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Vulnerability and Resilience of India and Indian States to Climate Change: a First Order Approximation

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Executive Summary

Climate change research increasingly focuses on vulnerability assessment. Indeed, the Intergovernmental Panel on Climate Change (IPCC) added "Vulnerability" to the title of the Working Group II's contribution to the 2001 Third Assessment Report (TAR).[1] The TAR recognized that evidence of changes in the climate necessitates scientific study of the extent to which societies are vulnerable to – that is, could be harmed by – such climate changes. Assessing societal vulnerability broadens the area of analysis to the context of sustainable development, and both qualitative and quantitative studies contribute to the analysis of vulnerability. A major focus of the IPCC is on analyzing candidate methods to summarize and compare socioeconomic and environmental conditions that contribute to vulnerability. However, no generally agreed-upon methodology or framework has appeared. Criteria for a framework include the following:

- capturing the important aspects of vulnerability (the subject of many debates within the research community)
- allowing for comparison among countries, regions, and smaller geopolitical areas
- using quantified indicators where possible to facilitate comparisons and integrated analysis
- utilizing a transparent methodology so that users of the framework understand the results and are able to analyze them with qualitative information.

One area of research concerns the development of indices of vulnerability, based on sets of indicators of vulnerability's various aspects. Summary numbers must be used with caution, of course, since it is difficult to boil down complex cultural-social-economic-resource-political structures into one number or even a set of numbers. The IPCC report reviews the efforts made to perform vulnerability assessments using indicators.[2] This report is an addition to that research.

In the analytical framework we developed, the Vulnerability-Resilience Indicator Prototype or VRIP, vulnerability is composed of (positive) coping-adaptive capacity and (negative) sensitivities to climate change. Evaluation of a society's coping and adaptation capacity is based on society's human resources, economic capacity and natural capital. Sensitivity of a society to climate variability and change is based on an evaluation of its food and water security, its settlement security, the health of people, and natural resources. However, the quantitative analysis does not include relevant and important characteristics such as governmental capacity, cultural worldviews and beliefs, and institutional opportunities and limitations; a brief qualitative discussion complements the quantitative analysis. Furthermore, all of the relevant characteristics have developed over time and will change in the future, but future projections are not part of the current study.

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[1] James J. McCarthy, Osavaldo F. Canziani, Neil A. Leary, David J. Dokken and Kasey S. White, *Climate Change 2001: Impacts, Adaptation, and Vulnerability*, Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge: Cambridge University Press, 2001). The previous assessment was titled *Climate Change 1995: Impacts, Adaptations, and Mitigation of Climate Change: Scientific-Technical Analyses*.

[2] Q.K. Ahmad, Richard A. Warrick, T.E. Downing, S. Nishioka, K.S. Parikh, C. Parmesan, S.H. Schneider, F. Toth and G. Yohe, Methods and Tools. In McCarthy et al., op. cit.

The quantitative analysis in this report is a snapshot of present vulnerability in the identified sectors. In each of these sectors, data-based indicators represent aspects of coping-adaptive capacity or sensitivity (see Table ES-1 below).

The VRIP had previously been used[3] to compare national vulnerability-resilience indices against a global index. The VRIP as an analytical framework seemed very appropriate for a first-order approach to comparing Indian states, based on a survey of data availability and descriptions of Indian states. Applying the VRIP model to 26 of the Indian states, we used the following method:

- collected the necessary 17 indicator values for each state
- scaled the indicators against world values
- calculated index numbers for each sector as geometric means of each sector's indicators (the climate-sensitivity sectoral indicators [negatives] and the coping-adaptive capacity sectoral indicators [positives])
- calculated the overall sensitivity and the overall coping-adaptive capacity as geometric means of the participating sectors
- calculated the net vulnerability-resilience indicator value as the simple arithmetic summation of a state's sensitivity (-) and adaptive capacity (+).

The result is that the states' indicator values can be compared with India as a whole and with the global indicators.

Our findings are presented in detail in the following report. Overall, we found only 3 states more vulnerable than India as a whole, 23 states less vulnerable, and 9 states showing resilience (see Figure ES-1).

The small mountainous northern inland states show the highest resilience among Indian states. These small northern mountainous states have high values for environmental capacity. This is mainly due to low sulfur emissions and a relatively large percentage of unmanaged land. Taking the step of determining the basis for higher or lower resilience is important, for the analyst can then evaluate the adequacy and completeness of the set of indicators. For example, in the case of mountainous relatively clean air states, the indicator set does not account for the risks of increased erosion, mudslides and other natural hazards that can be anticipated with climate change.

With regard to economic capacity, all states rank lower than the global representation.[4] Kerala shows the highest economic capacity among Indian states because of its relatively low inequality, which plays a role in this indicator.

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[3] Richard H. Moss, Antoinette L. Brenkert and Elizabeth L. Malone, *Vulnerability to Climate Change: A Quantitative Approach*, PNNL-SA-33642 (Washington, DC: Pacific Northwest National Laboratory, 2001), http://www.pnl.gov/globalchange./projects/vul/index.htm.

[4] Calculated in Moss, Brenkert and Malone, *Vulnerability*.

Table ES-1. Data based indicators

	Sectoral indicators	Proxy variables	Proxy for	Functional relationship
Coping & Adaptive Capacity	Economic capacity	GDP(market)/ capita	Distribution of access to markets, technology, and other resources useful for adaptation	Coping-adaptive capacity ↑ as GDP per capita ↑
		An income equity measure	Realization of the potential contribution of all people	Coping-adaptive capacity ↑ as poverty or inequity ↓
	Human and civic resources	Dependency ratio	Social and economic resources available for adaptation after meeting other present needs	Coping-adaptive capacity ↓ as dependency ↑
		Literacy	Human capital and adaptability of labor force	Coping-adaptive capacity ↑ as literacy ↑
	Environmental capacity	Population density	Population pressure and stresses on ecosystems	Coping-adaptive capacity ↓ as population density ↑
		SO2/ state area	Air quality and other stresses on ecosystems	Coping-adaptive capacity ↓ as SO2 ↑
		% Land unmanaged	Landscape fragmentation and ease of ecosystem migration	Coping-adaptive capacity ↑ as % unmanaged land ↑
Sensitivity	Settlement/ infrastructure sensitivity	Population at flood risk from sea level rise	Potential extent of disruptions from sea level rise	Sensitivity ↑ as population at risk ↑
		Population no access clean water/sanitation	Access of population to basic services to buffer against climate variability and change	Sensitivity ↑ as population with no access ↑
	Food security	Cereals production/ crop land area	Degree of modernization in the agriculture sector; access of farmers to inputs to buffer against climate variability and change	Sensitivity ↓ as production ↑
		Protein consumption/ capita	Access of a population to markets and other mechanisms (e.g., consumption shift) for compensating for shortfalls in production	Sensitivity ↓ as consumption↑
	Ecosystem sensitivity	% Land managed	Degree of human intrusion into the natural landscape and land fragmentation	Sensitivity ↑ as % land managed ↑
		Fertilizer use/ cropland area	Nitrogen/phosphorus loading of ecosystems and stresses from pollution	Sensitivity is ↓ if use < 60 kg/ha, sensitivity or > 100 kg/ha
	Human health sensitivity	Completed fertility	Composite of conditions that affect human health including nutrition, exposure to disease risks, and access to health services	Sensitivity ↓ as fertility ↓
		Life expectancy		Sensitivity ↓ as life expectancy ↑
	Water resource sensitivity	Renewable supply and inflow	Supply of water from internal renewable resources and inflow from rivers	Sensitivity calculated using ratio of available water used: Sensitivity ↑ as % water used ↑
		Water use	Withdrawals to meet current or projected needs	

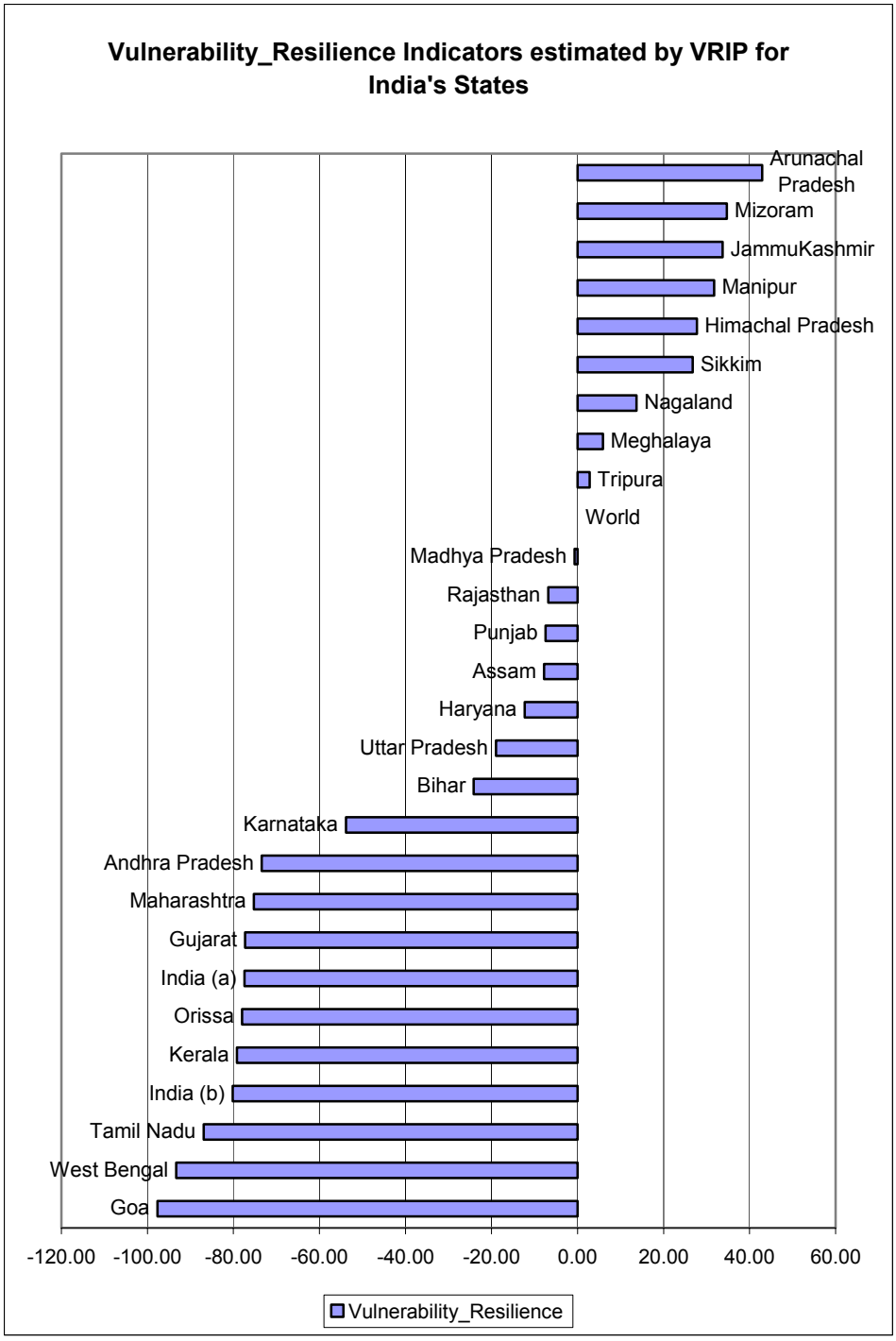

Figure ES-1. An overview of the range of the vulnerability-resilience indicators for the different states in India, calculated with the VRIP methodology

All coastal states show high vulnerability, especially Goa, for which it is reported that over 7% of the population would be affected by 1 m sea level rise. Presently, Goa has a relatively high sensitivity to sea-storm surges. Orissa and Tamil Nadu also show high sensitivity to sea-storm surges (see Figure 9 in the main report).

National data were used for all the states for water availability: it thus does not contribute to the states' sensitivity differentiation. A much more in-depth study would have been needed for a representative state water-availability sector.[5] Sensitivity indicators of food security are different among the states, with Kerala and Sikkim being rather sensitive, but not Punjab. Ecosystem sensitivity is found to be the largest in the Punjab, mainly due to fertilizer use and its polluting consequences.

Because data were not available for a particular base year, we used data from various years between 1990 and 1998, not for one particular base year.[6] We proceeded with the calculations, however, not only to illustrate the methodology and show obtainable results, but also to help formulate the next level of questions with regard to vulnerability analyses.

State-level analyses can show the value-added of the VRIP approach. For example, a detailed analysis of the contributions of the various proxy values to Andhra Pradesh's vulnerability shows Andhra Pradesh to be a very representative state for all of India (see Figure ES-2[7]). Andhra Pradesh has an overall level of vulnerability that is similar to India as a whole (also shown in Figure ES-1), albeit slightly less; the reasons for this difference can be graphically analyzed. The lower level of vulnerability is attributable to less pollution from fertilizer use and to slightly less risk of the population to impacts from sea level rise; India as a nation includes a number of more vulnerable states with regard to sea level rise than Andhra Pradesh. Andhra Pradesh is very representative of the national income level, literacy rate, food security, life expectancy and land use. (National water availability and access to sanitation data were used for Andhra Pradesh.)

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[5] This study has been pursued; a draft report is available from the authors.

[6] In the prototype exercise, all data were from 1990. See Moss, Brenkert and Malone, *Vulnerability*. However, data from one year may not represent the general status of a situation. It is therefore advisable for indicator calculations to incorporate a representative mean of the variable information to be processed. Depending on the questions asked in the research, a five-year average of a proxy value might be a better indicator than a single-year value.

[7] Given the non-linear nature of our model structure, the proxy values displayed in the figure indicate that some proxy values weigh heavier than others in the final vulnerability-resilience indicator value calculation. Moss, Brenkert and Malone, *Vulnerability*, explore this in depth by means of a Monte Carlo based uncertainty analysis. They analyze the interplay of model structure, proxy values and changes over time.

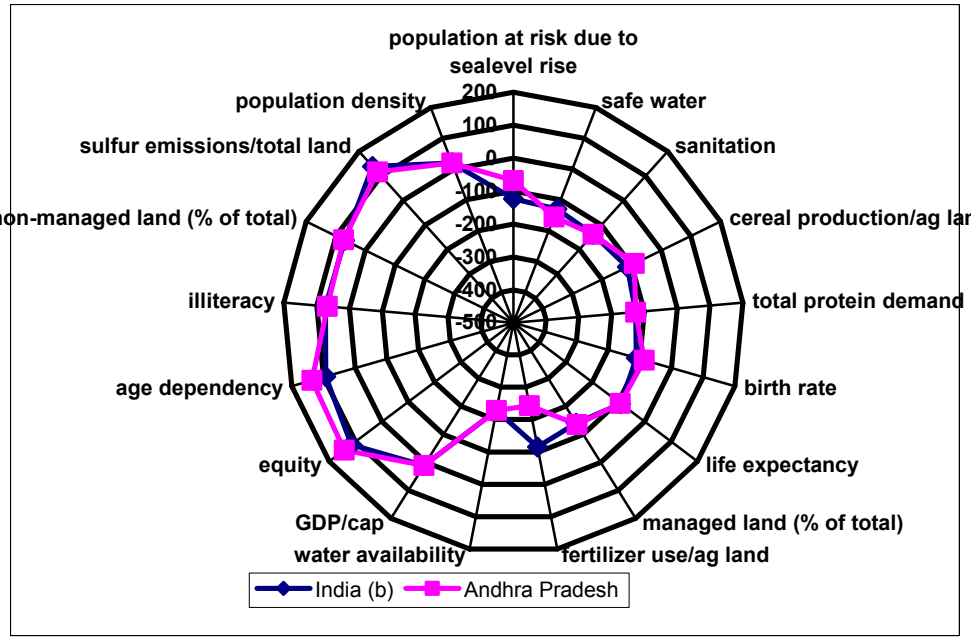

Figure ES-2. A detailed comparison between the contributions of the 17 indicator proxies to India's and Andhra Pradesh's vulnerabilities.

The results show that a vulnerability analysis using this framework may provide a means to ask structured questions about the elements of vulnerability in particular places. The modeling framework allows analysts and stakeholders to systematically evaluate individual and sets of indicators and to compare geographical or political units (for example, river basins or states). The transparency of the framework provides ready explanations for differences in the result. Thus, the framework indicates, to a first approximation, where the likely vulnerabilities are in the area being assessed; these areas are then candidates for a more in-depth, qualitative examination.

We found that

1. For India and its states detailed data are available.
2. Most data need interpolation, averaging or scaling such that proxy values are obtained that are consistent and comparable.
3. Water availability and access to clean sanitation need in-depth study for state comparisons.
4. Land use and its consequences constitute an important issue.
5. The assumed linear relationship between sulfur emissions and environmental capacity needs re-evaluation. We might need to find a relationship as we did for fertilizer use: both too much and too little result in negative impact. For sulfur emissions, too little industrial development is not necessarily good given the lack of job diversification, but too much dirty industry is detrimental to the environment and human health.

In order to achieve a functional framework, we have used the existing structure of the Vulnerability-Resilience Indicator Prototype and somewhat modified requirements for indicators; thus, we are at a preliminary scoping and surveying stage. The framework and

results presented here represent a first-order modeling effort, which needs to be refined and developed. There are issues of interactions among indicators and projections into the future that lend themselves to exploration, but data are, in general, available.

We did not attempt to extend our VRIP modeling exercise with long-term scenario building and projections. In our previous experience with the VRIP model we calculated future vulnerability-resilience indicator values by using the methods and values of the IPCC's *Special Report on Emissions Scenarios* (SRES)[8] scaled to the regional model outputs of PNNL's integrated energy and economics model, MiniCAM and its post-processor Sustain.[9] For the global and national projections, scaling down from aggregate, established scenarios was an adequate approach.

Attempting to make projections into the future for Indian states would require an approach at a more detailed level. Not only would we need a re-evaluation of baseline data used, with regard to initial values for the calculations, we also would need to look at state-by-state historical development pathways, and state plans for future development. Income growth has varied greatly by state, for example.

Acknowledgment

Many thanks to Joel Smith for giving us the opportunity to perform this analysis of India's vulnerability-resilience to climate change. We also appreciate very much the material contributions of Sangamitra Ramachander in gathering the data necessary for the modeling exercise described in this report. Ramachander, a graduate student in economics at the University of Maryland, assisted in locating, preparing, and interpreting available datasets.

[8] Nakicenovic, et al., *Special Report on Emissions Scenarios* (Cambridge: Cambridge University Press, 2000).

[9] Hugh M. Pitcher, "Mitigation Options in a Sustainable Development World," *Environmental Economics and Policy Studies* 3:2 (2000).

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Background: The Need for a Vulnerability-Resilience Assessment Framework

Climate change research is focusing more and more on vulnerability and adaptation studies. This reflects two realizations: (1) efforts to achieve significant emissions reductions are unlikely to be successful anytime soon, and (2) climatic changes are evident today, whether one believes such changes are caused by human activities or not. The Third Assessment Report of the Intergovernmental Panel on Climate Change[10] placed a new emphasis on vulnerability (and on sustainable development), and the National Communications being prepared by non-Annex I countries under the Framework Convention on Climate Change consider adaptation needed based on vulnerability. Even in industrialized countries, the indications of climate change that are occurring have spurred interest in thinking prospectively about how vulnerable or resilient relatively wealthy societies might be to, for example, sea level rise or changes in fresh water availability.

However, many different definitions of vulnerability exist, and, to date, no generalized framework for vulnerability assessment has been established. Such a framework would capture the important aspects of vulnerability (the subject of many debates within the research community) and would allow for comparison among countries, regions, and smaller geopolitical areas. The framework would use quantified indicators where possible and utilize a transparent methodology so that users of the framework understand the results and are able to analyze them with qualitative information. Use of the framework would yield insight into the particular places for which the assessment is conducted and into vulnerability more generally. What are the resources or structural features of a society that make it able to cope with short-term climate variability and build adaptive capacity to long-term climate change?

The Environmental Protection Agency (EPA) has funded a study aimed at developing a vulnerability framework and exercising it for India and its states. The contractor for that study, Stratus Consulting, requested that researchers at Pacific Northwest National Laboratory draw on their experience in developing a model and methodology for assessing vulnerability to climate change, and apply it to the country and states of India. The research tasks are to develop an analytic framework for assessing India's overall vulnerability to climate change, to assess data availability for regional (by state, sector, and possibly socio-economic groups) vulnerabilities within India, and to define next steps in framework development.

[10] See especially McCarthy et al., *Climate Change 2001*.

