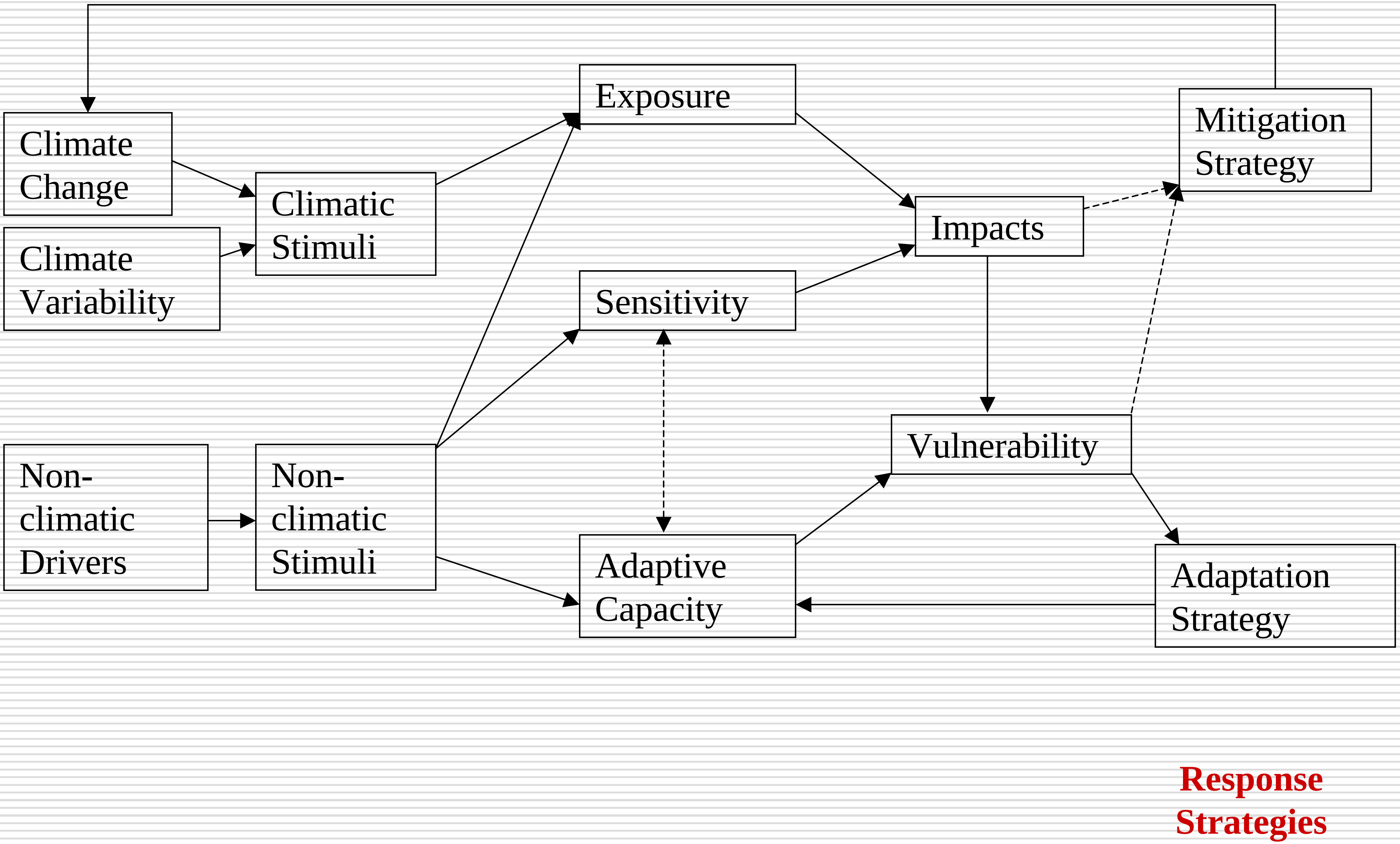
Climate Change Projections – India (Lal et al., 2001)

Year	Season	Increase in Temperature, °C		Change in Rainfall, %	
		Lowest	*Highest*	*Lowest*	*Highest*
2020s	Rabi	1.08	1.54	-1.95	4.36
	Kharif	0.87	1.12	1.81	5.10
2050s	Rabi	2.54	3.18	-9.22	3.82
	Kharif	1.81	2.37	7.18	10.52
2080s	Rabi	4.14	6.31	-24.83	-4.50
	Kharif	2.91	4.62	10.10	15.18

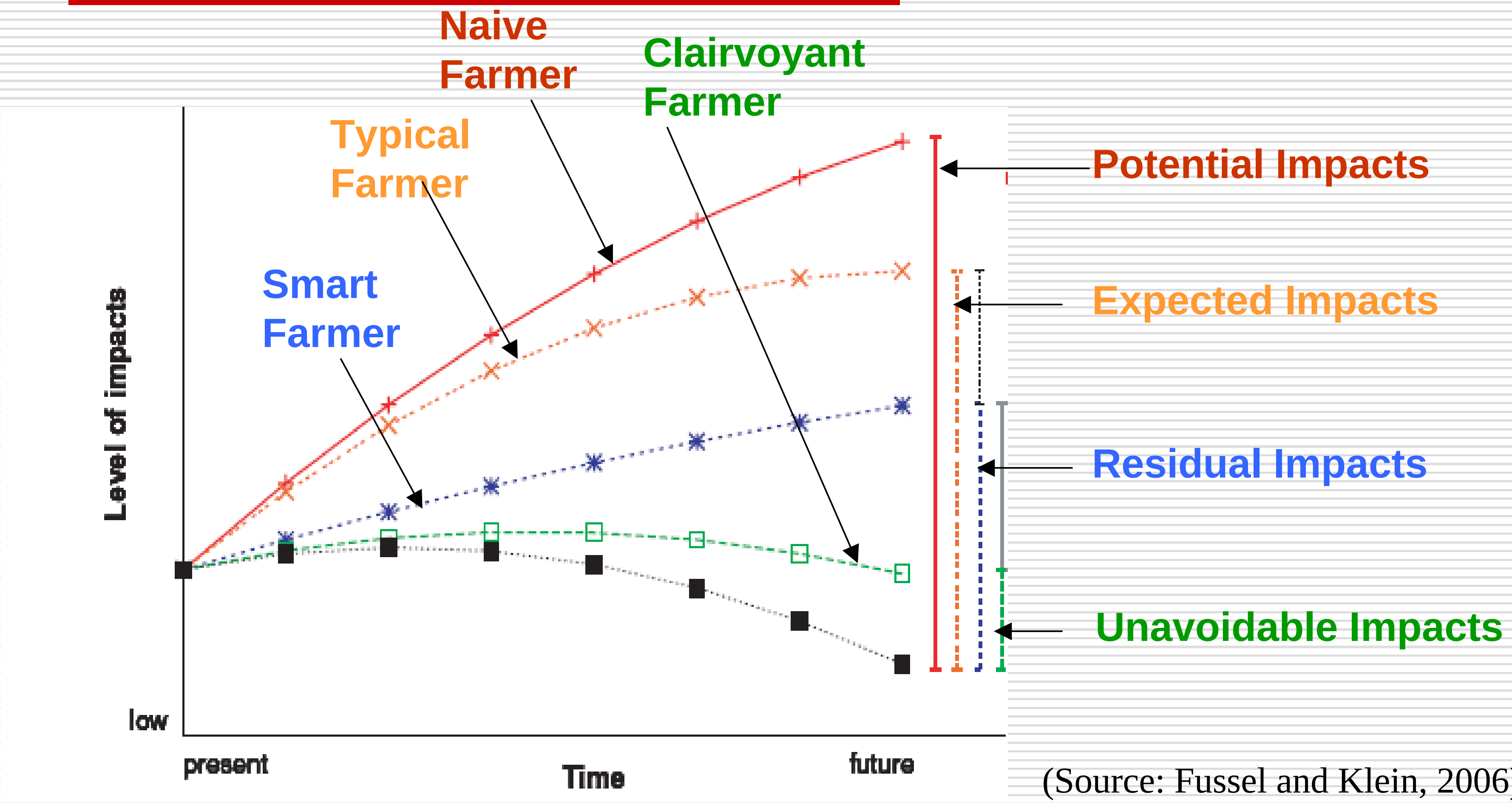
Research Questions

- Will climate change affect Indian agriculture adversely? If so, what is the extent of impact?
  - Impact Assessment; inputs for **mitigation policy**
- How to characterize the vulnerability of a farmer to climate change and climate variability? Which regions are more vulnerable and why?
  - Vulnerability Assessment; inputs for **resource allocation & adaptation**
- How to assess effectiveness of adaptation options in ameliorating the present and future vulnerability?
  - Adaptation Assessment; inputs for **adaptation policy**

Assessment Framework



Conceptualization of Impacts

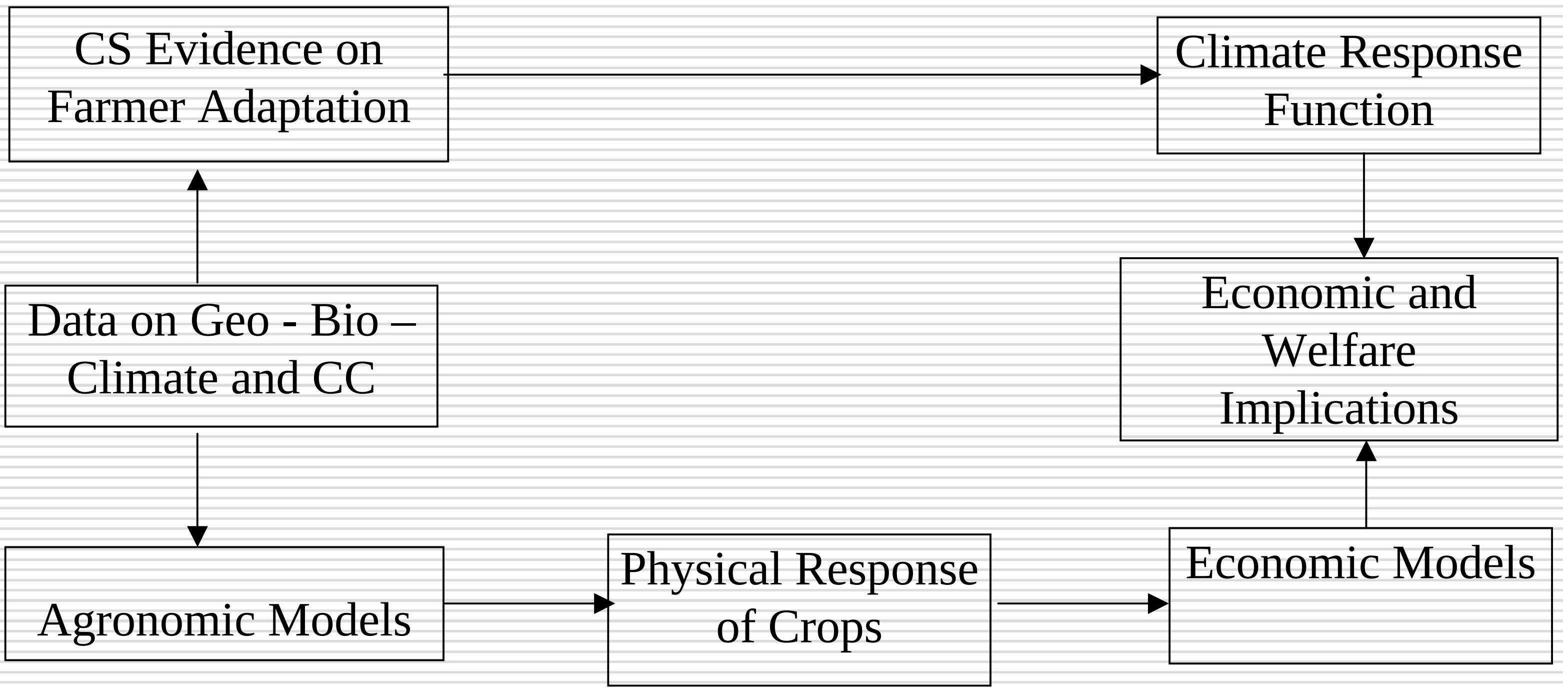


(Source: Fussel and Klein, 2006)

Economic Impact Assessment Approaches

Spatial Analogue Approach

Mendelsohn et al., 1994; Kumar and Parikh, 2001; Kumar, 2003; Kurukulasuriya and Ajwad, 2004; Mendelsohn et al. 2004a, 2004b, 2004c; Rosenberg et al., 2000



Agronomic-Economic Approach

Adams et al. 1990, 1999; Rosenzweig and Paryy 1994; Kumar and Parikh,2001; IIASA, 2002