The State of the Literature on Vulnerability-Resilience Assessment

Vulnerability to climate change, as a research concept, is both overdetermined and underspecified. The concept of vulnerability is emerging in response to greater emphases on unequal distribution of adverse impacts of climate change and on adaptation research, but it is far from clear what "vulnerability" means except in the most general terms. Vulnerability studies extend impact studies, but is vulnerability just the logical conclusion or is it the meaning of potential impacts? The Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)[11] is subtitled "Impacts, Adaptation, and Vulnerability."[12] The formal definitions used in the IPCC report are as follows:[13]

> (Climate) Impacts—Consequences of climate change on natural and human systems. Depending on the consideration of adaptation, one can distinguish between potential impacts and residual impacts. Potential Impacts—All impacts that may occur given a projected change in climate, without considering adaptation. Residual Impacts—The impacts of climate change that would occur after adaptation.
>
> Adaptation—Adjustment in natural of human systems in response to actual or expected climatic *stimuli* or their effects, which moderates harm or exploits beneficial consequences. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation.
>
> Vulnerability—The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. 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.

Thus, impacts and adaptation may involve beneficial consequences of climate change, but vulnerability focuses on adverse impacts, i.e., the *extent* of adverse impacts and the *ability* to adapt reduce vulnerability.

Figure TS-1[14] in the IPCC report shows "Impacts" and "Vulnerabilities" as two integrative concepts in a box that analyses the process of responses to climate change

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[11] McCarthy et al., *Climate Change 2001*.

[12] The Working Group II's Second Assessment Report (Robert T. Watson, Marufu C. Zinyowera and Richard H. Moss (eds), *Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses*, Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change [Cambridge: Cambridge University Press, 1996]) was subtitled "Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses." The assessment of mitigation research was moved to the Working Group III report in the Third Assessment Report, and vulnerability was added to the Working Group II report.

[13] McCarthy et al., *Climate Change 2001*, pp. 989, 982, 995.

[14] McCarthy et al., *Climate Change 2001*.

(Exposure → Initial Impacts or Effects → Autonomous Adaptations → Residual or Net Impacts). The resultant Policy Responses can lead either to Mitigation or to Planned Adaptation. Thus, impacts produce or reveal vulnerabilities, presumably lessened by the extent of autonomous adaptations, then by mitigation or adaptation policies.

However, the interdependence of the concepts may be contributing to the circular character of the three definitions listed above. That is, each is defined in terms of the other two. For example, adverse impacts contribute to vulnerability; but if a region were not vulnerable to a given impact, it would not be considered adverse. Similarly, autonomous adaptation lessens vulnerability, but planned adaptation is needed in the case of regional vulnerability.

The multiple meanings of vulnerability are attributable, at least in part, to its relative newness as an area within climate change research. Research on vulnerability to climate change extends impacts research. Impacts are typically assessed on *natural systems* and *managed resource systems*, such as agriculture. Vulnerability-resilience assessment focuses on *societal* systems and *individual humans*. Studies have often conflated impacts and vulnerability, assuming that changes in the environment are self-evident *problems* for human systems and for humans themselves. For example, changes in the timing or amount of precipitation may be assumed to cause damage to agriculture and, thus, to food security and the livelihood of farmers. In part, such a conflation reflects assumptions that a static world is better than a changing world and that any change will carry costs. Although many instances of large-scale, high-cost environmental change can be cited, the general assumptions are dubious at best and could be countered by examples of favorable changes. Both the physical and the social worlds could change – and have changed – for the better.

In the early impacts research and continuing in current studies is a belief that negative impacts of climate change would be so great that projections of these impacts would drive mitigation policies. When the model projections did not show dire consequences, the policy driver was thereby weakened. Over time, the research community has begun to emphasize social factors rather than impacts and adaptation policies along with mitigation policies.

Vulnerability-resilience analysis (which is associated with adaptation to climate change) thus not merely extends impacts research but also changes focus from relatively more physical and quantifiable impacts to meaningful consequences for human societies, as shown below. Research on vulnerability is part of the shift from physical/economic representations of climate changes, emissions-producing activities, and effects of crop yields and water availability to (usually more qualitative) representations of human attributes and institutions such as land tenure systems, modes of production, and governance. The tools of impacts research were predominantly models; the tools for vulnerability research have been predominantly case studies.

Impacts	Vulnerabilities	Adaptations
Changes in crop yields	Chance of hunger, loss of validity of traditional agricultural knowledge	Changes in crop types or agricultural management
Changes in water availability	Potential for insufficient water for consumption, irrigation, and hydropower	New catchments for altered runoff, recycling, improved efficiency in irrigation systems
Increased heat/precipitation changes	Threat of spread of vector-borne diseases	Improved public health systems, research on treatments
Differences in impacts on mid-latitudes and tropics	Exacerbation of inequities in human well-being	Technology transfers, emissions trading

Definitions from Related Research Areas

Most scholars agree on the broad definition of vulnerability as "the capacity to be harmed." The IPCC definition given above, although more specific about the mechanism of the harm, remains neutral about what kind of "system" can be said to be vulnerable to climate change. Moreover, the use of the term varies among disciplines and research areas. Geography, ecology, economics, and political science are among the disciplines represented in vulnerability-related research. Depending upon the orientation, "capacity" and "harm" can have quite different meanings.

If the broad definition is meant as the capacity to receive harm, then a consequence would be that, if the capacity to receive harm is greater than the harm, the receiver is exposed to the receiver can be considered resistant or resilient. If the capacity to resist harm is intended, then we are dealing again with recognizing capacity and harm as polar opposites but with different connotations than the first interpretation of the definition. In this interpretation, the capacity to resist or be resilient is a more active connotation in the interplay of receiver and actor than the capacity to receive (the potential harm). Through adaptation, resistance and resilience can be enhanced. Adaptation to enhance capacity to be harmed is a different matter. Vulnerability defined as "susceptibility to be harmed" is less confusing in this regard.

Cutter[15] identifies three distinct foci of definitions for vulnerability: (1) as risk[16] of exposure to hazards (e.g., settlements in flood plains), (2) as a capability for social

[15] S.L. Cutter, "Vulnerability to Environmental Hazards," *Progress in Human Geography* 20 (1995), 529-539.

[16] Risk is defined as the probability of observing (experiencing) a specified effect as the result of a defined level of exposure. The specified effect should be measurable. And the specified effect should stimulate concern among society members and policy makers (adapted from S.M. Bartell, R.H. Gardner and R.V. O'Neill, *Ecological Risk Estimation* [Boca Raton, FL: Lewis, 1992], 108-109).
Risk Assessment (in the context of human health): The determination of potential adverse health effects from exposure to chemicals, including both quantitative and qualitative expressions of risk. The process of risk assessment involves four major steps: hazard identification, dose-response assessment, exposure assessment, and risk characterization. Risk Management (in the context of human health): A decision

response (e.g., exit road systems; insurance), and (3) as an attribute of places (e.g., vulnerability of coastlines to sea level rise). Cutter proposes a "hazards of place" model that bridges various definitions, proposing a definition of vulnerability as "the likelihood that an individual or group will be exposed to and adversely affected by a hazard. It is the interaction of the hazards of place (risk and mitigation) with the social profile of communities."[17]

The first and third of Cutter's clusters both emphasize the potential negative impacts of climate changes, i.e., the physical changes, as do other researchers. For example, Downing[18] makes vulnerability one variable in a definition of risk; risk, in his conceptual framework is the sum of vulnerability and hazard. Vulnerability is exposure and susceptibility to losses; hazard is the potential threat to humans and their welfare. Here the definitional center is in the losses themselves. Similarly, Reilly and Schimmelpfenning[19] define vulnerability as "a probability weighted mean of damages and benefits" and give as examples "yield vulnerability," "farmer or farm sector vulnerability," "regional economic vulnerability," and "hunger vulnerability."

Cutter's second cluster of definitions emphasizes human capabilities in the face of potential negative changes or losses. Blaikie et al.[20] locate vulnerability in people: "the characteristics of a person or group in terms of their capacity to *anticipate, cope* with, *resist* and *recover* from the impacts of natural hazards." Vogel,[21] continuing the Blaikie et al. definition, points to the importance of the relationship between empowerment and vulnerability, e.g., "how do different social actors gain access to and control of various resources?"

Ribot[22] separates the physical and the social by assigning the physical to impacts assessment and the social to vulnerability assessment. He describes *climate impact assessment* as addressing the magnitude and distribution of the consequences of climate variability and change, while *vulnerability assessment* extends impact assessment by highlighting *who* (as in what geographic or socioeconomic groups) is susceptible, *how* susceptible they are, and *why*. He considers vulnerability to be *specific* in that it is concerned with a particular consequence, such as a famine or loss of livelihood.

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making process that accounts for political, social, economic and engineering implications together with risk-related information in order to develop, analyze and compare management options and select the appropriate managerial response to a potential chronic health hazard. (http://www.epa.gov/iris/gloss8.htm)

[17] Cutter, "Vulnerability," p. 532.

[18] T.E. Downing, *Climate Change and Vulnerable places*. Research paper No. 1. (Oxford: Environmental Change Unit, University of Oxford, 1992).

[19] J.M. Reilly and D. Schimmelpfennig, "Agricultural Impact Assessment, Vulnerability, and the Scope for Adaptation, *Climatic Change* 43 (1999), 745-788, p. 775.

[20] P. Blaikie, T. Cannon, I. David, and B. Wisner, *At Risk: Natural Hazards, People's Vulnerability, and Disasters* (London: Routlege, 1994).

[21] C. Vogel, "Vulnerability and Global Environmental Change," *LUCC Newsletter* 3, http://www.lucc.vogel.vuln.review.article.html.

[22] J.C. Ribot, "Introduction," *Climate Variability, Climate Change and Social Vulnerability in the Semi-Arid Tropics*, J.C. Ribot, A.R. Magalhães, S.S. Panagides (eds) (Cambridge: Cambridge University Press, 1996), p. 15.

Definitions of vulnerability and adaptation are similarly interwoven. Adaptation to climate change that happens autonomously, without explicit cost and explicit awareness, constitutes one aspect of vulnerability. If such changes can be presumed to deal with all the impacts of climate change, a society will not be considered vulnerable to climate change impacts; if, on the other hand, autonomous adaptations are not possible and the impacts are negative, a society may be considered highly vulnerable, especially if it cannot cope, plan and pay for necessary adaptations. An example in the first category might be autonomous adaptations to an urban heat island; an example of the latter would be sea level rise that inundates a poor country. In this context, resilience would mean that a measure of adaptation has taken place such that the society can deal effectively deal with an impact or hazard.

Thus, we recognize that both physical and social factors are at work. As Rayner and Malone[23] have pointed out, climate change research began with physical and chemical research into the greenhouse effect on the climate, and the physics paradigm persists in "human dimensions" research of the social sciences. However, many social science researchers take a stance that is situated within the social system. That is, the starting point of analysis is social structures and processes, not climate and geography. The world simply looks different if we study it as a climate system or as a social system; the two standpoints yield different insights.

Our work on developing vulnerability-resilience indicators and indices focuses on human systems and welfare at the present and into the future. Thus, the vulnerability indicators are part of the shift from physical representations of climate change to human societal and institutional representations. The full range of human dimensions and aggregate physical factors is shown in the choice of sectors: food security, water availability, ecosystems, and health as sectors demonstrating potential sensitivity to climate change impacts; and environmental capacity, human resources, and economic capacity as sectors demonstrating potential positive response capabilities resulting in potential resilience to such impacts. The prototype model aims at identifying who is most vulnerable and (comparatively) how vulnerable certain groups are.

Our definition of vulnerability, building on the IPCC definition, ultimately specifies the harm from climate change impacts to *social* systems, taking into account factors that might make physical and social systems resilient to climate change. Vulnerability and/or resilience can be thought of as the sum of *negative* sensitivities to climate change impacts and *positive* adaptive capacity.

Methods of Vulnerability-Resilience Analysis

Researchers have used two broad approaches to vulnerability assessment. There is a rich literature of case studies, involving various places and people. These case studies include vulnerability to social conditions such as hunger and to hazards such as flooding and drought. On the other hand, a number of aggregated, quantitative studies have been

[23] Steve Rayner and Elizabeth L. Malone, "The Challenge of Climate Change to the Social Sciences," in *Human Choice and Climate Change, Volume 4: What Have We Learned?* (Columbus, Ohio: Battelle Press, 1998).

carried out, notably under the guidance of the Intergovernmental Panel on Climate Change's *Common Methodology for Assessing Vulnerability to Sea Level Rise*.[24] This sectoral analysis resulted in country- and local-level analyses of people, capital value, land, and wetlands at risk.[25] Other sectors that have received much research attention are agriculture/land use and water resources.[26] "The details of vulnerability and adaptation as intermediate factors between change and impact have, however, remained largely implicit in impact assessment."[27] This has been largely true in highly aggregated and quantitative studies of agricultural productivity.[28]

The use of indicators – that is, direct statistics that represent a societal condition – has been common, although implicit, in modeling efforts on climate change. GDP per capita, for example, is often used as an indicator of human well-being. The IPCC's most recent scenarios of the future[29] use only a handful of indicators in conjunction with "storylines" in constructing the scenarios. The sustainability literature uses indicators to quantify aspects of concern; however, the research community has achieved little, if any consensus about which indicators are important. The sets of indicators are very diverse.[30]

India

India is one of the most important countries in the world with regard to the environment. With a large and growing population,[31] India's emissions of greenhouse gases are increasing.[32] Potential climate impacts in India include sea level rise,[33] changes in the monsoon (timing and intensities), increased severe storms and flooding, and drought. And its continuing dependence upon agriculture for food and livelihood (67%, 1995

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[24] Intergovernmental Panel on Climate Change, *Common Methodology for Assessing Vulnerability to Sea Level Rise*, Report of the Coastal Zone Management Subgroup, IPCC Response Strategies Working Group (The Hague: Ministry of Transport, Public Works and Water Management, 1991).
[25] See, e.g., R.J. Nicholls, "Synthesis of Vulnerability-Analysis Studies," *Proceedings of World Coast '93*, P. Beukenkamp, P. Gunther, R. Klein, R. Misdorp, D.Sadacharan, L.D. Vrees (eds), CZM publication 4 (The Hague: Ministry of Transport, Public Works and Water Management, 1995); and R. Warrick and A. Rahman, "Future Sea Level Rise: Environmental and Sociopolitical Considerations," *Confronting Climate Change: Risk, Implication and Response*, I. Mintzer (ed), (Cambridge: Cambridge University Press).
[26] For a brief review of this literature, see William B. Meyer, W. Neil Adger, Katrina Brown, Dean Graetz, Peter Gleick, John F. Richards and Antonio Maghalães, "Land and Water Use," in *Human Choice and Climate Change, Volume 2: Resources and Technology*, Steve Rayner and Elizabeth L. Malone (eds) (Columbus, Ohio: Battelle Press, 1998).
[27] Ibid., p. 128.
[28] See, e.g., N.J. Rosenberg, (ed), "Towards an Integrated Impact Assessment of Climate Change: the MINK Study," *Climatic Change* 24:1-2(1993), 1-173 (special issue); and C. Rosenzweig and M.L. Parry, "Potential Impact of Climate Change on World Food Supply," *Nature* 367, 133-138.
[29] Nakicenovic et al., *Special Report*.
[30] The range of indicators is demonstrated in B. Moldan and S. Billharz (eds), *Sustainability Indicators: A Report on the Project on Indicators of Sustainable Development*, (Chichester: John Wiley & Sons, 1997).
[31] July 2001 estimate of 1,029,991,145 total population; the rate of population growth is 1.55% pa, or, currently 1.6% pa, which is expected to fall to 1.4% pa in the next 2 decades, CIA World Factbook, http://www.odci.gov/cia/publications/factbook/geos/in.html
[32] See Appendix for more detailed information.
[33] See Appendix.

estimate[34]) makes the Indian people vulnerable to climate variation and change. Most studies project decreased yields in non-irrigated wheat and in rice, and a loss in farm-level net revenue between 9% and 25% for a temperature increase of 2-3.5 degrees Centigrade.[35] The costs of a 1-meter sea level rise could include up to 7 million people displaced, and 5764 sq km of land and 4200 miles of road lost.[36]

The diversity and extremes of India's climate and geography are characteristic of its society as well. However, the social characteristics are in many respects difficult to include in a quantitative model of vulnerability; we discuss these characteristics as part of the qualitative context in which the quantitative indicators are developed.

Religious and cultural diversity is a major feature of Indian life. The strong Hindu traditions have been synthesized with and challenged by other religions, notably Islam, Christianity, and Sikhism. There are at least 300 known languages in India, 24 of which have at least one million speakers each. There are differences, sometimes amounting to estrangement, between the North, with its history of grand-scale invasions, and the relatively stable South. Religious divisions became geographical divides when Muslim Pakistan (1947), then Bangladesh (1971), were created, but ethnic strife among groups persists.

The extended family is a core feature of Indian life. Together with a sense of civil society's claims on individuals and families, the extended family knits the society together and emphasizes interdependence.[37]

Since 1990 India has moved aggressively from a centrally planned economy to private ownership of businesses and trade liberalization. It has "developed a diversified industrial base and sophisticated financial sector. Its software subsector – one of the most dynamic in the world – has experienced a sustained and rapid growth."[38] India has made substantial strides in reducing infant mortality, increasing life expectancy, and improving literacy. Yet poverty (35% of the population[39]) and malnutrition[40] continue to plague India, as well as serious environmental issues. In addition, the ongoing dispute with Pakistan over Kashmir and ethnic strife claim national attention.

India's broad spectrum of highly articulated national policies includes goals in the areas of economic development, human development, and environmental protection. India has put in place its tenth Five-Year Plan, and each state prepares an annual plan that is commented on by the national planning commission. National goals are, of course, differentially implemented in India's 26 states, which exhibit widely varying degrees of social and economic development.

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[34] CIA Factbook.
[35] Tata Energy Research Institute, http://www.ccasia.teri.res.in/country/india/impacts/impacts.htm
[36] Gannon, Martin J. and Associates, *Understanding Global Cultures* (Thousand Oaks, California: Sage, 1994)
[37] Gannon and Associates, *Understanding*.
[38] World Bank, "Country Brief: South Asia Region (SAR) – India, 2002," http://www.Worldbank.org
[39] CIA World Factbook.
[40] World Bank, "India."

A World Bank report[41] places India within the East Asian experience of the 1970s and 1980s. Citing the differential experience of India's states, the report makes the obvious suggestion that India needs to get back to a higher growth path, which can contribute to reducing poverty through improved public spending and a strengthening of incentives, institutions and governance, particularly in the poorer states.

According to the report, India's growth rate of 6% in 1998-99, one of world's best, was attributable mainly to good harvests; all major non-agricultural sectors grew at a much slower rate.[42] The reversion to the average post-1980 growth trend during the last two years may partly reflect excess capacity and partly the slowing world economy. However, another important factor is probably the slowing of reforms, along with a worsening of the fiscal deficit and rises in tariffs reforms that had earlier contributed to higher productivity, a higher share of world trade, and rapid growth. Also, India's social services and anti-poverty programs, necessary to include the poor in the growth process, would have benefited not only from higher funding but improved institutions and governance.

At the national level, India's climate change policies are subsumed in its economic-industrial and human development policies, which come first. Generally speaking, climate change policy has been reactive rather than proactive and focused largely on the energy sector. In India, coal accounts for 55% of primary, commercial energy, and energy demand is growing quickly; burning coal is a major source of greenhouse gas emissions and air pollution. For the first time, in the eighth 5-Year Plan (1992-1997), funds were provided for energy efficiency measures. An OECD report[43] says that India, through normal policy developments, is "making significant progress in limiting greenhouse emissions" through energy efficiency improvements and environmentally friendly energy development. More aggressive measures, India feels, should be financed by developed nations as they lead by reducing their own emissions. In the area of disaster mitigation, much has been done to document conditions leading to vulnerability. For example, there is a *Flood Atlas of India* and a *Disaster and Vulnerability Atlas of India*[44]; the latter assesses the vulnerability of housing and infrastructure to earthquakes, cyclones and floods to improve zoning and construction.

Internationally, India has played a key role in climate negotiations at several points (e.g., breaking the impasse at the first Conference of the Parties by leading the development of a common statement that became the basis for the Berlin Mandate). India, bolstered by NGOs such as the Tata Energy Research Institute (TERI) and the Centre for Science and

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[41] *India: Policies to Reduce Poverty and Accelerate Sustainable Development*, Executive Summary. http://www.andhrapradesh.com/worldbank.

[42] *The Economist* 03-08-03 reports that 'The countryside, where 70% of the population live, has been affected with one of the worst droughts in decades, affecting nearly a third of the country. Agricultural production, still about a quarter of Indian output, is forecast to have fallen by 3.1% in the fiscal year that began in April 2002. Yet the economy will still have grown by 4.4%'; an example of the problematic implications of scale 'who or what is vulnerable to what level of impact.'