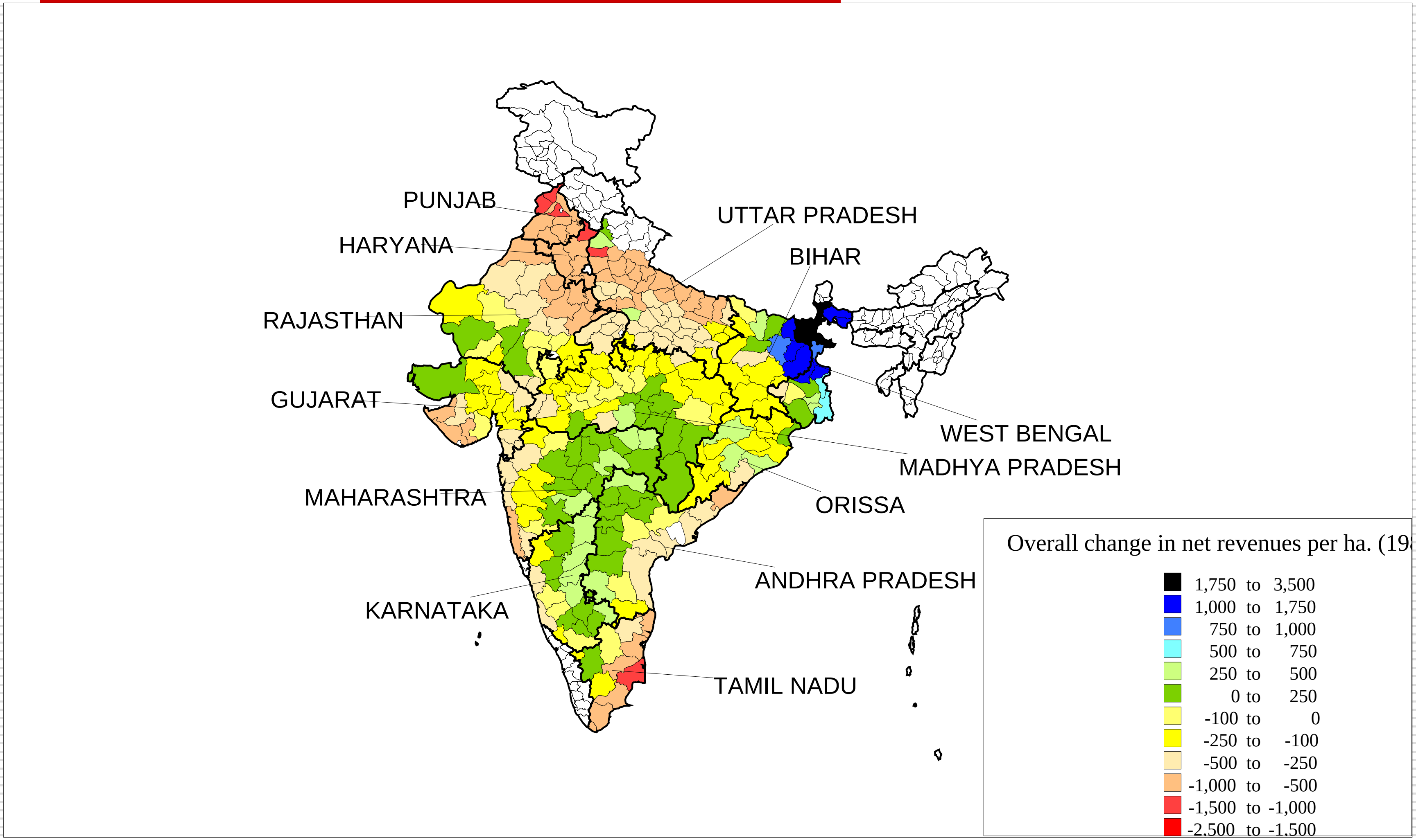
Agronomic-Economic Modeling – Macro Estimates

Variable	GFDL	GISS	UKMO
GDP (%)	-1.8	-2.5	-3.4
Cal per cap (%)	-18.2	-19.5	-21.6
Pop. prop. in bottom two expenditure classes - rural (base 0.183)	0.283	0.294	0.311
Pop. prop. in bottom three expenditure classes – urban (base 0.145)	0.208	0.214	0.226

(Kumar and Parikh, 2001)

Ricardian Approach: District-wise Impacts

(+2ºC Temperature and +7% Rainfall Change)



Source: Kumar and Parikh (2001)

Ricardian Approach:
Role of Climate Variation

ΔT/ΔP	Impacts as percentage of Net Revenue		
	Without Variation Terms	With Variation Terms	With Variation Terms and 5% Higher Variation
2^oC/7%	-7.8	- 6.8	-9.5
3.5^oC/14%	-24.0	- 17.8	-28.1

Source: Kumar (2003)

Naïve vs. *Clairvoyant* Farmer

- Two extremes – *naïve* farmer (or, analyst?) *vs.* *clairvoyant* farmer, leading to systematically lower biased estimates in Ricardian approach
- Ricardian approach is criticized to be based on so-called *homo economicus* assumptions of utility maximizing and perfectly rational economic agents
  - i.e., farmers are assumed to identify instantaneously and perfectly any change in climate, evaluate all associated changes and then modify their actions to maximize profits
- These assumptions also imply that agricultural system is *ergodic* – i.e., space and time are substitutable

Naïve vs. *Clairvoyant* Farmer

- *Ergodic* assumption imply, for example, that skills, institutional and financial endowments for responding to drought (that are typically refined in arid places) are assumed to be available for use by people in humid areas (where such resources are under-developed) immediately and in essentially cost-less manner
- Thus Ricardian climate sensitivity estimated for one point in time or place may not represent sensitivities for other times or places

Ricardian Approach with Space

- Spatial lag operators can be introduced in the analysis to capture information diffusion process and inter-farmer communication
  - A significant coefficient on spatial lag operator indicates that land use in a region is influenced by land uses in adjacent regions
- Similarly group-wise heteroscedastic terms can be introduced to account for differences between broad regions (meso-scale)
  - Schlenker et al., 2005, 2006; Polsky, 2004
- Analysis in Indian context indicated significant influence of inter-farmer communication and inter-regional differences on climate sensitivities

Spatial Dependence

High-high spatial dependence is found among parts of western Tamil Nadu and Karnataka, northern Uttar Pradesh and Punjab; whereas low-low spatial dependence is found among south central and western (Gujarat) parts of India.

$$R = f(T_j, T_j^2, P_j, P_j^2, T_j P_j, DT_j, YT_j, YP_j, SOIL, BULLOCK, TRACTOR, POPDEN, LITPROP, CULTIV, HYV, IRR, LAT, ALT, RLAG)$$

$$R = f(T_j, T_j^2, P_j, P_j^2, T_j P_j, DT_j, YT_j, YP_j, SOIL, BULLOCK, TRACTOR, POPDEN, LITPROP, CULTIV, HYV, IRR, LAT, ALT, ULAG)$$

Climate Response Function - With Weather Variation Terms

Base Model			Spatial Lag Model			Spatial Error Model		
Variable	**Coefficient**	***p*-value**	**Variable**	**Coefficient**	***p*-value**	**Variable**	**Coefficient**	***p*-value**
tnjan	96.295	0.000	tnjan	37.547	0.005	tnjan	84.960	0.000
tnapr	-42.522	0.001	tnapr	-49.312	0.000	tnapr	-44.008	0.000
tnjul	-38.861	0.006	tnjul	-18.696	0.151	tnjul	-39.709	0.004
tnoct	-14.711	0.329	tnoct	14.773	0.286	tnoct	-16.178	0.263
tnjansq	-5.694	0.001	tnjansq	-3.533	0.020	tnjansq	-4.555	0.004
tnaprsq	-9.019	0.007	tnaprsq	-5.205	0.089	tnaprsq	-6.083	0.058
tnjulsq	-2.880	0.230	tnjulsq	-5.919	0.007	tnjulsq	-4.348	0.059
tnoctsq	4.730	0.140	tnoctsq	5.742	0.051	tnoctsq	4.252	0.167
rnjan	23.767	0.000	rnjan	14.137	0.000	rnjan	19.353	0.000
rnapr	13.153	0.000	rnapr	14.287	0.000	rnapr	12.668	0.000
rnjul	-1.062	0.000	rnjul	-0.923	0.000	rnjul	-1.234	0.000
rnoct	-1.629	0.084	rnoct	-2.462	0.004	rnoct	-1.008	0.266
rnjansq	-0.611	0.000	rnjansq	-0.588	0.000	rnjansq	-0.544	0.000
rnaprsq	-0.400	0.000	rnaprsq	-0.418	0.000	rnaprsq	-0.383	0.000
rnjulsq	0.001	0.000	rnjulsq	0.001	0.000	rnjulsq	0.001	0.000
rnoctsq	-0.034	0.000	rnoctsq	-0.021	0.000	rnoctsq	-0.034	0.000
			Lag NetRev	**0.463**	**0.000**	**Lag Error**	**0.375**	**0.000**
Adj.Rsq.	0.501		Adj. Rsq.	0.582		Adj.Rsq.	0.541	

Vulnerability Assessment

- Vulnerability in the context of climate change – emerged as a key notion in the past two decades
  - More than 700 articles in the global change literature used the term 'vulnerability' as key word (Janssen *et al*, 2005)
- By focusing on the mechanism that facilitates or constrain a system's ability to cope, adapt or recover from various disturbing forces, vulnerability assessments help in not only identifying 'who', but also 'why'
- Such information is critical in prioritizing limited resources for 'most vulnerable' and also for designing 'most effective' vulnerability-reducing interventions