[43] Parikh, Jyoti K. and Kirit Parikh, *Climate Change: India's Perceptions, Positions, Policies and Possibilities* (Paris: Organization for Economic Cooperation and Development, 2002), p. 25

[44] http://www.bmtpc.org/disaster.htm

Environment (CSE), focuses on per capita emissions (low in India and high in most developed countries) and on cumulative emissions (also low in developing countries and high in developed countries), as the indicators of who should undertake mitigation first. Government officials press developed nations to establish and conform to emissions reduction goals and to engage in technology transfer to developing countries. Researchers at CSE authored the widely cited report, *Global Warming in an Unequal World.*[45] CSE rebutted the second World Resources Report,[46] making the distinction between "subsistence emissions" of the poor (mostly in developing countries) and the "luxury emissions" of the rich (mostly in developed countries). CSE has also characterized "green" policies dictated by the North (e.g., debt-for-nature swaps) as unwarranted interference in other nations, as exacerbating inequality among nations, and as likely to foster unsustainable management.[47] India has criticized the Global Environmental Fund as being too controlled by developed countries, and has not submitted its National Communication under the Framework Convention on Climate Change.

Jasanoff [48] analyzes the sources of and constraints on Indian environmental policy generally. At one level, all policy relates to a distinctively Indian story: the Nehruvian bureaucratic state (centralized, committed to technological development, allied with business and industry) versus the India of vibrant local initiative (age-old customs, critical of development). At another level, India has allied with the global South in a parallel worldwide controversy on development, North versus South. This latter commitment draws much of its strength from the grassroots NGOs, perhaps epitomized by the Chipko (tree-hugging) movement, which gathered steam in the 1970s and emerged during the 1980s as the authentic symbol of rural resistance to destructive urbanization. Common themes include deforestation, hydropower, and institutional change. Deforestation is a reliable panic button, connecting bare hillsides and flash floods, loss of fuelwood, burden of women's work, poverty, and population pressure.

The dilemma for India is how to transform environmental activism into government action. "Most Indian NGOs derive strength from their rootedness in local concerns, their responsiveness to ordinary people's demands, and their oppositional relationship to the state. To move toward national coordination, they would have to loosen precisely those grassroots connections that have made them so effective in the past and align themselves uncomfortably with the impersonal – and ineffectual – bureaucratic apparatus of the state."[49]

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[45] Agarwal, Anil and Sunita Narain, *Global Warming in an Unequal World*. (New Delhi: Centre for Science and Environment, 1991).
46 Agarwal, Anil and Sunita Narain, *Towards a Green World: Should Global Environmental Management Be Built on Legal Conventions or Human Rights?* (New Delhi: Centre for Science and Environment, 1992).
[47] Ibid.
[48] Sheila Jasanoff, "India at the crossroads in global environmental policy," *Global Environmental Change* 3:1(1992), 32-52.
[49] Jasanoff, "India," p. 51.

The Vulnerability-Resilience Indicator Framework

Broadly, a country's (or region's) vulnerability to climate change is a function of three factors (see Figure 1):

- Exposure – The nature and extent of changes to a country's climate variables, e.g., temperature, precipitation, extreme weather events, as well as changes in sea level (if it has a coast).
- Sensitivity – How biophysical systems could be affected by the change in climate, e.g., how much land could be inundated by sea level rise, how much crop yields might change, or how much runoff might change.
- Adaptive Capacity – How much capacity a country has to adapt to the changes so as to maintain, minimize loss of, or maximize gain in welfare.

To assess vulnerability, then, we look at exposure to climate change, sensitivities to those changes, and societal coping and adaptive capabilities.

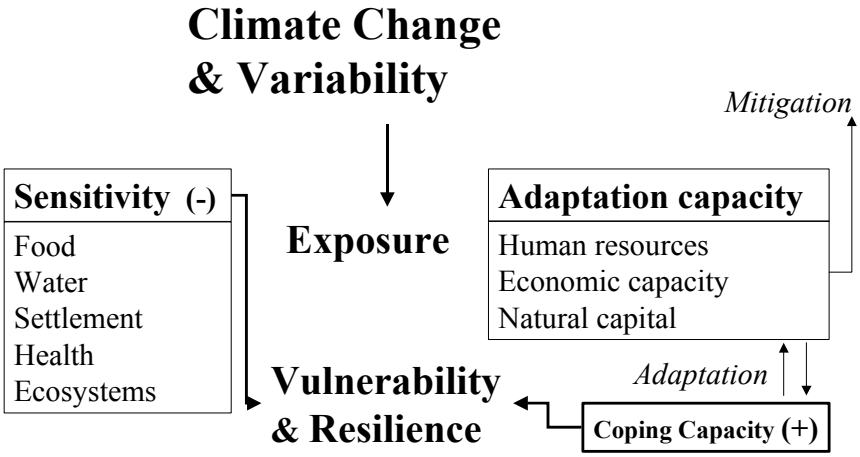

Figure 1 A climate change and variability impacts framework: the Vulnerability-Resilience Indicator Prototype: VRIP

Our basic premise is that the impact of exposure to climate variability and to potential climate change is first of all dependent on the local historical response of a socio-economic system, and how the managed natural resources and natural resources partake of that system. Our second premise is that through decision-making (governance) we ought to be able to manage our resources to secure people's well-being.

We outline below a basic analytical framework to aid in thinking about the interacting socio-economic and climate-related forces that determine local potential of well-being. Human well-being can be expressed as finding oneself at a minimum level of vulnerability and a maximum level of resilience towards external forces, natural and socio-economic.

Exposure to Climate Hazards

The basic determining factors of climate, temperature, precipitation and wind, set the stage for how people have been able to survive and/or thrive. Climate is an important resource, on the one hand, and an important hazard, on the other, to human societies. The current example of climate in India demonstrates its importance.

In 2002, India's harvest has suffered from unusually high temperatures, including a heat wave with maximum temperatures reaching 45°C or more in May over most of the North and Central India. In addition, the year's monsoon was late and weaker than normal. Less rainfall lowered India's estimated rice harvest from 90 million to 80 million tons. Meanwhile, water tables are falling, as farmers pump more water to meet the growing demand for food. Water tables are now dropping in key farming areas. In India, 50% of the food grain comes from irrigated land. Implications of decline in water resources due to more frequent droughts in India as a consequence of climate change are likely to be serious in terms of malnutrition, starvation, migration and social strife.[50]

The Himalayan snow and ice support three main river systems, viz., Indus, Ganges and Brahmaputra, with an average annual stream flow of 206, 525 and 586 km^3 respectively. More than 50% of water resources of India are located in various tributaries of these three river systems. A warming is likely to increase the melting far more rapidly than the accumulation. Glacial melt is expected to increase under changed climate conditions, which would lead to increased summer flows in some river systems for a decade or so, followed by a reduction in flow as the glaciers disappear (IPCC, 1998, cited in Lal[51]).

Presently, what counts, with regard to natural resources and human well-being, is availability of clean water, clean air, a sufficient level of biodiversity and ecosystem integrity such that managed resources, which provide food, water, settlement security, health security and human resources, are secure and renewable.

Sensitivity [52]

Changes in climatic conditions will affect *demand, supply and water quality*. In regions that are currently sensitive to water stress (arid and semi-arid regions of India), any shortfall in water supply will enhance competition for water use for a wide range of

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[50] Based on Murari Lal, *Country Studies Vulnerability and Adaptation*, Work Assignment 402 - Task 11 under Stratus Consulting Contract 68-W6-0055 (Washington D.C: U.S. Environmental Protection Agency. 2002).
[51] Ibid.
[52] Ibid.

economic, social and environmental applications. Therefore, efforts are needed for more efficient groundwater recharge and harvesting of rainwater through identification, adoption and adaptation of technological options. Restoration, revival, revitalization and upgrading of existing/traditional rainwater harvesting structures should ensure sustainability of water resources. Keeping in view the huge demand on the water resources and the present state of India's water sources, alternatives must be devised to supplement the present reserves of fresh water (e.g., through micro-watershed development) and reduce over-exploitation. Major initiatives need to be taken in India to plan and implement water resource conservation programs. Disputes over water resources in South Asia may well be a significant social consequence in an environment degraded by pollution and stressed by climate change.

Low-lying coastal cities of the Indian subcontinent will be at the forefront of impacts; these include Karachi (Pakistan), Mumbai (India) and Dhaka (Bangladesh), all of which have witnessed significant environmental stresses in recent years. In addition, rise in temperature can lead to increased eutrophication in wetlands and fresh water supplies.

The farming of fish, shrimp, shellfish and seaweed has become a vital source of food supply in parts of India in recent decades. Fisheries products are staples for large population in some states of India and are embedded in its culture. Fish, an important source of food protein, is critical to food security in many countries of South Asia, particularly among poor communities in coastal areas. India was one of the five top fishing countries in Asia in 1996. The fishery resources of India are being depleted by overfishing, excessive use of pesticides, and industrial pollution. The increase in marine culture products and decline in the marine fishery output are the current trends in commercial fishery activity. The impact of global warming on fisheries depends on the complicated food chain in the ocean, which is likely to be disturbed by sea level rise; change in ocean currents; and alteration of the mixing layer thickness.[53] Increased frequency of El Niño events, likely in a warmer atmosphere, could also lead to measurable declines in fish larvae abundance in coastal waters of South Asia. These phenomena are expected to contribute to a general decline in fishery production in the coastal waters of India.

Climate-related stresses in coastal areas include loss and salinization of agricultural land due to change in sea level, the likely changes in intensity of tropical cyclones and possibility of reduced productivity in coastal and oceanic fisheries. The coastal areas in India would be sensitive to climate change impacts and also to unsustainable utilization of resources in these areas. The impacts could be exacerbated by continued population growth in low-lying agricultural and urban areas. Appropriate adaptation strategies will alter the nature of the risk and will change the socially differentiated nature of vulnerability of the populations living in the hazardous regions.

[53] McCarthy et al. *Climate Change 2001*.

Health outcomes in response to climate change are the subject of intense debate. Global warming will likely increase the incidence of some diseases, such as respiratory and cardiovascular diseases in India. Climate is one of a number of factors influencing the incidence of infectious disease. Heat stress and smog-induced respiratory illnesses in major urban cities of India would increase. Exposures to higher temperatures and air pollutants appear to be significant risk factors for cerebral infarction and cerebral ischemia during the summer months. An increase in the frequency and duration of severe heat waves and humid conditions during summer will increase the risk of mortality and morbidity, principally in the older age groups and the urban poor populations of South Asia. Heat stress-related chronic health damages are also likely on physiological functions, metabolic processes and immune systems.

The distribution of vector-borne infectious diseases such as malaria is influenced by the spread of vectors and the climate dependence of the infectious pathogens. Malaria is still one of the most important diseases in India due to high summer temperature and humidity.[54] The changes in environmental temperature and precipitation could expand vector-borne diseases such as malaria and dengue fever. Warmer sea surface temperatures along Indian coastlines would support higher phytoplankton blooms. These phytoplankton blooms are excellent habitats for survival and spread of infectious bacterial diseases such as cholera. Water-borne diseases – including cholera and the suite of diarrheal diseases caused by organisms such as giardia, salmonella and cryptosporidium – could also become common with the contamination of drinking water quality.[55] For preventive actions, impact assessments are necessary on the various aspects such as nutritional situation, drinking water supply, water salinity and ecosystem damage. The risk factor of diseases will depend on improved environmental sanitation, the hygienic practice and medical treatment facilities. In India, a better understanding of the interaction among climate change, and environmental and health status in communities at regional and local scales is crucial to forge physiological acclimatization and social adaptation.

Responses: Coping and Adaptive Capacity

Dealing with actual negative climate impacts – excessive precipitation, resulting in floods and mudslides; droughts, resulting in crop failure; hurricanes, resulting in property damage – requires immediate response. In general, these types of impacts and responses are dealt with in the hazards literature.[56] The coping capacity of society is tested each time that society responds to a climate impact. Historically, society's coping capacity might have been tested locally, often, and society might have adapted to climate variability impacts in ways that have built up certain levels of resilience.

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[54] R. Akhtar and A.J. McMichael, Rainfall and Malaria Outbreaks in Western Rajasthan, *Lancet* 348 (1996), 1457-1458.
[55] McCarthy et al., *Climate Change 2001*.
[56] A natural hazard is a rare or extreme event in nature that adversely impacts human life, property, or activity (http://www.ngdc.noaa.gov/seg/hazard/resource/introdir.html).

There always will be events, however, that exceed established coping capacity limits. Considering the risks of these potential impacts leads to questioning the long-term adaptation capacity of a society. Such considerations also may lead to questions of sustainability[57] and to policy questions about where, how much, and in what to invest. Risk considerations also raise questions about the economic capacity not only of the local community but the larger socio-economic framework in which the locally impacted communities partake. This involves planning and policy; it involves governance and responsibility. Local responsibility remains, e.g., with regard to building on floodplains or on low-lying or easily swept away coastal areas. Responsibilities of governance pertain to the larger scales, e.g., to laws, restrictions, and/or investment, e.g., dike building, education, health services.

Within the context of global climate change and the above-discussed progression from testing of local coping capacity to the larger scale (socio-economic, spatial as well as with regard to time) adaptation capacity, one more aspect of potential response needs discussion. Through mitigation[58] of the causes of the (negative) impacts on human well-being, populations might not only be able to lessen the potential risks of impacts, but also increase the coping and adaptation capacity of society.

Greenhouse gas emissions are recognized as being the major cause of anticipated global climate change. If climate change would change climate patterns in a predictable way, societies might be able to develop a clear adaptation pathway. However, we have not been able to predict, where, how, and how much climate will change. We have general ideas but weather remains unpredictable, and weather determines agricultural yield, local water availability, floods, hurricanes and a variety of other potential hazards. Mitigation of greenhouse gas emissions is one way of decreasing potential man-made risks by purposely lessening the greenhouse gas impact (see also Figure 1). Thus, while climate change and variability hazards are local, at a global level all people are responsible for the potential impacts global climate change may have.

One of the beneficial consequences of taking responsibility and action towards mitigation of greenhouse gas emissions is the evaluation and improvement of technology, especially energy producing technologies and transportation, such that other hazardous emissions will also be reduced. Human health is greatly impacted by air quality. Human productivity is one of the major means of maintaining and/or improving human well-being. Maintaining and/or improving human health (and the 'health' of natural and managed systems) can be additional major beneficial aspects of mitigation strategies.

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[57] See http://www.johannesburgsummit.org/ for the key outcomes of the Johannesburg's Sustainable Development Summit (September 2002).

[58] Mitigation is understood as actions taken to reduce the causes of negative impacts on human well-being, e.g., reduction of greenhouse gas emissions in industry and transportation; reduction of water and air pollutants.

Vulnerability

Socio-economic conditions and climate conditions are highly interdependent and interrelated; the two together determine the vulnerability of a society to climate change (Figure 2). Responses by society to climate variability and to potential climate change can be categorized as climate-sensitive (-) and as having coping and adaptive capacity potential (+) (see Figure 1). Positive and negative responses are not necessarily just climate-related, of course. Responses to other societal stresses may also have effects on the ability of the society to build resilience to climate changes. For example, government responses to disasters may deplete resources needed to institute effective proactive policies with regard to climate change. The coping-adaptive capacity of society (from the individual to a nation, to a region, to the globe) can be defined as a capacity to respond to and deal with an impact, either after it has occurred, or in anticipation of it. Through the recognition of the decision-making capacity in society with regard to anticipated forces,[59] society can pursue specific adaptation decision-making.

Figure 2 illustrates the relationships between climate-related driving forces and socio-economic driving forces and attempts to illustrate the direct and indirect relationships among the different aspects.

Direct socio-economic driving forces (direct effects 1) are demographics, the economy, politics and policy. These factors affect all sectors of human well-being: food security, water availability, settlement/shelter security, human health and all aspects of human resources/capital. The sectors include various aspects. For example, settlement security includes population distribution (rural versus urban, agricultural versus industrial versus service-based economy, laws and regulations, population group movements, immigration), the propensity to favor security or risk (laws and regulations, social networks, insurance), and accessibility (access and escape routes).

If we view socio-economic driving forces as multi-scaled, we may view their impacts as more under societies' (human) control because of adaptive choices that people can exercise on the pathways to human well-being.

Climate-related driving forces (direct effects 2) are temperature, precipitation, and wind. These affect natural resources (clean water and air, biodiversity, and ecosystem integrity), managed resources (agriculture, fisheries, animal husbandry, forestry, and protected land), and all the sectors of human well-being. Besides these direct effects, there are indirect effects (1, 2, and 3) in the form of interactions and mutual dependencies among natural and managed resources, and human well-being sectors.

[59] The term "forces" is used here to describe the causes of impacts on society and human well-being. They may be explicit, such as legislation, agreements, etc. But they also are the more amorphous phenomena such as climate variability, climate change, population increases, and changes in the economy.

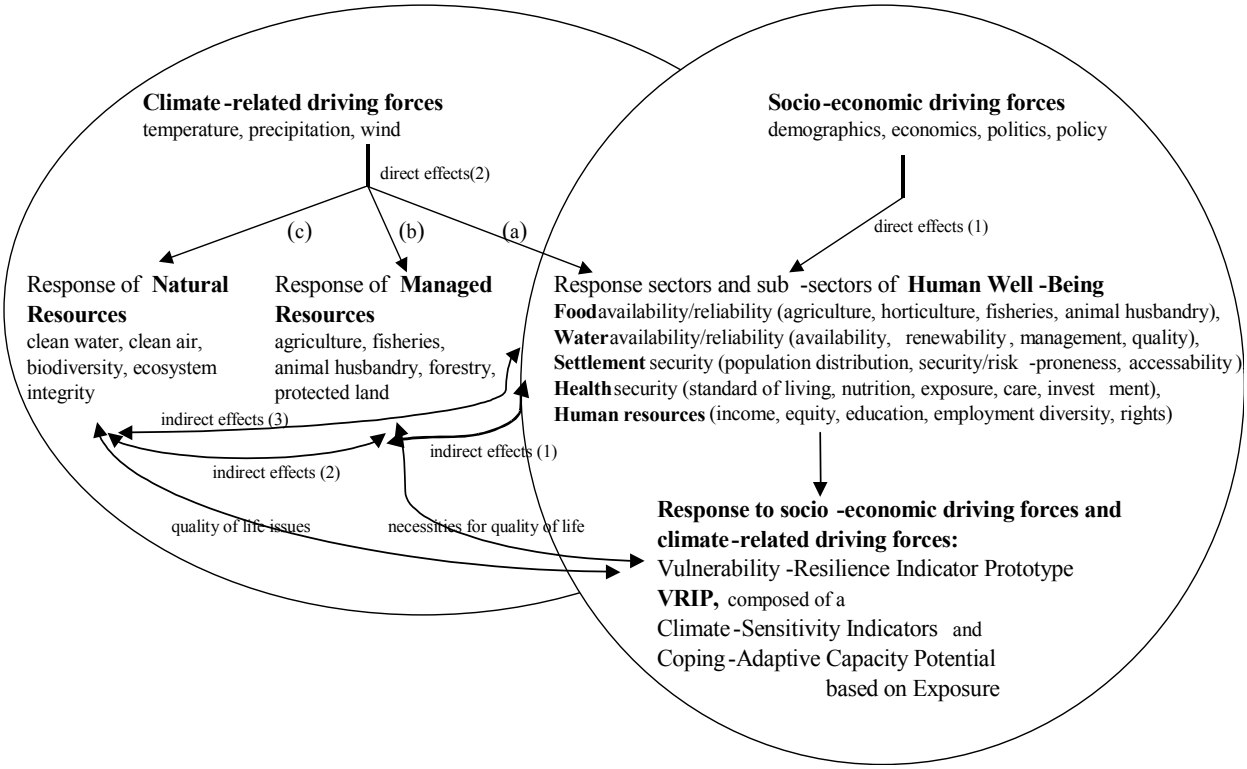

Figure 2 Relationships among socio-economic factors and climate factors.

Thus, linkages among the sectors within the categories need analyses. For example, education levels under human resources are indirectly linked (indirect effects 1) to management and technological development potential of agriculture and water. Population distribution and employment diversity are linked (direct effects 1). Changes in temperature and precipitation affect managed resource responses like agriculture (direct effects 2), which might affect the food sector under human well-being, but also farmers' income and trade balances (indirect effects 1). Within-country population migration (direct effects 1) might affect the settlement sector, but also the average national income and equity, and health indicators. Investment in infrastructure in the form of road building might positively affect average national income and improve equity and commerce, but may have negative impacts on natural resources through increased landscape fragmentation, increased run-off, siltation and pollution. Linkages between natural resources and human well-being can be seen as quality of life issues; they border, however, on basic needs such as sustainability of clean water and air.

In addition, there may be multiple impacts on an indicator, sub-sector, or sector. For example, food might become scarcer as population increases, but more food may become available through agricultural technological improvement, through trade, or through aid.

Although models cannot now account for these complex interlinkages, we can now define, with initial assumptions, the relevant factors in vulnerability-resilience assessment as those named in Figure 1. Then the modeling task becomes to quantify these factors. Because not everything is measurable or quantifiable, proxies need to be found that represent as sufficiently as possible what a sector or subsector stands for with regard to its evaluation/analysis potential towards sensitivity to, coping with, and adaptation potential to change. And because we have to differentiate between "what impacts what" and "why or how," the figure depicts the "why's" and "how's" as arrows, and the "what's" as sectors, broken down into subsectors for which indicators have to be determined.

Responses to socio-economic driving forces and climate-related driving forces can be captured in the Vulnerability-Resilience Indicator Prototype (VRIP) composed of indicators of (climate) sensitivity and coping-adaptive capacity based on experienced (actual impacts) and/or potential (risk) exposure.

To quantify indicators, the analyses of potential changes in forces and responses need to proceed on a sector-by-sector level such that transparency of what values stand for is maintained. To represent sectors (and/or subsectors) that may respond to impacts, we use proxies, given that hard data are not necessarily available for phenomena of interest. We search therefore for representative, measurable identities. Indicators should have evaluation/analysis potential towards sensitivity to, coping with, and adaptation potential to change. The responses to driving forces have to be expressed as changes in the states of sector (or proxy) values, while the driving forces themselves represent the "causes" of the changes of the sector (or indicator) values. Relationships between driving forces and impacts on indicators may be linear or may be complex functional relationships. The VRIP (Figure 1) is a first approximation of the more complex framework depicted in Figure 2 above.

Indicators

Our Vulnerability-Resilience Indicator Prototype (VRIP) is a model composed of 17 indicators, including Climate-Sensitivity Indicators (negatives) and Coping-Adaptive Capacity Indicators (positives) aggregated into sectors.[60] Table 1 lists the proxies, sectors, and the sensitivity and coping-adaptive capacity clusters. In general, for comparing national vulnerabilities we chose indicators for which well-established data sources were available (see Table 1). In our previous work, projections were made using outputs of an integrated energy and economics model, the MiniCAM, and a postprocessor to the MiniCAM, Sustain.[61] Country-level proxy values were scaled to the world baseline values. Sector values were calculated as the geometric mean of the scaled proxies

[60] Moss, Brenkert and Malone, *Vulnerability*.
[61] Hugh Pitcher, "Sustainability."

included in the sector. A country's sensitivity and adaptive capacity were calculated as geometric means of the participating sectors. The final vulnerability-resilience indicator value is then the simple arithmetic summation of a country's sensitivity and adaptive capacity. An example for India under different scenario projections for the year 2005 will be given later in this report (see Figure 4).

The next sections discuss the reasons for choosing the indicators currently used and provide brief notes on the data gathering for India's states. Table 1 lists the data sources for the different sectors and proxies for the Indian states.

Table 1 Sectors, indicators, and data sources used in the VRIP

	Sector	Proxies	Source
Adaptive Capacity (+)	Economic Capacity	GDP per capita	World Bank 1998
		Income distribution equity	World Bank 1998, Deininger and Squire 1996, 1998 & www.worldbank.org/research/growth/dddeisqu.htm
	Human and Civic Resources	% Population in the workforce	World Bank 1998
		Illiteracy	World Bank 1998
	Environmental Capacity	% Non-managed land	FAOSTAT98
		SO_2 emissions	GEIA, Benkovitz et al. 1991
		Population density	World Bank 1998
Sensitivity (-)	Settlement/ Infrastructure	Sea level rise resulting in number of people at risk	Delft Hydraulics 1993
		% Population with access to safe water	World Bank 1998
		% Population with access to sanitation	World Bank 1998
	Food Security	Cereal production/ agricultural land	World Bank 1998 & FAOSTAT98
		Animal protein demand per capita	World Bank 1998 & FAOSTAT98
	Human Health	Birth rate	World Bank 1998
		Life expectancy	World Bank 1998
	Ecosystems	% Managed land	FAOSTAT98
		Fertilizer use/area cropland	World Bank 1998
	Water Resources	Water sensitivity, based on availability and consumption	World Resources 1994-95

Coping and Adaptive Capacity Indicators

The socio-economic conditions that bear on coping and adaptive capacity include demographic characteristics, economics, politics/governance, management of natural resources and civil society. In the VRIP, the sectors are described as follows:

Economic capacity

Wealth generally provides access to markets, technology, and other resources that can be used to adapt to climate variability and change. Hence we have included GDP (market[62])

[62] We did not use purchasing power parity (PPP) adjusted GDP per capita because over the course of the century for which we make projections. PPP will clearly change as countries develop. Using a fixed PPP

per capita as one of the proxies for economic capacity. However, in societies where the distribution of wealth or income is very unequal, coping capacity will also be unequally distributed. Thus we included unequal distribution of wealth income within a society, indicated by the Gini coefficient as a component of our indicator of coping-adaptive capacity.

For India's states we found 1990-1991 state income (see the Appendix: Tables 5 and 6 and Figure 18 for background information) and converted these to US dollars. We substituted, for the Gini as equity measure, a measure of state poverty and inequity (see Table 8 in the Appendix). For missing values we substituted India's national measure. Table 8 also lists state urbanization ratios.

Human resources

Human and civic resources are another critical component of coping and adaptive capacity. This category includes literacy, level of education, access to retraining programs, and other factors that determine how flexible individuals may be in adapting to new employment opportunities or shifts in living patterns brought about by climate variability or change. As indicators, we selected the dependency ratio and the literacy rate. The dependency ratio measures the proportion of economically active and inactive individuals in a population; a higher rate of dependency would indicate that economically active individuals had many others to support, and resources for adapting to changes in climate would be more limited. The literacy rate was also included as a measure of the skills that individuals would have to have in order to adapt.

Closely related to human resources are civic resources, which include associations among individuals, either informal or formal, through kinship relations, civic associations, or other institutions that would lead to feelings of obligation to help those who may be negatively affected by climate. In future versions of the model, civic resources will clearly need to be included.

In the case of Indian states, we calculated the state-specific dependency ratios from the state-specific percentage of male and female, urban and rural populations in the workforce and averaged these (see Tables 9 and 10 in the Appendix). If we could have included the urbanization percentages for both male and female populations, we could get a better estimate. These data were not available, however.

State-specific literacy rates were available from a variety of sources (see Tables 11 and 12 in the Appendix).

Governance

A crucial component currently missing from the quantitative indicator set is the role of governance. A stable government that makes and effectively implements environmentally sound policies can play the central role in addressing climate change risks. Instability, such as the ethnic conflicts and Kashmir dispute in India, deflect attention and resources

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adjustment wildly inflates the level of wealth in countries that are currently poor to the point that their GDP per capita dwarfs that of those countries that are currently economically developed.

from environmental issues – although India has a stable, legitimate central government. How good the environmental laws and regulations are, how well these are integrated with general development (both economic and human) policies, and how effectively all policies are implemented are matters for qualitative analysis, but they have not been satisfactorily quantified.

Adger et al.[63] analyze resources necessary for adaptation, but point out that the political will to confront climate change is essential for developing adaptation capacity. Furthermore, the relationship of the national government and its institutions with those who will need to adapt to climate change is "important in determining whether policies designed to facilitate adaptation will be successful."

Environmental coping and adaptive capacity

As discussed above, natural systems are sensitive to climate stimuli and thus will need to adapt to climate variability and change. Adaptation may involve a variety of eco-physiological changes, changes in species mix, migration, or even the loss of some species or ecosystems. The survival of current ecosystems will depend not only on the degree of climate variability or the rate and magnitude of climate change but also on the baseline condition of the systems themselves. For proxies of the resilience or coping and adaptive capacity of ecosystems we take three available measures of the amount of natural capital that is available: population density, SO_2 emissions/area, and the percentage of unmanaged land in a country.

From the Global Emissions Inventory Activity's (GEIA)[64] gridded data of SO_2 emissions and from the Carbon Dioxide Information Analysis Center's (CDIAC) [65] gridded state codes we generated state sulfur emission estimates per state per ha land (Table 13 in the Appendix).

Population density was calculated for each state from population data and land area data and checked against population density data (see Table 14 in the Appendix).

Land use was explored rather extensively, given its present use, potential use, relationship to general environmental conditions and climate. Tables 18 through 21 in the Appendix show the large number of land use categories Indian institutions employ to define land use.

[63] Draft Technical Paper 7, "Adaptive Capacity," UNDP Adaptation Policy Framework, www.undp.org/cc/apf-outline 2002. Other technical papers cover vulnerability, socio-economic conditions and prospects, and monitoring and evaluation of adaptive measures.
[64] http://weather.engin.umich.edu/geia/
[65] http://cdiac.esd.ornl.gov/home.html

Sensitivity Indicators

Sensitivity sectors include settlements/infrastructure, food security, ecosystems, health, and water resources. For each sector, 1-3 indicators were selected to represent aspects of the sector that could be quantitatively modeled.

Settlements/infrastructure sensitivity

Settlement sensitivity includes effects on economic activities in the industrial, energy, and transportation sectors, as well as effects on human settlements. Climate variability and change have direct impacts through flooding, droughts, changes in average temperatures (e.g., leading to thawing of permafrost), temperature extremes, and extreme weather events (e.g., hurricanes). In addition, climate variability and change can affect markets for goods and services in these sectors, as well as natural resource inputs important to production.[66] Settlements in coastal margins and on small islands are affected through sea level rise and through storm surges, while these areas and inland settlements can be affected by weather-related events that act directly on infrastructure (e.g., leading to river basin flooding, landslides, and the like) and indirectly through effects on other sectors (e.g., water supply, agricultural activity; human migration patterns). Patterns of effect are different for urban and rural settlements, but both have been shown to be sensitive to climate variability and change.[67]

Three proxies are used for approximating sensitivity of settlements and infrastructure in industry, energy, and transportation: population at flood risk due to sea level rise, and populations without access to clean water and sanitation.

Table 15 in the Appendix lists the information on Indian state populations potentially affected by 1 m sea level rise; these data were used in the VRIP exercise after scaling[68] for people affected by present-day storm surges and people affected by 1 m sea level rise. This means that the vulnerability-resilience indicator shown in the results incorporates, most likely, a larger risk factor than warranted because the difference between present and future national data is relatively small. The previously used data include preventive measures against sea level rise, while the Indian state 1 m sea level rise information does not include these, resulting in this overestimation of people who are currently affected.

Available data on access to safe water are listed in Table 16 in the Appendix. These data were obtained from state information[69] on water availability classified on the basis of the source of drinking water as 'safe' or 'otherwise.' If the household had access to drinking

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[66] R. Acosta Moreno and J. Skea, A. Gacuhi, D.L. Greene, W. Moomaw, T. Okita, A. Riedacker and Tran Viet Lien, "Industry, Energy, and Transportation: Impacts and Adaptation," in Watson et al., *Climate change 1995.*

[67] M.J. Scott, A.G. Aguilar, I. Douglas, P.R. Epstein, D. Liverman, G.M. Mailu and E. Shove, "Human Settlements in a Changed Climate: Impacts and Adaptation," in Watson et al., *Climate change 1995.*

[68] Based on national data from Delft Hydraulics 1993. Different sources give different numbers. We scaled so that we still could use word data based indexing.

[69] State-level per capita public expenditure on Health (Medical and Public Health) and Family Welfare, including Water Supply and Sanitation: http://www.rainwaterharvesting.org/resources/statistics/stat531.htm

water supplied from a tap, handpump or tubewell situated within or outside the premises, it was considered as having access to safe drinking water.

For the Indian states, data on access to sanitation were not available. In Table 16 in the Appendix one may find, however, state data on per capita expenditures on health, which includes water supply and sanitation.[70] These data were not used in the VRIP exercise given that a scaling procedure could not be worked out in the present timeframe. National data were used instead for all states.

The World Bank reports through the India Water Resources Management reports, which are co-published and distributed by Allied Publishers Limited of India,[71] that more than 75 percent of the rural population, some 520 million people in India, do not have access to public water supply facilities and that achievements in sanitation coverage have been even less extensive, with only 3.6 percent of the rural population covered at present. While actions to improve coverage of sanitation have been stepped up recently through provision of subsidies and technical assistance for household construction of sanitation facilities, national guidelines and investments in the rural water supply and sanitation sector neglected to ensure that the quality of services to rural areas remained adequate. The demands on the urban water supply and sanitation sector, which serves both urban domestic and industrial needs, are tremendous. To date, the sector has under-performed, resulting in harmful impacts on consumers, especially the poor, and on the environment.

Food sensitivity

Sensitivity to food security is defined as the potential for changes in the availability of food in a particular geographic area. It encompasses both production of principal foodstuffs (e.g., crops, livestock, fish) as well as socioeconomic issues such as type of production system, access to production inputs that can offset changes in climatic conditions, and access to markets for purchase of food. Climate variability and change can affect food sensitivity through a variety of mechanisms, particularly related to food production. Variability in temperature and precipitation affects crop production directly, as well as through impacts on soils (e.g., erosion), pest and disease outbreaks, and other mechanisms. In addition, floods, droughts and periods of extreme temperatures can affect livestock and fisheries production.[72] Climate change is projected to have impacts on agricultural production through these mechanisms and through changes in atmospheric concentration of CO_2, which affects productivity and water use efficiency, particularly in C_3 plants. Impacts on agricultural production may also be felt through changes in

[70] See "State Wise Per Capita (Public Sector) Expenditure on Health (Medical and Public Health) including Water Supply and Sanitation and Family Welfare (During 1985-86 to 1989-90)," http://www.indiastat.com.

[71] http://www.andhrapradesh.com/

[72] P.C. Stern and W.E. Easterling (eds), *Making Climate Forecasts Matter: Panel on the Human Dimensions of Seasonal-to-Interannual Climate Variability* (Washington, DC: National Academy Press, 1999).

availability of water resources for irrigation.[73] Climate variability and change also cause changes in livestock and fisheries production through a variety of mechanisms.[74]

Two proxies represent food sensitivity in the VRIP. Cereals production per unit area is intended to capture the degree of modernization in the agriculture sector and the access of farmers to production inputs that can be used to buffer against the effects of climate variability and change. Systems with high production per unit area are presumed to be less sensitive than those with low production. Animal protein consumption per capita is an imperfect proxy for the degree of modernization in processing and distribution of agricultural goods for consumers. Populations with high levels of animal protein consumption are presumed to have lower food sensitivity than those with low levels of consumption.

We looked extensively at agricultural data for the different states, given that 70% of the population in India is agrarian. Figure 22 in the Appendix shows the different rates of change in the economically active agrarian and non-agrarian population and find the non-agrarian economically active population increasing faster than the agrarian population. Projections through 2010 show even a faster change.

Rice is shown as major agricultural product in Figure 22 in the Appendix. Table 18 in the Appendix lists the different cereals produced in the different states with regard to land used for production. Eighty percent of the rice produced in India is grown in rain-fed lowlands. Increasing use of technical means like tractors, harvesters, irrigation and fertilizer is shown in Figure 23. Imports of agricultural products have been steadily increasing, while exports have been much more variable over the last 10 years (See Figure 24 in the Appendix). For the VRIP run we used the data shown in Table 17 in the Appendix for cereal production.

For India, the animal protein indicator is probably an inappropriate indicator of food security. Thus, in our within India state-by-state comparison we substituted total protein consumption for animal protein. These data are listed in Table 22 in the Appendix.

Human population health sensitivity

The health of human populations is affected by climate variability and change through both direct mechanisms (e.g., heat waves in conjunction with episodes of poor air quality, especially in urban areas) and indirect pathways (e.g., changes in prevalence of vector-borne and non-vector-borne infectious diseases). Populations with different levels of technical, social, and economic resources would differ in their sensitivity to climate-induced health impacts. Sensitivity to climate variability and change would be expected

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[73] J. Reilly, et al., "Agriculture in a Changing Climate: Impacts and Adaptation," in Watson et al.,*Climate Change 1995*.

[74] Ibid.; also B. Allen-Diaz, F.S. Chapin, S. Diaz, M. Howden, J. Puigdefábregas and M.S. Smith, "Rangelands in a Changing Climate: Impacts, Adaptations, and Mitigation," in *Climate change 1995*, op. cit.; J.T. Everett, A. Krovnin, D. Lluch-Belda, E. Okemwa, H.A. Regier and J.-P. Troadec, Fisheries, in Watson, et al., *Climate change 1995*.

to be higher for those populations with poor basic living conditions such as overcrowding, malnutrition, and inadequate access to health services. Thus sensitivity of human population health to climate conditions can be expected to be highest in developing countries and among the poor in transitional and developed countries.

We used two proxies to represent sensitivity of health to climate variability and change: completed fertility and life expectancy. These variables represent a variety of conditions that affect human health, including nutrition, exposure to disease risks, and access to health services.

For states in India information on fertility rates and life expectancy was available (see Table 23 in the Appendix).

Ecosystems sensitivity

Ecosystems and the functions they provide to individuals and society (e.g., providing food, fiber, medicines and energy; processing carbon and other nutrients; purifying and regulating water resources; providing recreation and intrinsic value) are sensitive to variation and change in climate. The composition and distribution of ecosystems has changed in the past in response to shifts in climate, and models project future shifts in response to both the rate and magnitude of climate change.

Mechanisms through which climate impacts are felt are similar to those for agriculture, i.e., variation or change in precipitation and temperature, changes in atmospheric composition that affect the competitive balance among different types of plants, changes in soils, and changes in the incidence of diseases and pests. Ecosystems are also influenced by other environmental stresses, including pollution (both runoff in water courses and deposition from the atmosphere), increasing extraction of resources, and incursion/fragmentation. These factors have also been shown to affect the sensitivity of ecosystems to climate variability and change.

Two proxies represent the sensitivity of ecosystems: percentage of land area that is managed, and fertilizer use per unit land area. The percentage of land under management is a proxy for the degree of intrusion of human activity into the natural landscape and the potential fragmentation of land, which would increase the sensitivity of ecosystems to climate variability and change. The percentage of unmanaged land in a country consists of unmanaged and old forestlands. Fertilizer use per unit area captures nitrogen and phosphorus loading of ecosystems and is a proxy for ecosystem stresses resulting from pollution.

State information on fertilizer use is listed in Table 24 in the Appendix. These data were converted to fertilizer use per ha land by dividing by cropland area (see Table 19 in the Appendix).

Water availability

Climate variability already has had a large impact on the general hydrology of a landscape and on the availability of water at the local and national scale, and climate change can be expected to have as large or larger an impact. Presently, 19 countries around the world are classified as water-stressed.[75] This number can be expected to change due to population growth, changes in land use, precipitation, and evapotranspiration (linked to temperature increase). Moreover, not only will socio-economic aspects of society be affected through changes in water availability, but also government policies can be expected to respond.

Presently, we have defined the sensitivity to water availability through one proxy, composed of withdrawals to meet current or projected needs and (divided by the sum of) the supply of water from internal renewable resources and inflow from rivers.

Although India is listed under the water-abundant category of countries with 2,464 cubic meters of renewable annual fresh water available per person in 1990[76] water availability is a regional phenomenon. Moreover, according to long-range United Nations population projections, India's population could, under the low-growth projection, stabilize and eventually shrink in size after 2025, which would actually increase per capita water availability. Under the medium and high projections, however, the country would move into conditions of water stress and water scarcity, respectively (see Figure 26 in the Appendix).

The India Water Resources Management Report[77] states that groundwater is an important source of drinking water and food security for India's 1 billion inhabitants, and that it supplies 80 percent of water for domestic use in rural areas and perhaps 50 percent of water for urban and industrial uses. The report further states that rapid expansion in the use of groundwater, primarily for irrigation, has contributed significantly to agricultural and overall economic development in India but that, in many arid and hard-rock zones, increases in overdraft areas and associated water-quality problems are emerging. According to the report, sustainability of the resource base is thus critical for meeting an array of basic needs, from health to economic development, and groundwater cannot be managed in isolation from critical considerations such as integration with surface water; incorporation of water quality, pollution, environment, and health issues; and a broad array of resource allocation, economic and social concerns.

We have not been able to integrate the diverse pieces of information on water sources, water availability and water renewability into state-specific water availability, within the present timeframe of this report. Given that a very large percentage of the presently available water in India is used for agriculture, which might shift locally when industrial development requires more intense water use, and people require more water for personal use, water availability paired with climate change requires a more in-depth study than can

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[75] Robert T. Watson, M.C. Zinyowera, R.H. Moss and D.J. Dokken, *The Regional Impacts of Climate Change, An Assessment of Vulnerability* (Cambridge: Cambridge University Press, 1998).
[76] http://www.cnie.org/pop/pai/water-30.html
[77] http://www.andhrapradesh.com/

be presently delivered. For example, the above-quoted report identifies two broad issues that need to be addressed and proposes an action plan. First, solutions must be found for competing inter-sectoral demands. Mechanisms must be developed for allocating scarce water resources between competing uses such as irrigation, rapidly expanding domestic and industrial needs, hydropower, and environmental requirements. Second, water must be managed on a river basin basis, including states sharing the same river basin.