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

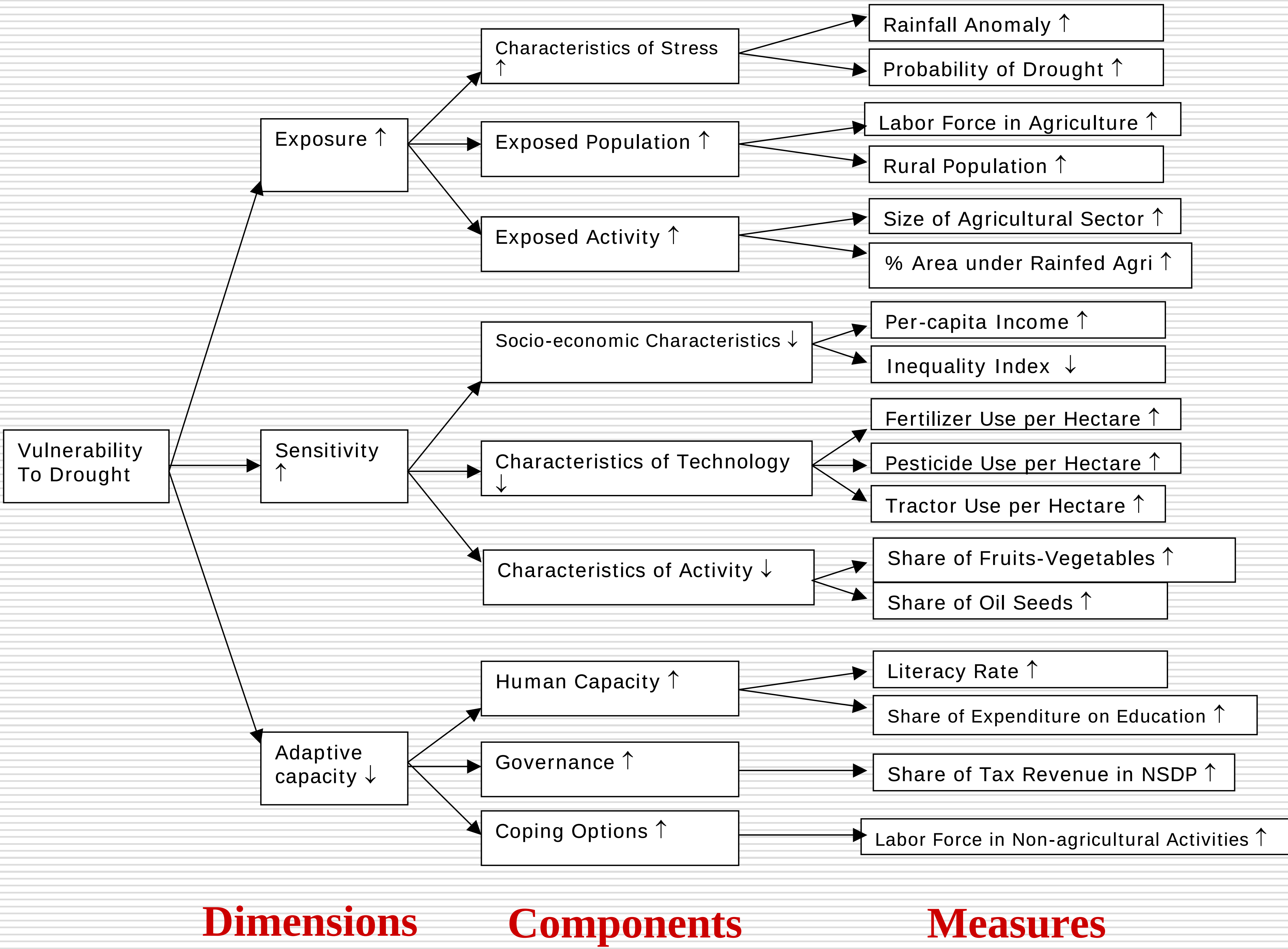
Vulnerability – Illustrative Example

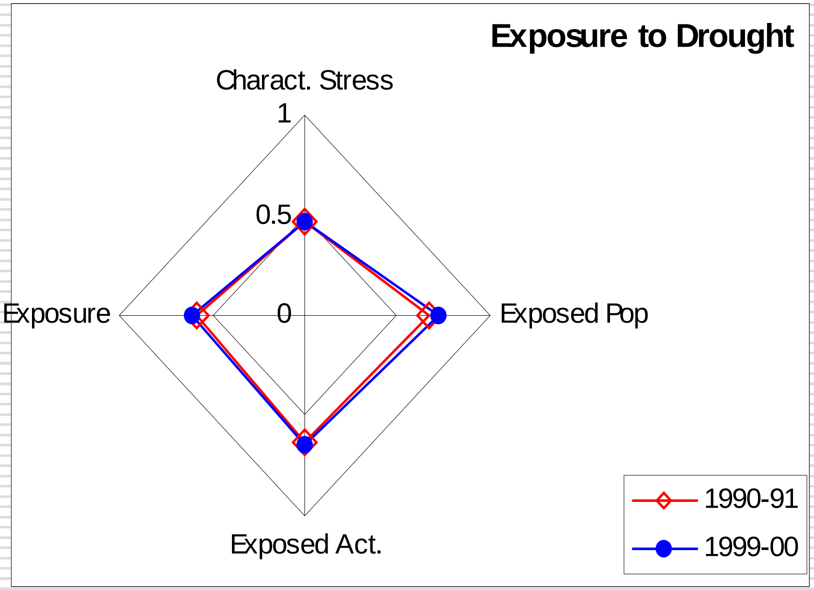
Challenges in formalizing vulnerability include

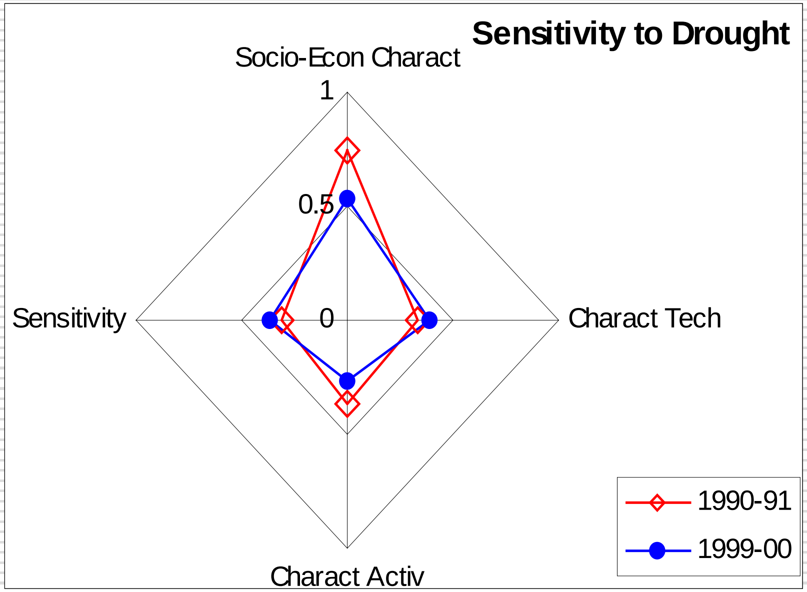
- How to account for comparative statements about same system but different attributes (1^{st} *vs* 2^{nd} motorcyclists)?
- How to compare different systems exposed to *similar* risks (1^{st} and 2^{nd} motorcyclists *vs* 3^{rd} and 4^{th} motorcyclists)?
- How to capture the ability of the vulnerable actor to act proactively to remove potential future hazards (e.g., 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)

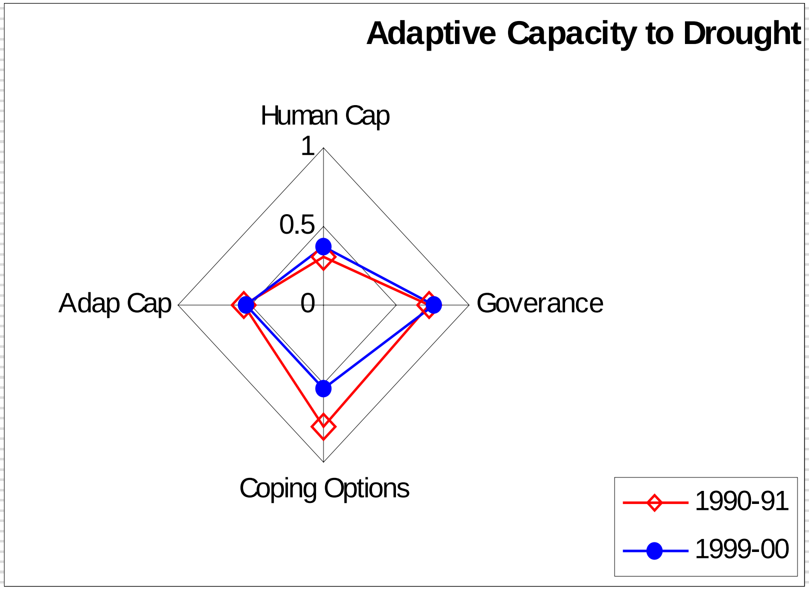
Vulnerability Assessment

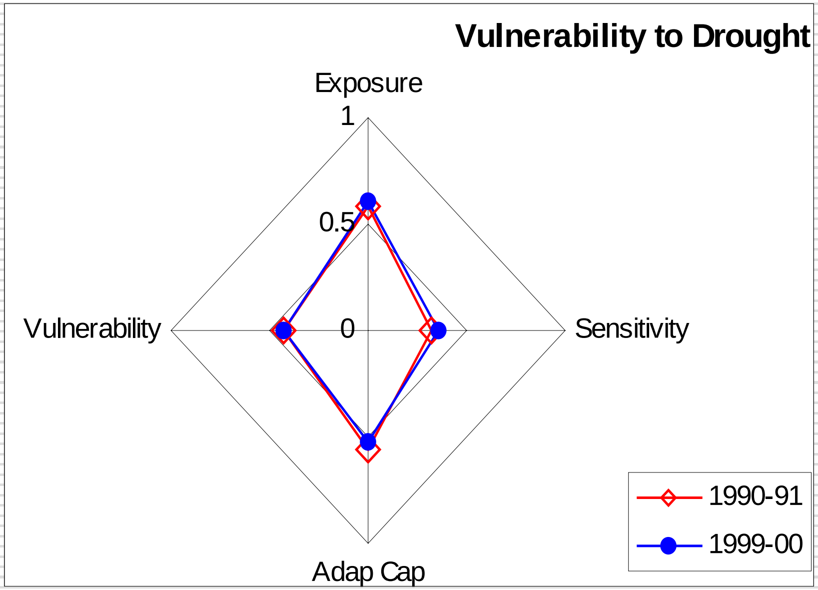
- Ionescu et al. (2006) while proposing a formal framework for vulnerability argued for specification of three primitives for characterizing vulnerability:
  - the entity that is vulnerable
  - the stimulus to which it is vulnerable
  - the preference criteria to evaluate the outcome of the interaction between the entity and the stimulus
- Vulnerability is ‘a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity’ – IPCC (2001)
- Most studies followed indicator based approach to assess vulnerability - O’Brien et al., 2004; Brenkert and Malone, 2004; Kumar and Tholkappian, 2005; ongoing works at MSSRF, World Bank


Vulnerability To Drought
Exposure ↑
Sensitivity ↑
Adaptive capacity ↓
Characteristics of Stress ↑
Exposed Population ↑
Exposed Activity ↑
Socio-economic Characteristics ↓
Characteristics of Technology ↓
Characteristics of Activity ↓
Human Capacity ↑
Governance ↑
Coping Options ↑
Rainfall Anomaly ↑
Probability of Drought ↑
Labor Force in Agriculture ↑
Rural Population ↑
Size of Agricultural Sector ↑
% Area under Rainfed Agri ↑
Per-capita Income ↑
Inequality Index ↓
Fertilizer Use per Hectare ↑
Pesticide Use per Hectare ↑
Tractor Use per Hectare ↑
Share of Fruits-Vegetables ↑
Share of Oil Seeds ↑
Literacy Rate ↑
Share of Expenditure on Education ↑
Share of Tax Revenue in NSDP ↑
Labor Force in Non-agricultural Activities ↑
Dimensions
Components
Measures









Slight increase in exposure and decrease in adaptive capacity are countered partly by the marginal decrease in sensitivity and the vulnerability level remained almost static over the period

Measuring Vulnerability

- Consider a representative farmer's vulnerability with regard to poor wheat yield caused by temperature change
- Farmer's vulnerability can be meaningfully expressed as: (a) vulnerability to poor wheat yield due to temperature change; or, (b) vulnerability to temperature change with reference to poor wheat yield
- Vulnerability measurement can draw insights from poverty literature (Dercon, 2005; Cesar and Dercon, 2005)

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

Vulnerability Assessment

$$V^{CC} = \sum_i \frac{\beta}{y_i / y_0} p_i$$

Specific form – Luers et al (2003, 2005)

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

General form

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

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

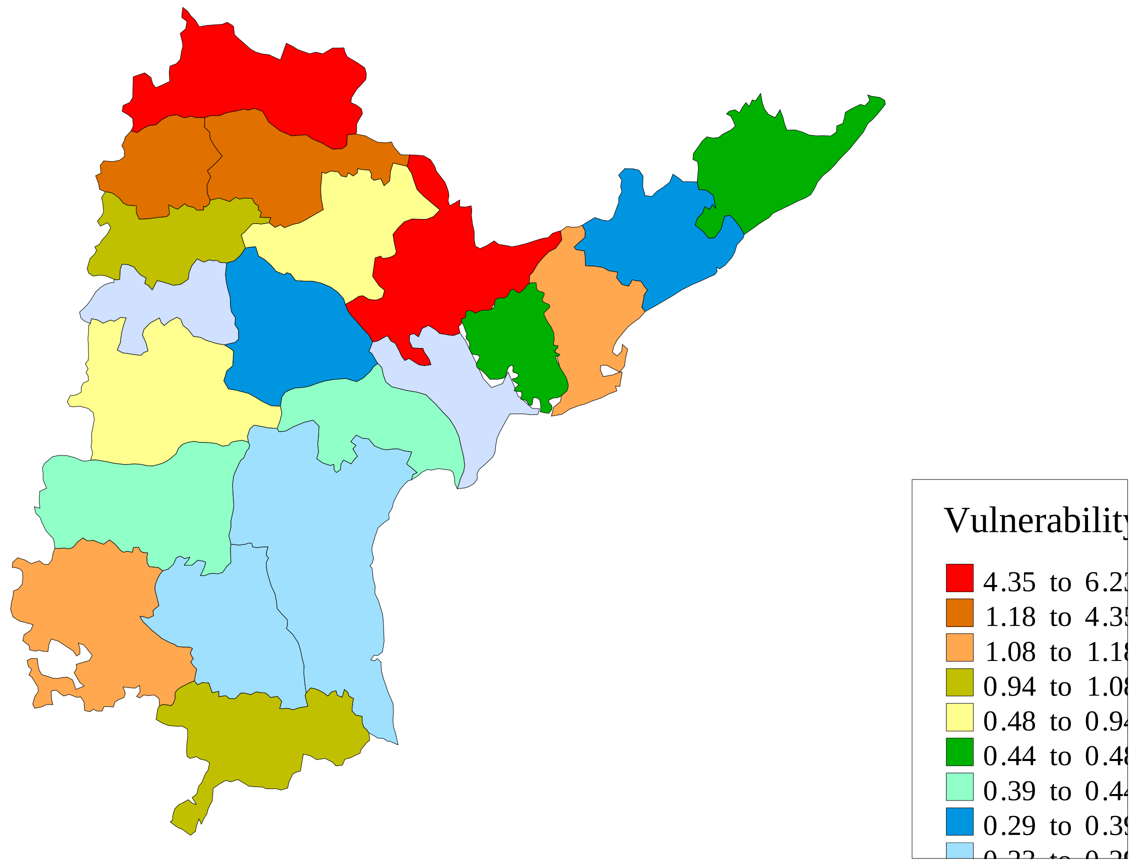
T is the exogenous input affecting the entity (e.g., temperature change)

p_i is probability of occurrence of state i

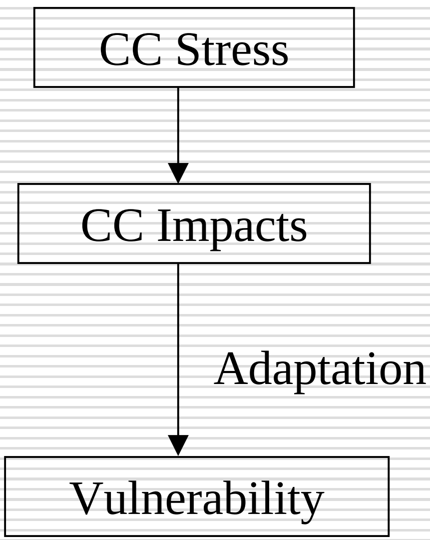
β is the sensitivity of the entity - links the outcome of concern and shock