Some essential background information is listed in the Appendix in Tables 25, 26 and 27. Figures 27 and 28 in the Appendix show India's dams (reservoirs) and areas irrigated.

Dynamics

A set of indicators is valuable as a "snapshot," or static picture of societal conditions. However, the reality is that both climate and socio-economic conditions are constantly changing. For example, each time that a climate event results in negative impacts, societies respond in various ways – government relief programs, insurance programs (payouts, changes in coverage), new building codes, physical protection infrastructure, new evacuation programs, to name just a few. As these short-term coping responses become institutionalized, they can build long-term adaptive capacity.

In addition, in the aftermath of coping activities and in the face of increased risks from climatic events, societies proactively develop new policies and programs, strengthen existing institutions, and so on. Thus, adaptive capacity is built both from experience and from other knowledge (see Figure 3). As conditions represented by the indicators and sectors in the model change, different levels and types of vulnerabilities may appear over time.

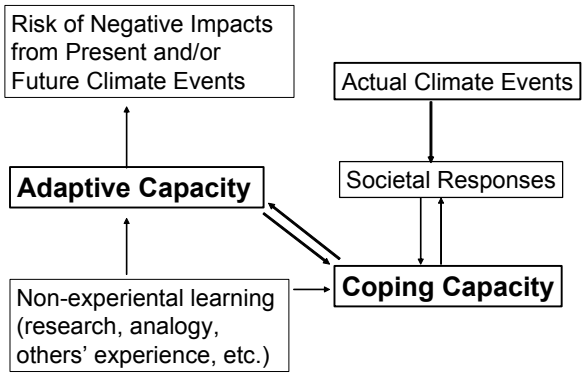

Figure 3 Societies build adaptive capacity based on experience with adverse climate events and on non-experiential learning.

In order the represent dynamic change over time, the VRIP model projections account for the initial values (base year, that is 1990 starting values) of the indicators, their

interaction within sectors, sectoral changes within the timesteps, and the negative/positive tradeoffs. Different starting configurations result in different vulnerabilities over time.

Figure 4 shows the results of running the VRIP model for India as a nation, given three scenarios of socio-economic development. The scenarios are drawn from the Intergovernmental Panel on Climate Change's *Special Report on Emissions Scenarios*.[78] These VRIP runs for India were initiated with 1990 national baseline values, indexed against 1990 global values and projected 15 years into the future based on MiniCAM and Sustain outputs.

The three scenarios differ qualitatively and quantitatively from each other:

In the "rapid growth" scenario (A1v2) economic development is robust and population growth moderate. Over time, current distinctions between "poor" and "rich" countries decrease. There is great improvement in the health and social conditions of most. With increases in income, dietary patterns shift towards increased consumption of meat and dairy products. Land use shifts to sprawling urbanization and intensification of agriculture.

In the "local sustainability" scenario (B2h) there is increased concern for environmental and social sustainability. Global average income per capita grows moderately. International income differences are reduced considerably. Education and welfare programs lead to reductions in mortality and fertility, with the population reaching about 10 billion people by 2100. Environmental protection is a priority, although strategies to address global environmental challenges are less successful than in other scenarios. In this world, there is less wealth for adaptation, but social networks would be presumed to be more effective. Ecosystems would also be under less stress than in the rapid growth scenario.

The third scenario, A2A1, is called "delayed development." In this scenario, economic development in Africa and parts of Asia and Latin America is less vigorous because of continuing institutional setbacks. People, ideas, and capital are less mobile so that technology diffuses slowly with the result that international disparities in productivity, and hence income per capita, are maintained or increased. Environmental damage is also uneven. Fertility rates decline only slowly, although they vary among regions. Vulnerability and/or resilience would be expected to vary from location to location but would be particularly high in those areas where economic development is delayed, population growth remains high, and environmental problems are not addressed.

[78] Nakicenovic et al., *Special Report*.

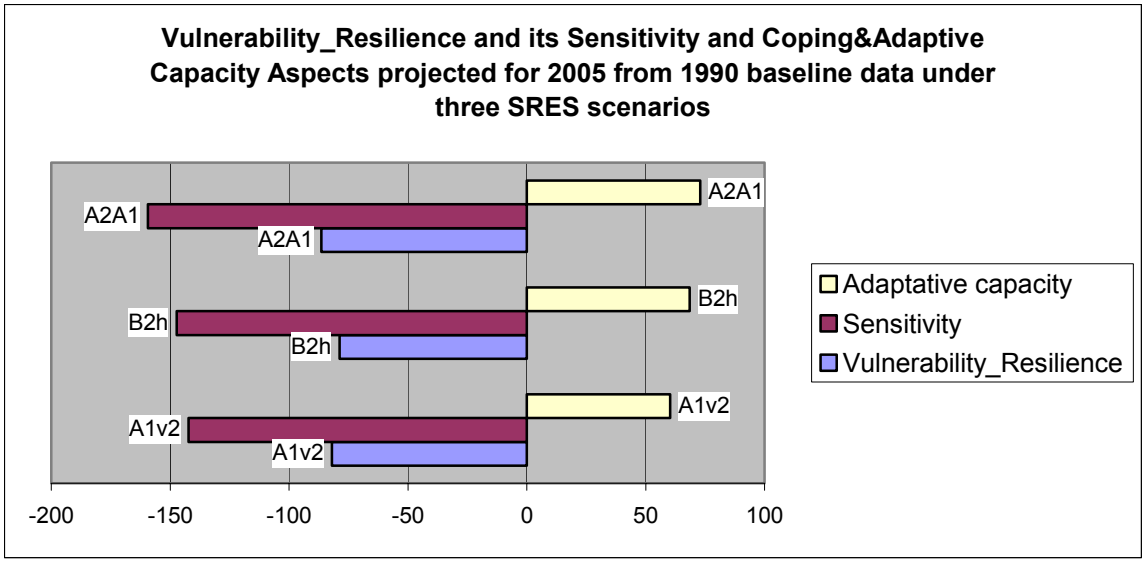

Figure 4 Vulnerability-Resilience under different scenarios of the future for India in 2005

Applying the Framework to India and Its States

In our previous study,[79] the prototype model produced quantitative vulnerability-resilience assessments for 38 countries and the world (see Figure 5). India ranks second-to-last in that analysis. This first, highly aggregated comparison is a result of the VRIP model but is only a starting point for an analysis. We need to examine why the vulnerability is so high (its value within the range of vulnerability to resilience is quite low). To do that, we look at the whole set of indicators for India.

[79] Moss, Brenkert and Malone, *Vulnerability*.

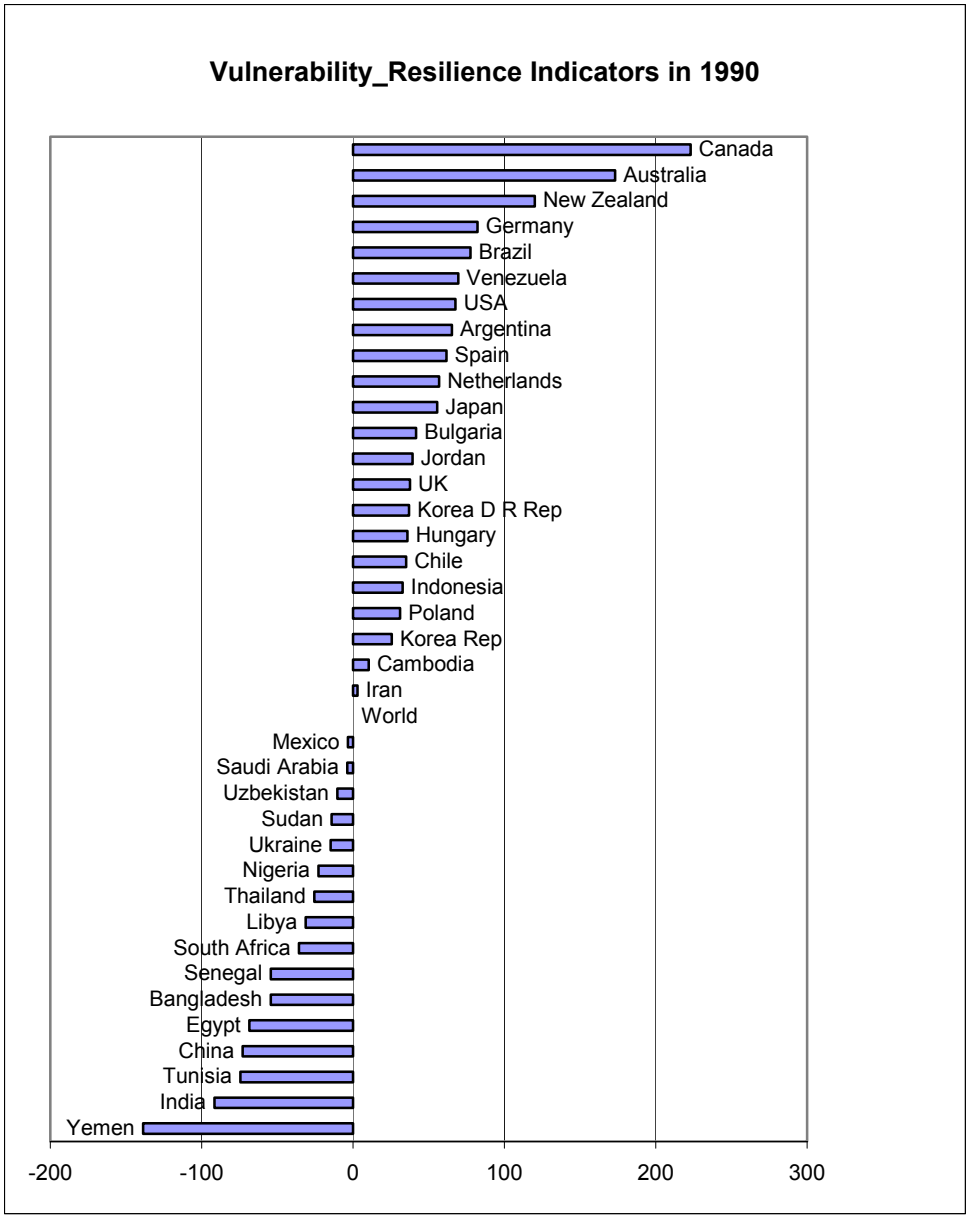

Figure 5 Vulnerability rankings of 38 countries

Figure 6 shows the contribution of various indicators to India's vulnerability. (Recall that the values of the sensitivity indicators are below the zero-line circle, while the values of the coping-adaptive capacity are above the zero-line circle) Obvious negatives that are making large contributions to vulnerability are water availability and animal protein. We know that animal protein is not necessarily an appropriate indicator for India, because of many dietary customs in India relating to religious and cultural beliefs. However, water availability is already an issue in the country, which has been plagued by drought in some parts – and by flooding in other parts – affecting the productive use of water for human

use, sanitation, industry, and irrigation in recent years. India is trying to realize more of its potential for irrigated crops, to lessen the effects of extreme climate events; this vulnerability assessment points us to water, including irrigation schemes, as a potential trouble spot.

On the positive side, age dependency is the highest valued indicator, especially in the local sustainability and delayed development scenarios. This indicates that many people will be available for the workforce in the future (2005), supporting relatively few people other than themselves.

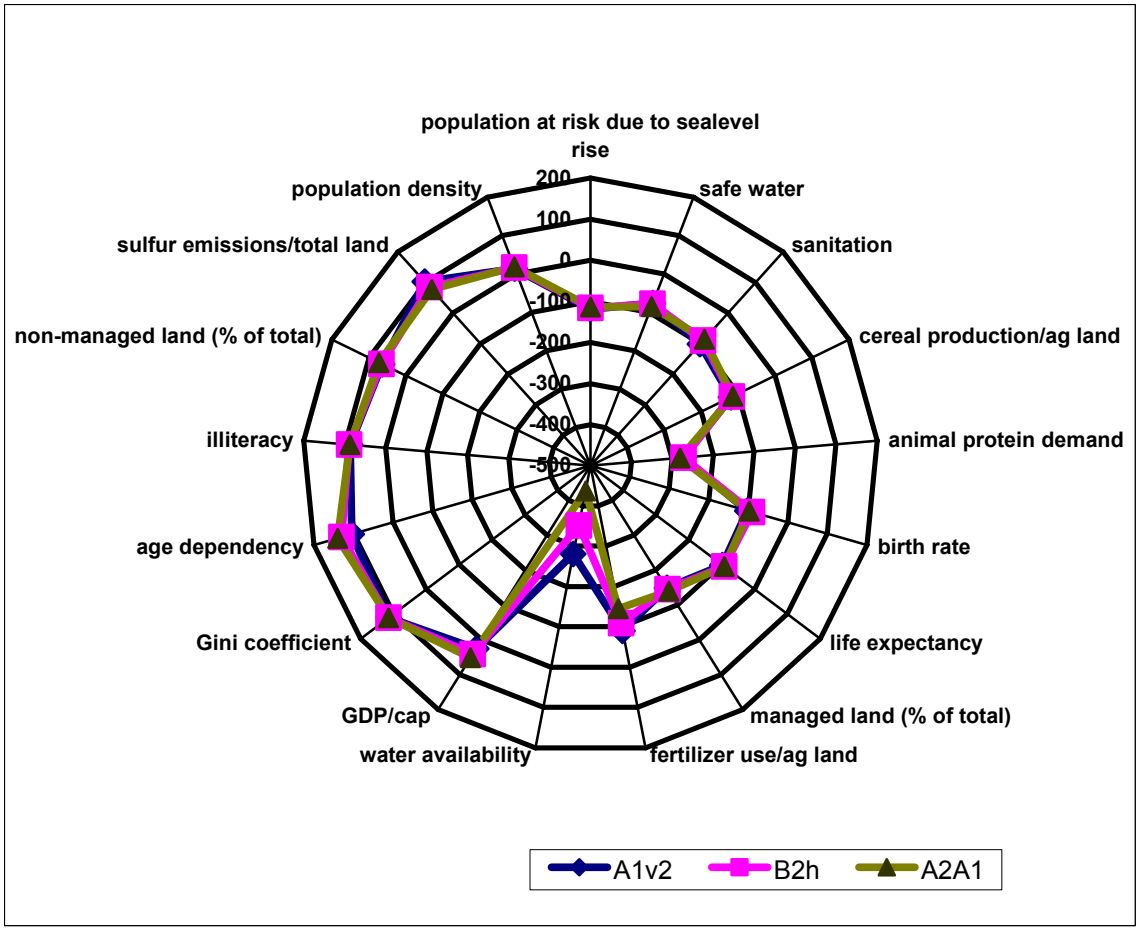

Figure 6 Differential contributions of indicators for three scenarios of the future for India (2005)

The Vulnerability and/or Resilience of India's States and Regions

Redirecting the assessment from India as a whole to Indian states brings into play a new level of detailed analysis. India's states are diverse in cultures, approaches to governance, natural resources, and emphases. They have been differentially affected by climate, both because of their dependence or non-dependence on agriculture and because of the climate events themselves. (Figure 18 in the Appendix shows a map of India's states; Figures 15 and 16 in the Appendix give an overview of India's climate.)

Sensitivities[82]

Floods and cyclones are two major natural disasters that visit India often. The adverse impacts of these two natural disasters include the economic effects of destruction of crops, property and infrastructure, as well as human misery in the form of death, disease, injury, loss of employment, psychological trauma. All of these impacts set back general socioeconomic development.

Rainfall fluctuations in India have been largely random over a century, with no systematic change detectable on either annual or seasonal scale. However, the linear trends of monsoon rainfall during 1871-1998 at each of over 300 observing stations spread over India show statistically significant trends in some broad contiguous areas. The increasing trends in the seasonal rainfall have been observed over Punjab, Delhi, Haryana and Chandigarh, no significant change along the West Coast, and decreasing trends over East Madhya Pradesh and Northeastern States of India during recent years. Intense deforestation has taken place along the foothills of Himalayas and in the Assam region, and land-use patterns have undergone definite changes over parts of Rajasthan and Punjab (Northwest India). (Figure 25 in the Appendix shows India's present forest cover.) Surface cooling with significant increase in rainfall has also been observed in the peripheral regions of the Rajasthan desert; increased area under irrigation (Figure 28 in the Appendix shows an irrigation map) may be one of the main casual factors.

The frequency of extreme weather events in India — for example, droughts, heat waves, and floods — has increased over the past two decades. For example, Orissa has been reeling under contrasting extreme weather conditions for more than a decade: from heat waves to cyclones and from droughts to floods (Figure 17 in the Appendix shows a map of Orissa). Since 1965, calamities are not only becoming more frequent but striking areas that never had a vulnerability record. For instance, a heat wave in 1998 killed around 1,500 people. Most of the casualties were in coastal Orissa, a region otherwise known for its moderate temperatures. Almost 490,000 hectares of fertile lands have been waterlogged, salinated and sandcasted in coastal Orissa due to cyclones and floods. The devastating floods in 2001 (15 floods were reported between July 8 — August 10, 2001) have already induced crop failure worth a whopping 150 billion Indian Rupees. Incessant rains for 40 days beginning the first week of July 2001 were largely responsible for the worst flood recorded in the last century. The 2001 floods (more devastating than the 1982 floods) were deadly because the Mahanadi, the Brahmani and the Baitarani rivers, sharing a common delta, flooded simultaneously. These floods inundated 25 of the 30 districts including hilly areas like Kalahandi and Phulbani and affected one-third of its 30 million residents. Around 2.12 million hectares of standing crop were also damaged. This year, while drought conditions prevailed in Vidarbha during June and July, heavy downpours in August amounted to 80 cms of rainfall against 95 cms of seasonal normal rainfall. Twenty-five cms of rainfall was recorded in just two days (September 2-3),

[82] Murari Lal, *Country Studies.*

which lifted the water level of Sardar Sarovar dam along Narmada River to 12 meters above its full capacity of 95 meters, resulting in inundation of hundreds of villages in the region. Such intense rainfall events have become more frequent in recent years in many parts of India, Nepal, and Bangladesh.

Drought has a chronic recurrence in west Orissa. However, it is not only the recurrence but also the expanse of the drought that haunts this State. The drought in the year 2001, the worst drought since 1866, engulfed districts like Sundergarh and the Kendrapada that have been historically drought-free and affected 25 of the State's 30 districts. By February 2001, Orissa's western districts were experiencing a severe water crisis and people started migrating. The most severely affected districts like Kalahandi and Balangir reported 60% less rainfall than normal. The situation in nine western districts was severe as it was the second consecutive drought. By May 2001, 61 starvation deaths had already been reported. The state government put the economic loss due to crop damage at 64.289 billion Indian Rupees. The Orissa drought in 2001 affected the lives of 11 million people.

In May 2002, more than 1,000 people died during a weeklong heat wave in the State of Andhra Pradesh that saw surface air temperatures soar to 45°C. It was the highest one-week death toll from thermal stress in Indian history. In 1994, monsoon rainfall was deficient (by between 20% and 43%) in 10 of the 35 meteorological subdivisions of India. Gujarat, West Rajasthan, Tamil Nadu and Kerala had deficient monsoon rainfall during the year 1999. Two consecutive droughts in 1999 and 2000 have been reported in Pakistan and the Northwest India when increased flooding occurred in the high rainfall areas of Bangladesh, Nepal, and the Northeastern States of India. Due to poor monsoon rainfall in Gujarat during 1999 and 2000, all the reservoirs contained only 50% or less of their installed capacity. The situation was further aggravated since back-to-back droughts occurred. According to official sources, out of 143 dams and other reservoirs in Kutch, Saurashtra, and north Gujarat, 107 had gone dry during the pre-monsoon months of the year 2001.

From a mild winter in North and Central India to copious downpours in Assam, Bihar and other Northeastern States during the monsoon season, India recorded unusual weather in the year 2002. There were droughts in Pakistan and in north and central parts of India, while Bangladesh, Nepal, and the Northeastern States of India suffered severe flooding during monsoon season. The northeast states of India – Assam, Bihar, Meghalaya, Tripura, and Arunachal Pradesh – were the hardest hit by flood waters this year. More than half of Assam was flooded as heavy rains burst dams and caused rivers to overflow, inundating more than 5,000 villages and destroying hundreds of thousands of houses during July and August 2002. About 2.5 million people fled to take shelter on higher ground. Monsoon rainfall on all India on a mean basis, as of 31 July 2002, was estimated to be 24% lower than normal. Erratic monsoon in Punjab, Haryana, Madhya Pradesh, Maharashtra, Orissa, Andhra Pradesh and west Uttar Pradesh sparked worries about economic growth, already dragged down by two years of industrial slowdown. The 2002 drought may have caused irreparable damage to the summer crops, since the summer crops, harvested in October or November, account for half of the year's agricultural output.