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

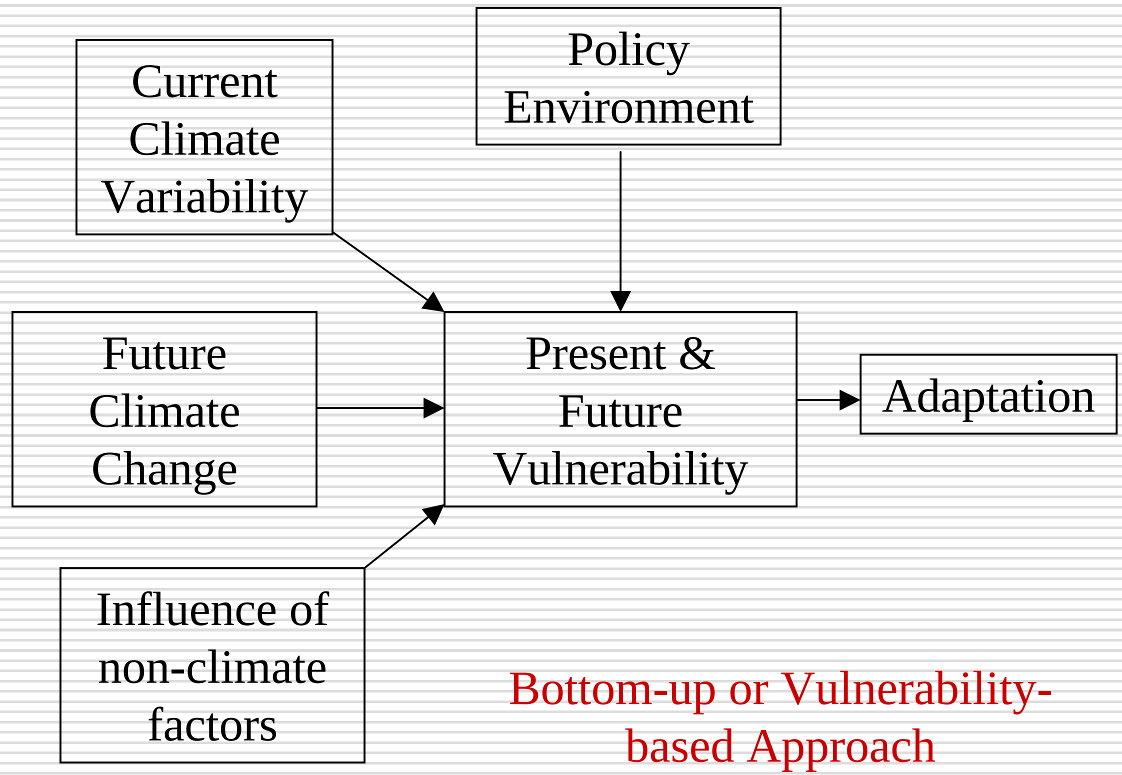
Vulnerability to Rainfall Change with Reference to Poor Rice Yield: Andhra Pradesh



Adaptation Assessment



Top-down or Hazard-based Approach



Bottom-up or Vulnerability-based Approach

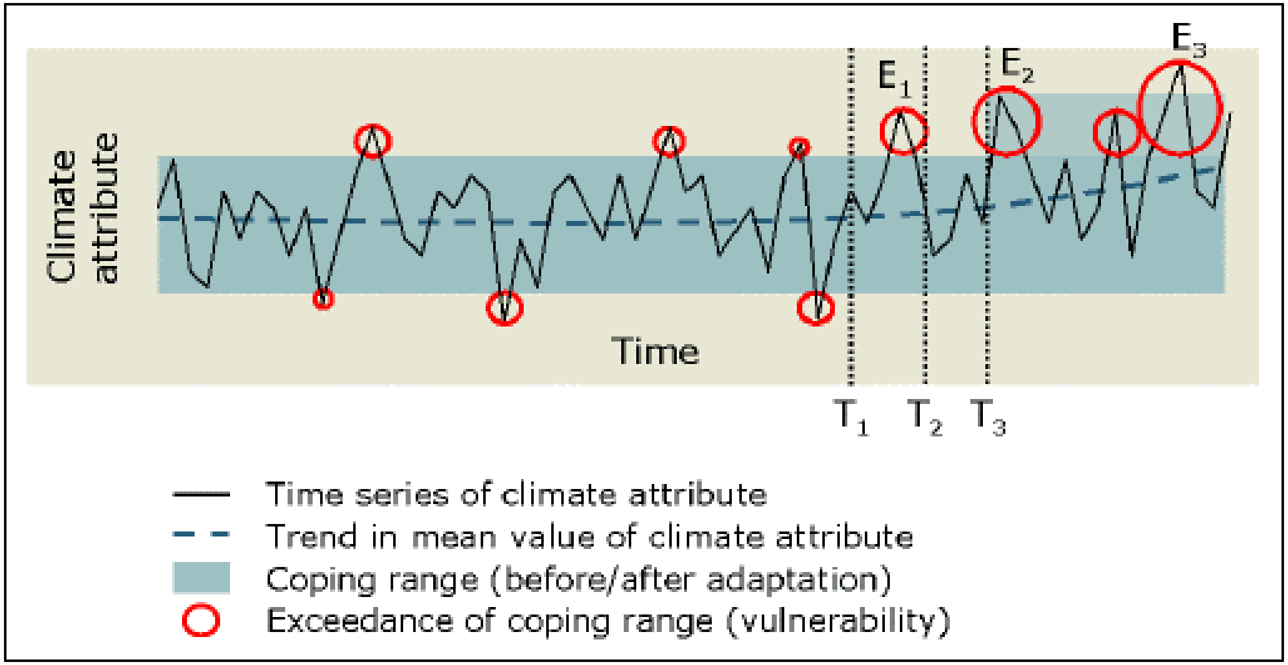
Adaptation Assessment

- ‘End-point’ characterization of vulnerability in climate change literature emphasizes on regional/national level adaptation strategies
- In contrast vulnerability assessments practiced by poverty and disaster management communities depend directly on the vulnerable community itself to make use of wider-range of social, cultural, economic and institutional factors; and also characterize vulnerability as ‘starting-point’ of their analysis
  - These aspects make vulnerability assessment conducive for providing local-scale guidance on adaptation

Adaptation Assessment

- As Klein (2004) argued even the most recent sophisticated scenario-based assessments of impacts and vulnerabilities (e.g., DINAS-COAST) may increase awareness for adaptation but give little information to the local decision makers on most efficient or effective adaptation strategies
- Such information may come only from local knowledge and one needs different tools/methods to comprehend the same

Adapt to *what*?



(Fussel, 2007)

Adaptation strategies geared to cope with (current) climate anomalies may embrace a large proportion of the envelope of adjustments expected under long-term climate change

How to Adapt?