Tropical cyclones are not part of the monsoons *per se* but they do cause devastating floods in coastal states of India. Severe tropical cyclones generally develop during the pre-monsoon or post-monsoon seasons (generally defined cyclone seasons are October-November and March-June). The eastern coast of India along Bengal, Orissa and Andhra Pradesh are prone to such tropical cyclones. Observational records suggest that, while the sea surface temperature over the Bay of Bengal has risen since 1951, the numbers of monsoon depressions and tropical cyclones forming over the Bay of Bengal and Arabian Sea exhibit a declining trend since 1970. However, the intensity of tropical cyclones in the Bay of Bengal seems to have increased in the recent past. A tropical cyclone hit the coast of Orissa in October 1999 with wind speed of 135 knots (about 260 kmph), causing severe floods. This cyclone ranked highest in the damage caused in terms of both life and property. According to official records, 9885 people lost their lives; 2142 people were injured; 370,297 cattle perished; and 1,617,000 hectares of paddy field and 33,000 hectares of other crops were damaged. Several villages were completely wiped out and over a million made homeless by a storm surge of height 9 meters above the astronomical tide level at Paradip.

Coping-adaptive capacity

Ideally, looking at the sub-national level would help us to better understand the tradeoffs between different assets for coping/enhancing resilience, and between different environment and development policy choices. We know that in the abstract, these tradeoffs involve many factors, including the rate of economic growth, the quality of the resulting wealth (its sectoral composition and degree of vulnerability to future climate changes), and tradeoffs across sectors (e.g., increasing agricultural resilience through increased irrigation, but corresponding increases in vulnerability in water resources and ecological systems). These different types of assets can be used to cope or increase resilience (in the longer term). One way to examine this issue, a step beyond what has been accomplished in the current study, would be to survey actual events and trying to compare how different states reacted to them, using the framework of indicators to see whether the indicators capture the strengths and weaknesses of the different actual responses.

Each state may call upon the resources of the central government, for example, in response to extreme climate events. Recent instances include the following:[83]

- Two very severe cyclonic storms occurred in October 1999, affecting 16 districts of Orissa, 12,922,000 people, 14,643 villages, and 1,842,000 hectares of crop area. The Natural Disaster Management Division of the Ministry of Agriculture coordinated relief and rehabilitation efforts to mitigate problems of affected people. The Prime Minister released Rs 5,000,000,000 from the National Fund for Calamity Relief and Rs 4,500,000,000 were advanced as plan assistance.

[83] Examples are from the Press Information Bureau, Government of India (2001), http://pib.nic.in/archieve/ppinti/ppioct2001/agriculture.html.

- Unprecedented flooding occurred in the river Sutlej on August 1, 2000, causing widespread damage in Himachal Pradesh. Bihar, Orissa, Assam, Uttar Pradesh and West Bengal experienced flood situations in 2001. Orissa was provided Rs 5,350,000,000 and 3 LT of rice worth Rs 2,100,000,000 under the Food for Work Scheme and other aid. One LT of foodgrain was provided to Bihar.

- Also in 2001 a very severe drought struck Rajasthan, Gujarat, Andhra Pradesh and Madhya Pradesh. The government provided Rs 10,370,400,000 assistance. Railways transported fodder and water freight free to drought areas. The government ordered 20 Kg of foodgrain per month to each family, including those below poverty line rates. Assistance came from various State governments, NGOs, and international agencies.

The nature and severity of direct climate impacts, and the type and extent of government intervention affect vulnerability in any state. So, too, does the state's approach to economic and human development generally. Within India, we may discern several different approaches. A brief discussion of two states, Kerala and Maharashtra, will illustrate a fundamental difference. Kerala has focused on human development; in contrast, Maharashtra has emphasized industrial/economic development. The results are evident in the statistics presented in Table 2. Kerala has a much higher literacy rate, lower fertility and infant mortality rates, and longer life expectancies than Maharashtra. Maharashtra has a much higher growth rate, higher per capita income, and almost seven times the installed generating capacity and almost four times the state domestic product (for fewer than three times the population).

Kerala has made specific choices to achieve its high levels of human development, although these are partly attributed to the enlightened nineteenth century maharajas and the work of Christian missionaries. The work of human development has been continued by the activism of the ordinary people. Several Left Front and Communist party elected governments have carried out the demands of popular progressive movements. Franke and Chasin[84] define the "Kerala Model of Development" as having three principal characteristics:

- A set of high material quality-of-life indicators coinciding with low per-capita incomes, both distributed across nearly the entire population of Kerala
- A set of wealth and resource redistribution programs that have largely brought about the high material quality-of-life indicators
- High levels of political participation and activism among ordinary people along with substantial numbers of dedicated leaders at all levels. Kerala's mass activism and committed cadre were able to function within a largely democratic structure, which their activism has served to reinforce.

[84] Cited in Sofia Checa, *Inequality in Three Indian States* (unpublished paper, 2001).

Table 2 Comparison of Kerala and Maharashtra in human and economic development

	Kerala	Maharashtra
Basic Statistics		
Area (sq km)	38, 863	307,713
Population	29,098,518	78,937,187
Population density	747 per sq km	256 per sq km
Urban population	26%	39%
Human Development		
Literacy (percent)	91%	63%
Fertility rate	1.8	2.7
Infant mortality rate (1997, per 1000 births)	12	47
Life expectancy (1996-2001)	70.93 years (68.23 for males, 73.10 for females)	65.88 years (65.45 for males, 66.31 for females)
Economic Development		
Growth rate	14%	25%
Per capita income (1990-91)	4,618 Rs.	8,180 Rs.
Installed generating capacity (1994-1995)	1,492 MW	9,987 MW
State Domestic Product (1998-1999)	56,563 Rs.	204,120 Rs.

Sources: All basic statistics, literacy, growth rate, per capita income, and installed generating capacity from www.webindia.com; infant mortality rate and state domestic product from Government of India Economic Survey, 1997-98, New Delhi.

However, the Kerala model has been criticized for its failure to strengthen the economic base, particularly industry. In addition, strong labor unions and high wages have kept industries and investment away from Kerala. The state depends, perhaps too much, on remittances from local people who are working abroad (mainly in the Gulf region).

Maharashtra describes itself as "the industrial powerhouse of India," with Mumbai (Bombay), its capital, as the commercial center of the country. Major international banks operate in Mumbai, and the two largest domestic banks are headquartered there. Its port, built by the British, remains a trade center.

These two states exemplify the contrasts in development styles in India, but great diversity exists. Andhra Pradesh is following a mixed strategy, still overwhelmingly agricultural but with great efforts being made in developing a high-technology sector (see box). Literacy rates in the states range from 44% to 91%, life expectancy from 58 to 70 years. Income per capita ranges from 3000 to 11000 Rs (current prices). There are great disparities, as noted in the previous section, in natural resources and climate hazards among Indian states.

Andhra Pradesh is the fifth largest state in India, both in area (275,048 sq km) and population (66,508,008 in 1991). The literacy rate is 44% — 55% for males and 33% for females. Cultivators and agricultural laborers constitute 81% of the workers in rural areas. 23% of India's software professionals are from Andhra Pradesh. (http://www.andhrapradesh.com)

Andhra Pradesh's Annual Plan developed for the National Planning Commission for the year 2002-2003 was finalized in July 2002. The Deputy Chairman of the Planning Commission complimented the State for initializing economic reforms, achieving reductions in population growth in spite of low per capita income and literacy, using technology extensively in government, and initiating power sector reforms. Rural poverty is lower than urban poverty, said the Deputy Chairman, reflecting positive reforms. However, inequality, poor revenue generation by the road transport corporation, and the need to encourage self-help groups were also cited.

This year, under drought conditions in Andhra Pradesh, the state released dam water for electricity generation but not for irrigation. Poor farmers respond to such policies by smashing the pumps of their richer neighbors. Quarrels over water rights between states can be bitter, too. Tamil Nadu claims that its neighbor state, Karnataka is violating agreements about sharing water from the Cauvery River. ("Water in India: nor any drop to drink," *The Economist* August 24, 2002, 31-32)

Vulnerability-Resilience Assessment of India and Indian States

The prototype framework discussed above, while suitable for a comparative country-level assessment, needs to be modified for a state-level analysis of India. In large part this is attributable to data availability and scaling considerations. Table 3 summarizes the indicators used in this preliminary data-gathering and modeling exercise.

Table 3 State-specific sectors and indicators for India

	Sector	Proxies	Sources
Coping-Adaptive Capacity (+)	Economic Capacity	GDP per capita	http://economywatch.com/database/income7.htm & http://www.indiainfoline.com/econ/andb/nia/nia3.html
		Income distribution equity	http://www.wws.princeton.edu/~rpds/Downloads/poverty-inequality-india-july8-2002.pdf .[85]
	Human and Civic Resources	Dependence ratio (calculated from % population in the workforce)	www.indiastat.com Table: Statewise workforce participation rate by rural/urban (93-94) http://www.indiainfoline.com/
		Illiteracy (calculated form literacy data)	http://www.cs.colostate.edu/~malaiya/india.html#States

[85] Angus Deaton and Jean Dreze, *Poverty and Inequality in India: A Reexamination* (Research Program in Development Studies, Woodrow Wilson School, Princeton University and Delhi School of Economics, 2002). Table 5 - 55th Round adjusted values. (Corresponding to the National Sample Survey: 1999-2000)

	Environmental Capacity	% Non-managed land	http://agricoop.nic.in/statistics/st3.htm
		SO_2 emissions (calculated)	GEIA http://weather.engin.umich.edu/geia/ & CDIAC http://cdiac.esd.ornl.gov/home.html
		Population density	http://www.economywatch.com/database/population4.htm & http://www.cs.colostate.edu/~malaiya/india.html & http://www.cyberjournalist.org.in/census/cenden0.html
Sensitivity (-)	Settlement/ Infrastructure	Sea level rise resulting in number of people at risk	Climate Change in Asia http://www.ccasia.teri.res.in/country/india/impacts/tables.htm & http://www.envfor.nic.in/cc/adaptation/coastal.htm
		% Population with access to safe water	http://www.rainwaterharvesting.org/resources/statistics/stat531.htm
		% Population with access to sanitation	www.indiastat.com Table: State wise Per Capita (Public Sector) Expenditure on Health (Medical and Public Health) including Water Supply and Sanitation and Family Welfare (During 1985-86 to 1989-90).
	Food Security	Cereal production/ agricultural land	http://agricoop.nic.in/statistics/stpart3d.htm for food crops & http://www.andhrapradesh.com/apwebsite/tables/statistics state/table-4.htm for production and areas
		Total protein demand per capita (animal+vegetable+pulses)	http://www.unu.edu/unupress/food/8F173e/8F173E08.htm
	Human Health	Fertility rate	http://www.censusindia.net/srs1.html
		Life expectancy	http://www3.who.int/whosis/hale/hale.cfm?path=whosis,hale&language=english
	Ecosystems	% Managed land	http://www3.who.int/whosis/hale/hale.cfm?path=whosis,hale&language=english
		Fertilizer use/area cropland	http://agricoop.nic.in/statistics/consum4a.htm
	Water Resources	Water sensitivity, based on availability and consumption	www.indiastat.com Table: Statewise groundwater resources and irrigation potential

Results

Applying our Vulnerability-Resilience Indicator Prototype (VRIP) model to each of the states, we collected the necessary 17 proxy values for each state, calculated (in a FORTRAN coded program) the climate-sensitivity sectoral indicators (negatives) and the coping-adaptive capacity sectoral indicators (positives) as geometric means of the proxies, which are scaled against world data. Then the state's sensitivity and adaptive capacity indicators were calculated as geometric means of the participating sectors. Finally, the final vulnerability-resilience indicator value was calculated as the simple arithmetic sum of a state's sensitivity and adaptive capacity. The result is that the state's indicator values can be compared with India as a whole, and with the global indicators.

Figure 7 shows the calculated values of the overall vulnerability-resilience indices of the different states within India, for a year between 1990 and 1998. We find only 3 states

more vulnerable than India as a whole, 23 states less vulnerable, and 9 states showing resilience. All states showing high vulnerability are coastal states. The small mountainous northern inland states show resilience.

Figure 7 shows two vulnerability values for India. Our original India estimate (India (a)) was based on 1990 proxy values and on an animal protein diet. Some proxies were re-evaluated for our present analysis, besides diet, e.g., population exposed to sea level storm surges, and the equity measure. This made India's (b) vulnerability indicator slightly higher (in the form of a larger negative value).

Figures 8 and 9 show the sectoral contributions to the coping-adaptive capacity and the sensitivity measures of the different states. The states are ordered similarly to those in Figure 7 from high resilience to high vulnerability. The small northern mountainous states show large environmental capacity; this is attributable mainly to low sulfur emissions and a relatively large percentage unmanaged land. This raises the question if, for mountainous relatively clean air states, the risks of increased erosion, mudslides and other natural hazards that can be anticipated with climate change are sufficiently represented in the indicator. With regard to economic capacity, all states rank lower than the global representation, with Kerala showing the highest economic capacity. That this indicator is higher for Kerala than, for example, for Punjab is due to the role equity pays in this indicator.

With regard to the sensitivity rankings of the different states, all coastal states show high vulnerability, especially Goa, for which it is reported that over 7% of the population would be affected by 1 m sea level rise, which translates in our case for a present relatively high sensitivity to sea-storm surges. Orissa and Tamil Nadu also show high sensitivity to sea-storm surges. National data were used for all the states for water availability: it thus does not participate in the states sensitivity differentiation. Sensitivity of food security shows differences among the states, with Kerala and Sikkim being rather sensitive, but not Punjab. Ecosystem sensitivity is found to be the largest in the Punjab, mainly due to fertilizer use and its polluting consequences.

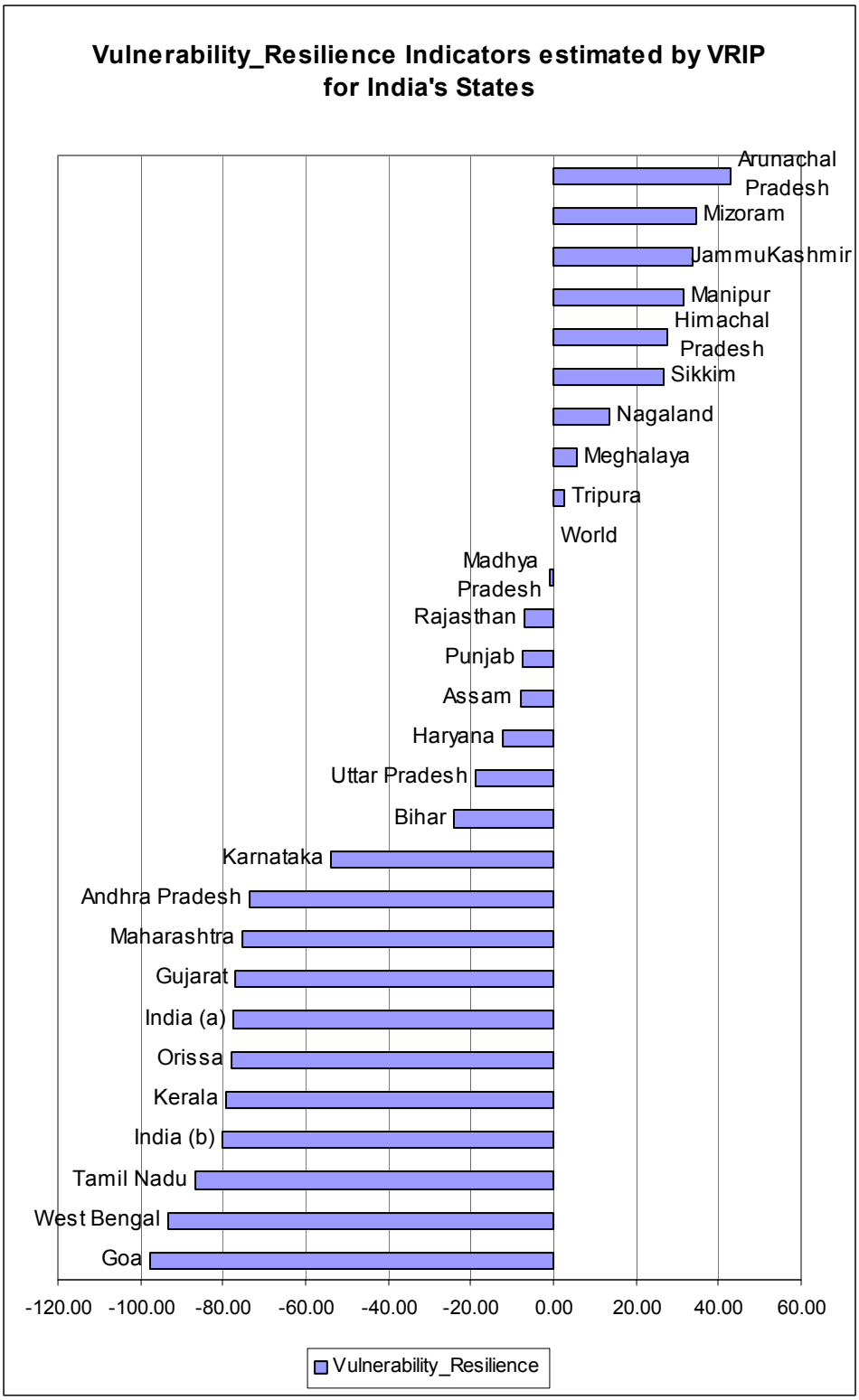

Figure 7 An overview of the range of the vulnerability-resilience indicators for the different states in India, calculated with the VRIP methodology.

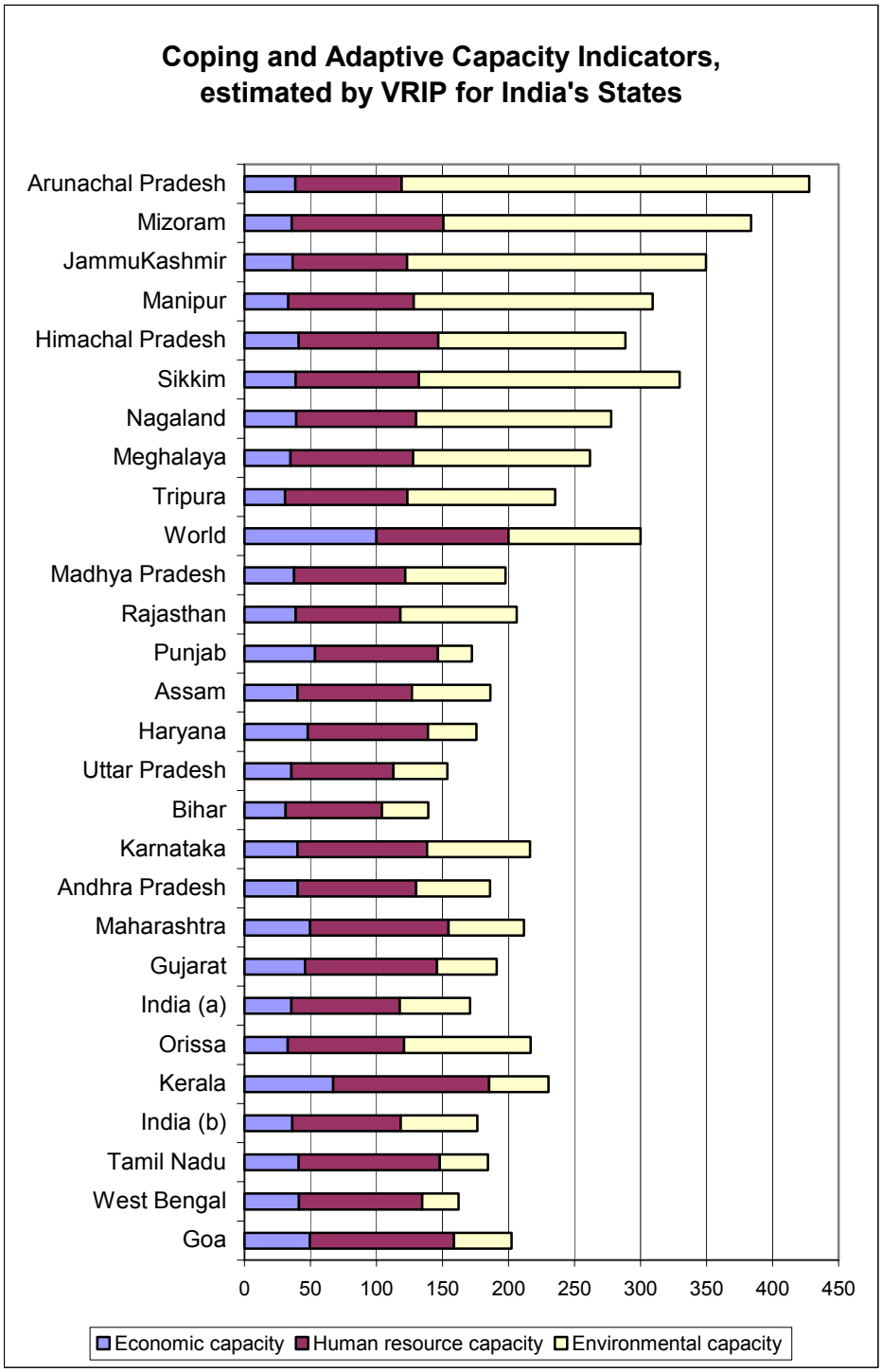

Figure 8 Adaptive and coping capacity of the different states in India and the participating sector values, calculated with the VRIP methodology.

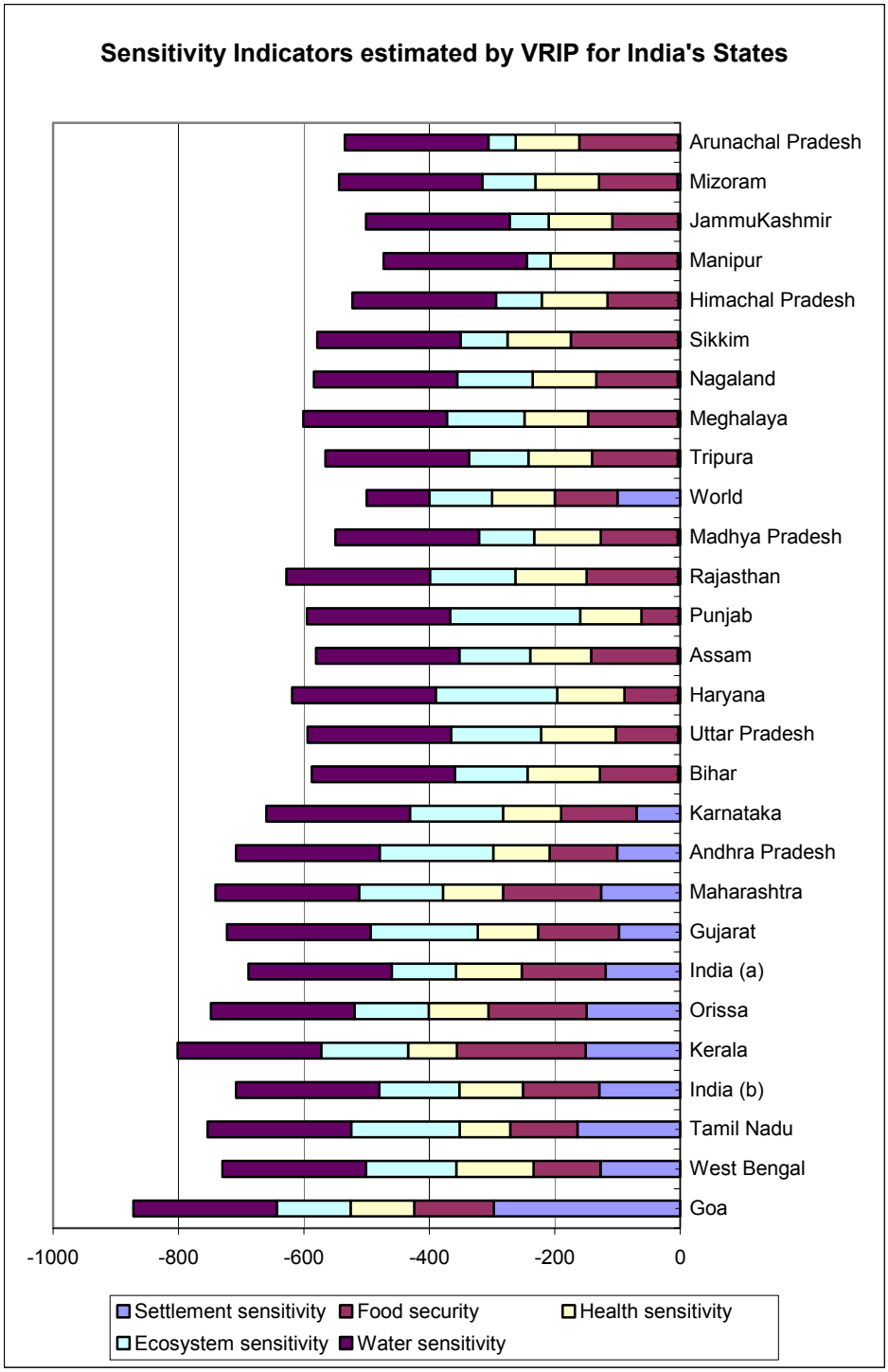

Figure 9 Sensitivities of the different states in India and the participating sector values, calculated with the VRIP methodology.

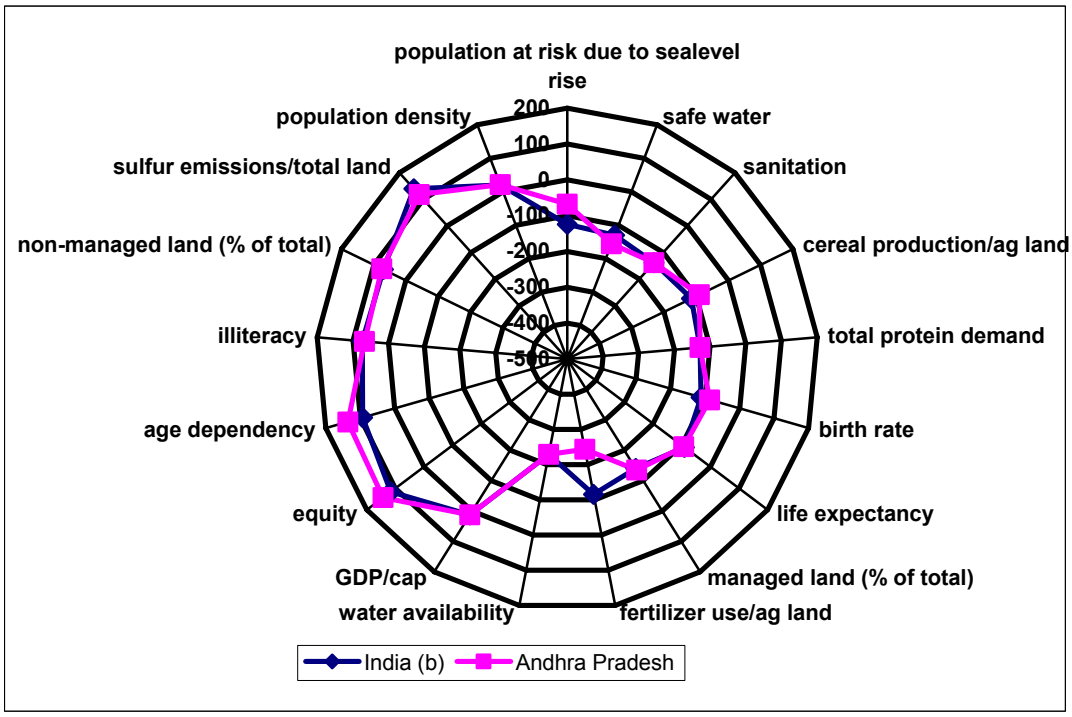

Figure 10 A detailed comparison between the contributions of the 17 indicator proxies to India's and Andhra Pradesh's vulnerability (note that protein demand and the equity measure are revised from Figure 6's display and that the data used range between 1990 and 1998)

We displayed in Figure 6 the contributions of the various indicators to India's vulnerability projected for 2005 for three SRES scenarios. Given the non-linear nature of our model structure,[86] the proxy values, displayed thus, only show which of the proxy values weigh heavier in the final vulnerability-resilience indicator value than others. Figure 10 above shows the comparison of the contributions of the various indicators for India and Andhra Pradesh (~1990-1998). We substituted total protein demand per capita for animal protein demand; we used a poverty measure instead of the previous national Gini for equity; we used national water availability data and national data on access to clean sanitation, given that the latter two proxies needed more in-depth study and were not readily available at the state level for immediate use.

In this analysis, Andhra Pradesh is very representative of India as a whole; this is apparent Figures 7, 8 and 9. Andhra Pradesh is slightly less vulnerable than India as a whole due to less pollution from fertilizer use and to slightly less risk of the population to sea level rise impacts than India as a nation, which includes a number of more vulnerable states with regard to sea level rise than Andhra Pradesh. Andhra Pradesh is very

[86] Moss, Brenkert and Malone, *Vulnerability,* explore this in depth by means of a Monte Carlo based uncertainty analysis.

representative of the national income level, literacy rate, food security, life expectancy and land use.

Discussion

The results show that a vulnerability analysis using this framework provides a means to ask structured questions about the elements of vulnerability in particular places. The modeling framework allows analysts and stakeholders to systematically evaluate individual and sets of indicators and to compare geographical or political units (for example, river basins or states). The transparency of the framework provides ready explanations for differences in the result. Thus, the framework indicates, to a first approximation, where the likely vulnerabilities are in the area being assessed; these areas are then candidates for a more in-depth, qualitative examination.

Caveats of the methodology and results

Calculating indicators is, like any modeling exercise, fully dependent on assumptions made. Modeling is useful in part because assumptions must be stated clearly in order to manipulate quantitative entities in a defined framework. Model outputs, in our case indicator values, are only relevant within the context of the assumptions made. These assumptions always need re-evaluation when analyzing the consequences of the assumptions. Below are some aspects of our indicator work that need immediate attention to make the work relevant. The transparency of the framework makes re-evaluation possible.

Not all collected data for input into the VRIP calculations were for one specific base year, e.g., 1990, as was achieved for our previous model runs in the calculation of national vulnerabilities.[87] Data from one year are, however, not necessarily representative of a general status of a situation and it is therefore advisable for indicator calculations to incorporate a representative mean of the variable information to be processed. Depending on the questions asked, a five-year average of a value might better represent an indicator or proxy. We proceeded with the calculations, however, not only to illustrate the methodology and show obtainable results, but also to help formulate the next level of questions with regard to vulnerability analyses.

A major issue is achieving a balance between simplified quantitative representations, on the one hand, and richly detailed qualitative information, on the other hand. Adding indicators may, in theory, better represent the complexity of the world. However, mathematically, many indicators would cancel each other out. Furthermore, it would become progressively more difficult to evaluate what the contributions of each indicator were to the summary numbers of sensitivity, coping-adaptive capacity, and vulnerability.

The same kind of balance needs to be achieved in the number and complexity of the layers in the hierarchical structure. Again, there are surely more than four layers in the

[87] Moss, Brenkert and Malone, *Vulnerability*.

world, but in a model, many more than four would tend to decrease transparency and make results difficult to evaluate.

Yet another issue is that indicators tend to have effects in more than one sector. A good example is water resources. Water contributes to food security (rainfall and irrigation), access to clean water and sanitation, and environmental capacity, to name only the obvious sectors. How do we decide where an indicator "belongs" and whether it has too much influence within the set of indicators because it is present implicitly in many of them?

The reverse, of course, is also true. More than one sector can have multiple impacts on an indicator. For example, food might become scarcer because of population increase, more available through agricultural technological improvement, through trade, through aid. Thus, linkages among the sectors within the categories need analyses, e.g., education level as a sector of human resources is directly linked to management and technological development potential of agriculture and water; population distribution and employment diversity are linked; nutrition and food availability are linked, etc.

Not having a systematic approach to base-year proxy-value evaluation hinders being able to obtain a consistent set of vulnerability-resilience projections into the future. Additional issues with regard to projections are discussed in the section below.

Projections

In our previous experience with the VRIP model we calculated future vulnerability-resilience indicator values by means of SRES-related regional model outputs of PNNL's integrated energy and economics model, MiniCAM and its post-processor Sustain. That was a responsible approach with regard to scale issues. Attempting to make projections into the future for Indian states requires a more detailed level of analysis.

We need not only a re-evaluation of baseline data used, with regard to initial values for the calculations, but also an examination of state-by state historical development pathways, and state plans for future development. Income growth has varied greatly by state, for example, as the two figures below show. Thus, the capacity of a state to invest in infrastructure will vary also. Investment potential with regard to adaptation to climate change will be state specific.

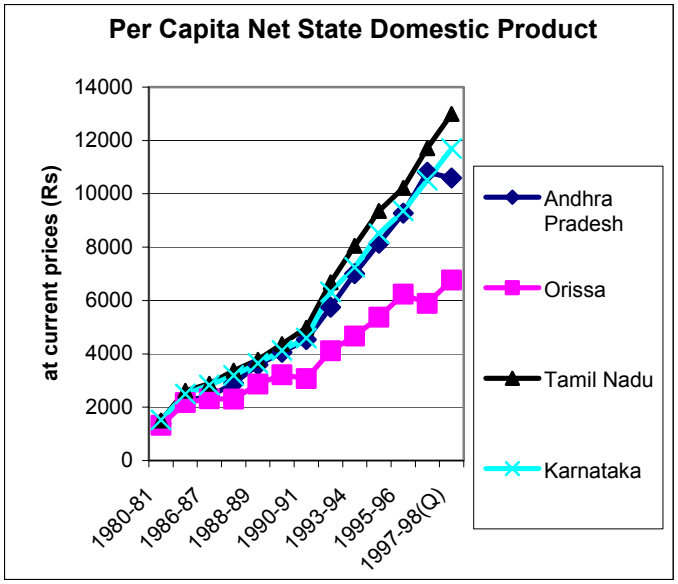

Figure 11 East coast states' per capita income from 1990 through 1998 (generated from http://www.economywatch.com/database/income7.htm)

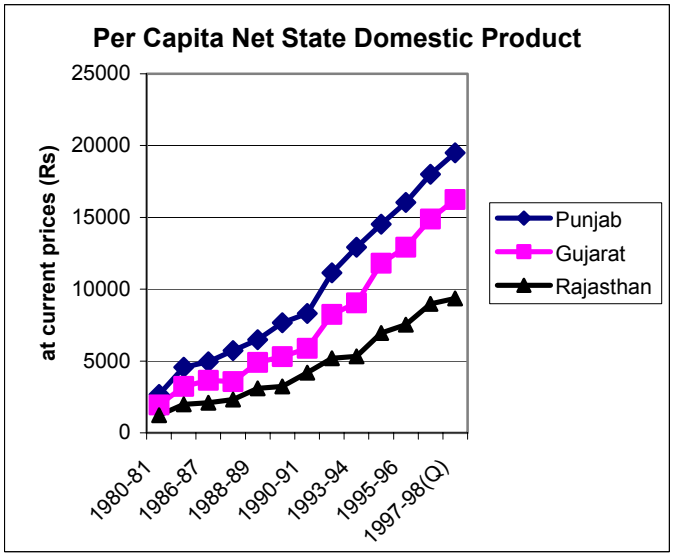

Figure 12 Western states' per capita income from 1990 through 1998 (generated from http://www.economywatch.com/database/income7.htm)

Additional information with regard to specific state projections of, for example, expected population growth needs to be incorporated in vulnerability-resilience projections (see for example Figure 13's projections of India's population over the next 15 years), as do expected changes in the different economic sectors and trade. Figure 19 in the Appendix depicts the 1990 economic sectors contributions to the national GDP for 1990. As has been pointed out elsewhere and what also is briefly mentioned in the state descriptions listed in Table 27 in the Appendix, the different states have various levels of industrial versus agricultural levels, and urban versus rural population ratios. Shifts in all of these

are expected to occur and might need to be incorporated in the assumptions about projections.

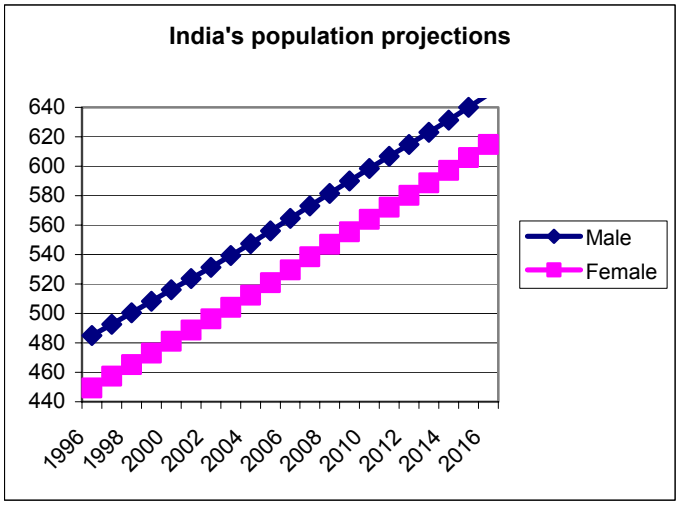

Figure 13 India's population projection through 2016 (generated from http://www.indiainfoline.com/econ/andb/pop/pop9.html)

Water use and water availability are also major factors that will impact future vulnerability, and socio-economic assumptions about the future will determine water availability as is shown in Figure 26 in the Appendix.

In addition, projections of actual climate change need to be incorporated to evaluate exposure and its repercussions to the system described in the VRIP.

We did not, therefore, attempt to extend our VRIP modeling exercise with scenario building and projections. In the next section we outline the necessary next steps for a re-evaluation of a state-by-state vulnerability-resilience assessment for India and for projections into the future.

Next Steps

In order to achieve a functional framework, we have used the existing structure of the Vulnerability-Resilience Indicator Prototype and somewhat modified requirements for indicators; thus we are at a preliminary scooping and surveying stage. The framework and results presented here represent a first-order modeling effort, which needs to be refined and developed. There are issues both about data availability and about some of the indicators used. Beyond these issues are matters of interactions among indicators and projections into the future.

1. For India in general, detailed data are available. However, the data for proxies that we have specified for the model are not always available, and sometimes not for the same year or scaled in a way that would be compatible with other indicators. The two most notable examples in the current exercise are water availability and

access to clean sanitation. Land use and its consequences constitute another important issue. The assumed linear relationship between sulfur emissions and environmental capacity needs re-evaluation; we might need to find a relationship as we did for fertilizer use: too much and too little result in negative impact. For sulfur emissions, too little industrial development is not necessarily good, given the lack of job diversification, but too much dirty industry is detrimental to the environment. Thus, in the future development of the framework, we need to evaluate additional and/or alternative methods for interpolating, scaling, and substituting available data to achieve a meaningful assessment of vulnerability.

2. The applicability of the chosen indicators to specific situations must also be evaluated. The most notable example for India is animal protein intake. This was originally chosen as a measure of development, i.e., the more meat incorporated into the diet, the more "Western" or "developed" an area becomes. However, major religious traditions in India limit the amount of animal protein in Indian diets. Therefore, this is not a good measure of development. Instead, we used total protein consumption for this indicator. In future iterations, and especially in consultation with stakeholders, this should be re-evaluated with the goal of representing improvements in diet.

3. As stated above, indicators and sectors exhibit overlap and multiple impacts. Given the mutual dependencies of the proxies as aspects of sector representation, not all important aspects of vulnerability are easily categorized purely in one sector or another. The model, however, assumes clear separations among sectors. In future framework development efforts, we plan to perform qualitative analyses that narratively describe some of the dependencies and linkages among sectors and indicators. This process will aid in modifying (weighting) the application (the full percentage change) of the major drivers (factors) to the indicators.

4. Projections of future vulnerability need to account for historical and current trends as well as alternative scenarios of the future. In the prototype model, we used the IPCC scenarios designed for projections of emissions, not vulnerability. This choice needs to be re-evaluated and alternatives need to be explored. Will we deal with detailed interpretations of the emissions scenarios' storylines (more or less economic growth, more or less attention to sustainability, expressed locally, nationally, regionally, globally) in evaluating linkages of indicators, sectors, and negatives/positives? This approach is a top-down strategy. Most vulnerability and adaptation studies utilize a bottom-up approach as more suited to the essential situational aspects of particular places. Bottom-up scenarios may be more appropriate for vulnerability assessment.

In order to deal with tradeoffs, we would need to develop a dynamic program. We presently can interpret tradeoffs from scenario descriptions that do not explicitly model investment choices in settlement protection, infrastructure, education, etc. but that have storylines of how different regions might develop and have the regions interact in a global context.

Conclusions

We have presented, in this report, an analytical framework for the analysis of vulnerability and resilience, sensitivity and coping and adaptive capacity of India as compared to global indicator values, and of Indian states compared to India as a whole. The vast array of data sources about the Indian states lends itself to a more in-depth study. Next steps, which can be pursued immediately, have been outlined.