- By linking climate change concerns with other non-climate concerns (e.g., globalization)
- By involving several stake-holders – scientists are just one of them
- When current climate risks are large, it is prudent to address them first
- Explore *soft* adaptation before undertaking *hard* options

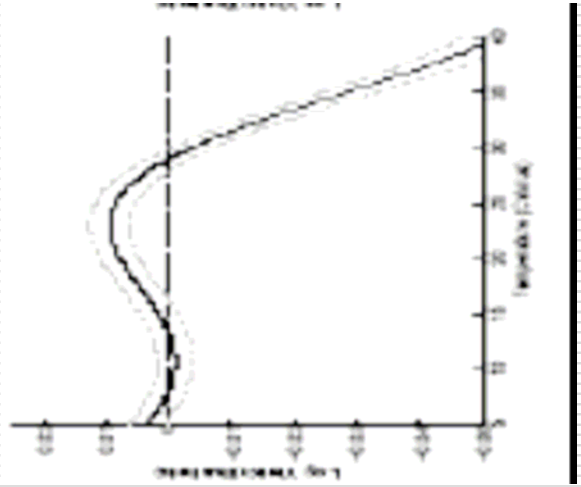
In sum, <u>‘main-stream’</u> the adaptation process

Adaptation Assessment - Example

- The results from Ricardian approach suggest presence of spatial features, possibly due to inter-farmer communication – but it remains to be seen exactly how farmers communicate
- Cognition allows the agents to receive and exchange information, to perceive and evaluate risks, to identify and weight options, to make decisions and perform actions, and modify and update profile based on the outcomes
- Social interactions of the agents could be based on social psychological consistency principle
- Agent based modeling strategy could be used to model vulnerability

Impact Assessment – Road Ahead

- Non-linear relationship between agricultural outcome and climate can be represented by quadratic function?
- Schlenker and Roberts (2006) suggest that the relationship is not *symmetrical*
- Higher CO_2 concentrations – influences other than fertilization?
- Competition between weeds and crops
- Impacts on variety of crops
- Integrated assessment – land use changes, water supply/demand changes, changing market conditions



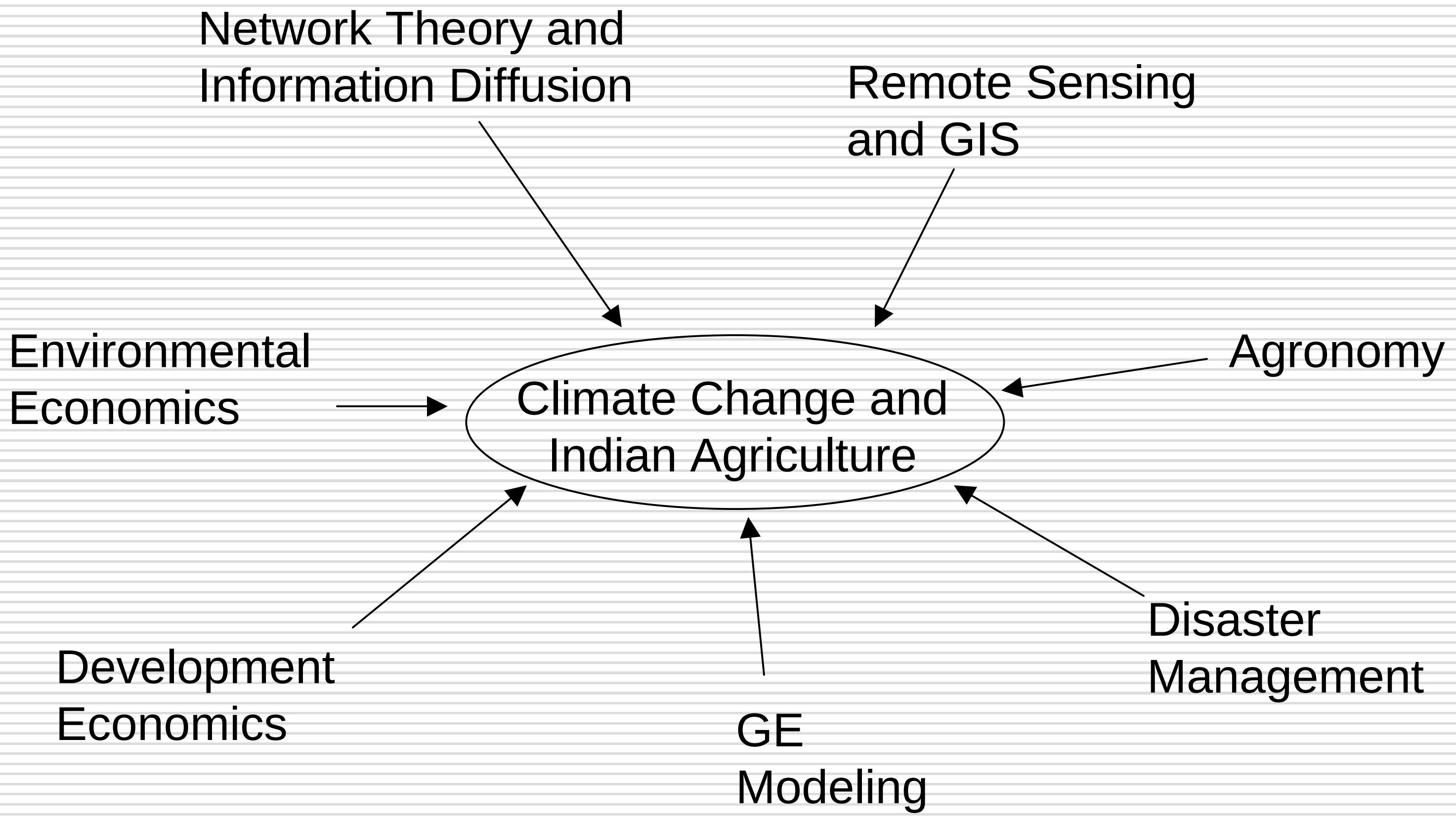
Vulnerability and Adaptation Assessment – Road Ahead

- Explore synergy between climate change and poverty; climate change and disaster management – for better understanding of methodologies and policy response
- Effective adaptation strategies require understanding of regional / local dimensions of vulnerability
- Climate change does not occur in isolation – multiple stresses ('Double Exposure' – O'Brien, 2004)
- Domestic policies can enhance or constrain farmers' ability to adapt to climate change
- Identify and prioritize adaptation options

Concluding Remarks

- Assessing impacts *per se* may have only limited use; effort should be towards vulnerability and adaptation assessment
- Since most adaptation takes place at local level, information on future climate change should be complemented with relevant local knowledge
- Adaptation strategies geared to cope with large climate anomalies may embrace a large proportion of the envelope of adjustments expected under long-term climate change
- However since UNFCCC mandates focus on ‘climate’ component, efforts should be made to *mainstream* climate policies

Inter-Disciplinary Nature of Subject



Thank You for Your Attention!