Relevant Web References

Vulnerability-Resilience Indicator Prototype:
http://www.pnl.gov/globalchange./projects/vul/index.htm
Climate change in India: http://www.teriin.org/climate/ghg.htm
Drinking water: http://www.nird.org/clic/data-bank.htm
More on water: http://www.american.edu/projects/mandala/TED/ice/CAUVERY.HTM
Sanitation data: http://www.childinfo.org/eddb/sani/asia/india-sanitation1.pdf
(Site has similar info for drinking water access).
Andhra Pradesh detailed information: http://www.andhrapradesh.com/
Water access data: www.rainwaterharvesting.org/resources/statistics/stat531.htm
Comprehensive list of important websites on India: http://sunsite.tus.ac.jp/asia/india
State profiles: http://www.indiainfoline.com/econ/andb/states/states0.html
Maps information: http://www.meadev.nic.in/map/indmap.htm
Specific information maps: http://www.mapsofindia.com
Data on poverty and inequality statewise:
http://www.wws.princeton.edu/~rpds/Downloads/ poverty-inequality-india-july8-2002.pdf
Pollution data: http://envfor.nic.in/soer/2001/ind-air.pdf
State of the Environment report (above - contains SO2 emissions for 12 capital cities of Indian states)
http://www.ccasia.teri.res.in/country/india/impacts/tables.htm : excellent general vulnerability study on India page and sea level rise data.
http://www.envfor.nic.in/cc/adaptation/coastal.htm - excellent site for general vulnerability stuff for India
http://www.envfor.nic.in/cc/adapt.htm (see also)
Food grain production (in tones):
http://www.indiainfoline.com/econ/andb/states/states1.html
(Also very good general state-wise profiles available).
http://www.cs.colostate.edu/~malaiya/india.html#States : Literacy rates and population by religion statewise.
http://www.censusindia.net/results/provindia1.html - sex ratio by state available, but not by rural-urban, male and female as we require.
http://www.cs.colostate.edu/~malaiya/india.html: vast amount of India-specific data

Appendix

Emissions

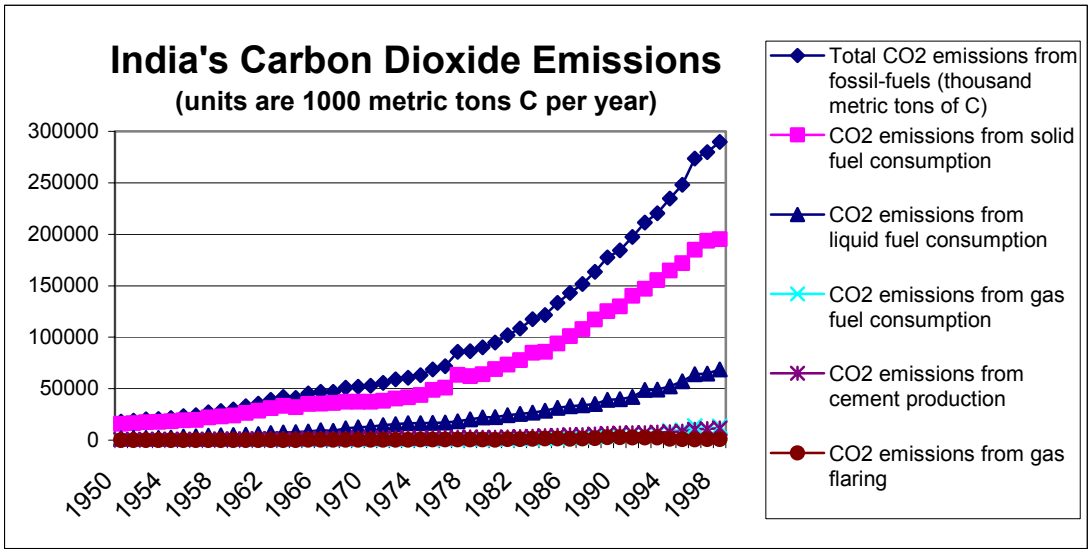

Figure 14 India's carbon dioxide emissions from 1950 through 1998 (generated from CDIAC's http://cdiac.ornl.gov/ftp/ndp030/CSV-FILES/)

Table 4 India's and the USA's per capita carbon emissions from 1990 through 1998

[88]	India	United States
1990	0.22	5.17
1991	0.23	5.15
1992	0.24	5.12
1993	0.24	5.3
1994	0.26	5.37
1995	0.27	5.31
1996	0.29	5.4
1997	0.29	5.46
1998	0.29	5.43

[88] CDIAC, http://cdiac.ornl.gov/ftp/ndp030/CSV-FILES/

Climate maps

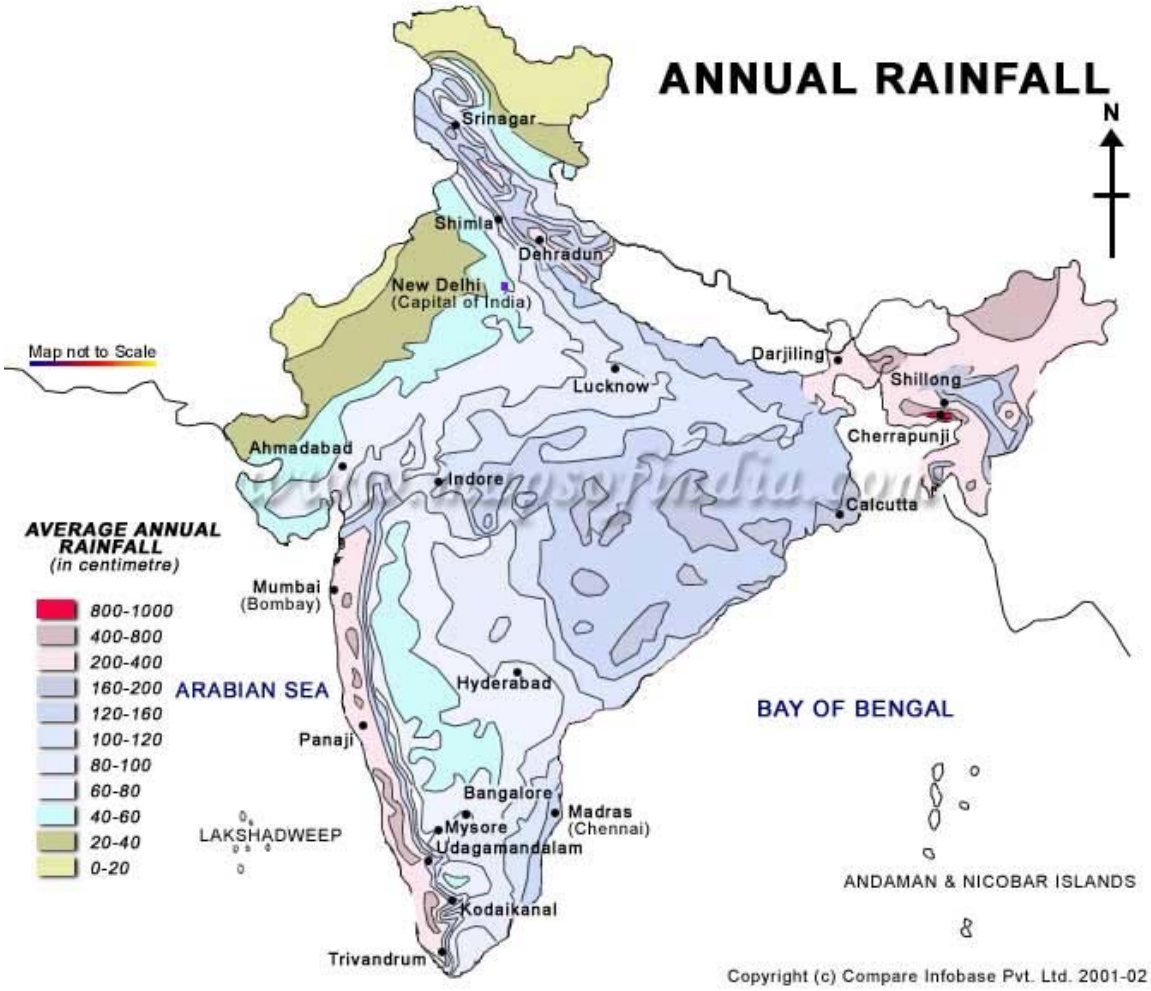

Figure 15 Rainfall map (http://www.mapsofindia.com/maps/india)

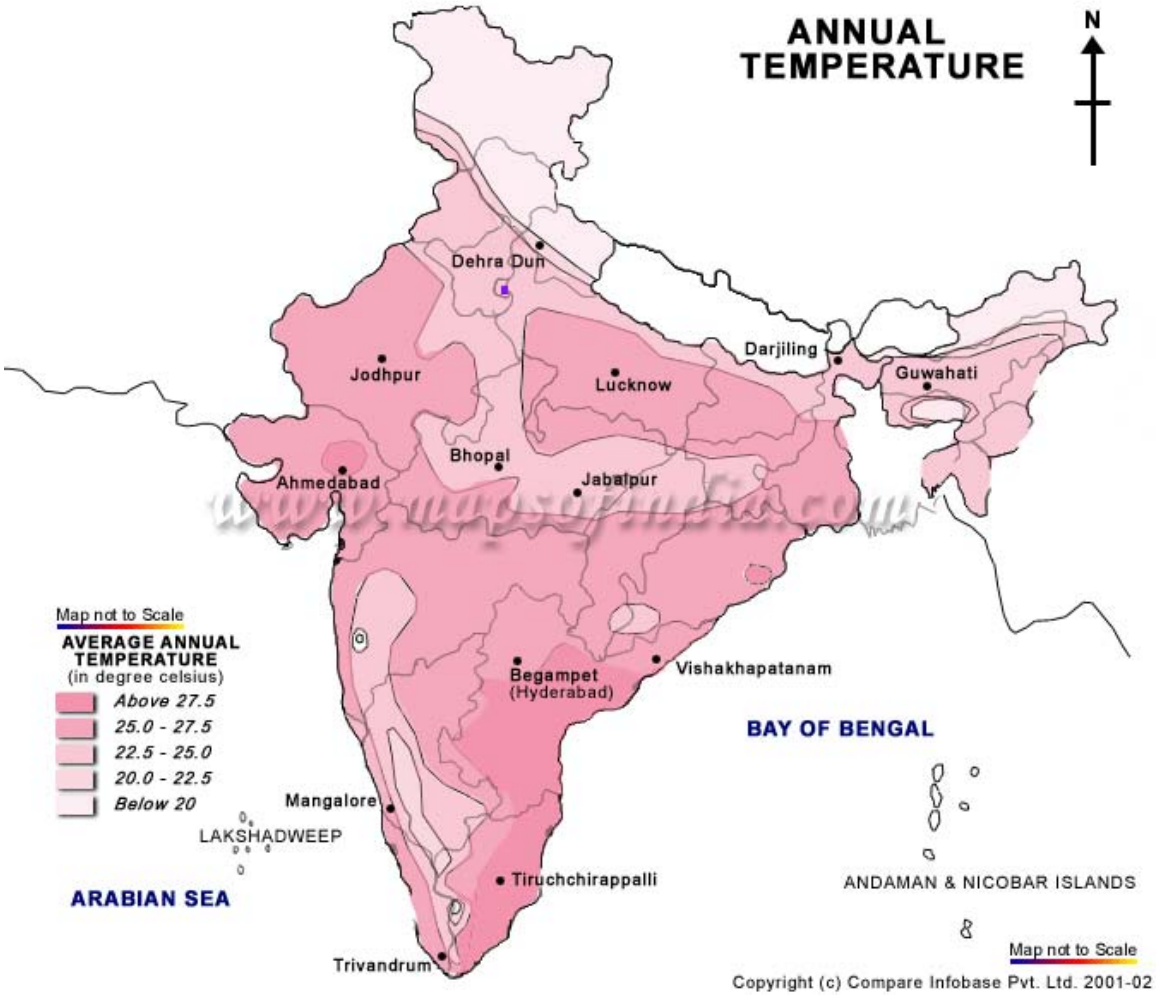

Figure 16 Temperature map (http://www.mapsofindia.com/maps/india)

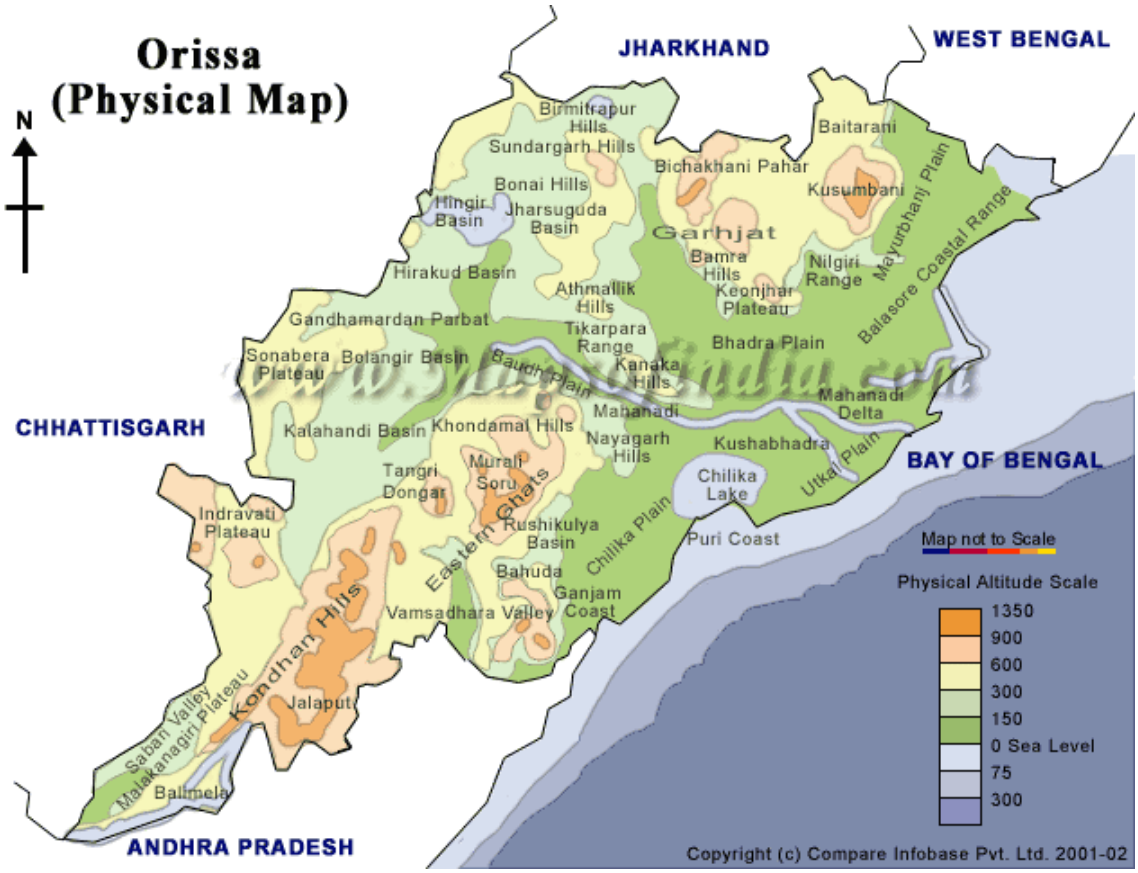

Figure 17 A map of Orissa (http://www.mapsofindia.com/maps/india)

Economic Capacity

Income

Table 5 Net Domestic Product of States at current prices from 1980-81 through 1997-98 (Rs bn)

[89]	1980-81	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97p	1997-98p	% growth 91-98
Andhra Pradesh	73.2	134.1	142.4	173.8	220.9	254.2	311.7	373.4	391.3	484.2	552.3	620.4	754.1	787.1	18.8
Arunachal Pradesh	1	2.5	2.7	2.8	3.3	3.7	4.6	5.7	6.8	8.2	9.4	10.6	11.9	13.7	23.1
Assam	23.6	51.8	54.8	59.9	65.6	80.6	95	106.3	115.4	131	144.9	153.2	174.8	188.7	12.7
Bihar	63.5	123.7	141.8	153.6	185.3	194.1	228.3	254	273.2	306.9	356.5	390.8	411.9	462.2	14.4
Goa	3.2	5.1	6.1	6.7	7.8	9.2	10.2	12.7	15.4	18.9	19.6	20.7	30.1	31.3	19.2
Gujarat	65.5	121	140.2	139.4	195	214.3	242.7	261.2	347.1	392.3	478.7	494.5	668.8	753.4	19.5
Haryana	30.3	57.9	60.8	67.4	88.8	99.2	122.4	146.4	154.2	183.5	217.9	250.1	303.6	332.8	19.6
Himachal Pradesh	7.2	12.4	13.6	15.4	19.3	21.8	25.2	29.8	34.1	37.4	43.4	49.3	-	-	18.3
JammuKashmir	10.5	19.3	21.3	20.9	25.5	26.9	27.6	29.4	32.2	34.7	49	53.3	58.1	-	-
Karnataka	56.1	102.2	118.5	135.5	158.1	178	205.5	267.4	291.3	337.9	391.6	434.2	513.6	579.5	20.6
Kerala	38.2	65	73.5	82.6	91.8	106.7	121.7	151	171.8	196.9	232.4	258	323.8	380	20.7
Madhya Pradesh	70.2	120.9	125.1	161.1	138.6	211.2	265.2	278.5	310.7	384.2	420.2	472.4	558.7	610.2	15.5
Maharashtra	151.6	264.7	284.3	337.7	400	501.4	581.8	652.3	798.5	968.4	1100.5	1315.8	1553.9	1645.8	22.6
Manipur	2	3.7	4.3	5.4	6.1	6.3	7.2	8.7	9.6	10.5	13.1	14.9	15.7	17.6	19.7
Meghalaya	1.8	3.4	3.9	4.7	5.1	6.6	7.7	8.8	9.8	11.3	12.6	13.8	17.6	-	15.8
Mizoram	0.6	1.6	1.9	2.6	2.6	2.8	3.1	4.2	4.8	5.6	6	-	11.3	-	-
Nagaland	1.1	2.4	2.7	3.4	3.9	4.7	6.6	7.6	8.4	8.8	-	-	17.2	-	-
Orissa	34.4	62.3	67.5	68.5	86.8	99.2	96.6	125.1	134.2	154.8	180	209.2	206.4	241.1	21.3
Punjab	44.5	83.5	91.7	108.2	125	150.6	167.4	202.5	232.8	275.5	313.5	342.9	405.9	447.9	19.6
Rajasthan	41.3	76.7	83.4	94.4	128.9	138.4	182.8	200.4	239.4	246	306.4	337.1	443.1	470.6	16.5
Sikkim	0.5	1.1	1.4	1.6	1.7	1.9	2.1	2.4	2.4	3.4	4	4.5	-	-	-
Tamil Nadu	72.2	136.8	153.1	181.7	204.2	239.4	276.5	325.6	378.6	461	531.3	576.6	690.4	773	20.2
Tripura	2.6	4.7	5.2	6	7.7	8.4	9.2	10.3	10.8	12.4	13.1	15.6	17	18.6	-
Uttar Pradesh	140.1	246.7	272.3	304.8	359.7	416.6	495	572.1	620.5	697.4	796	901.9	1028.6	1131.1	16.2
West Bengal	87.2	174.2	175	201.5	238.2	277.9	315	364.3	387.7	445.3	514.3	577.5	715.7	806.7	16.4

Table 6 State income at current prices from 1980-81 through 1997-98 (Rs bn)

[90]	1980-81	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91	1992-93	1993-94	1994-95	1995-96	1996-97(P)	1997-98(Q)	1998-99(A)
Andhra Pradesh	1380	2258	2394	2896	3584	4054	4531	5748	7006	8145	9274	10806	10590	-
Orissa	1314	2175	2315	2308	2871	3218	3077	4114	4662	5369	6236	5893	6767	-
Tamil Nadu	1498	2620	2885	3374	3782	4370	4983	6680	8051	9353	10222	11708	12989	-
Karnataka	1520	2495	2837	3186	3652	4124	4598	6321	7242	8504	9359	10504	11693	-
Arunachal Pradesh	1571	3403	3575	3680	4212	4467	5398	7514	8853	9417	11803	12032	13424	-
Tamil Nadu	1284	2612	2711	2904	3112	3589	4281	4973	5520	6017	6824	6928	7335	-

[89] http://www.economywatch.com/database/income7.htm
[90] http://www.economywatch.com/database/income8.htm

Bihar	917	1601	1798	1906	2253	2312	2649	2998	3417	3737	3533	4281	4654	-
Delhi	4030	6545	6726	7402	8433	9606	11057	15429	17522	19954	21830	22687	-	-
Goa	3145	4660	5484	5966	6865	7988	8797	12800	15332	16703	20141	23061	23482	-
Punjab	2674	4578	4940	5719	6487	7674	8318	11140	12934	14534	16053	18006	19500	-
Gujarat	1940	3221	3660	3571	4908	5304	5891	8235	9054	11810	12914	14875	16251	-
Rajasthan	1222	1978	2095	2310	3089	3241	4191	5197	5315	6951	7523	8974	9356	9819
Haryana	2370	4004	4106	4446	5714	6233	7508	9037	10526	12283	13573	16392	17626	-
Himachal Pradesh	1704	2649	2870	3185	3934	4375	4910	6390	6896	7846	8747	-	-	-
Jammu & Kashmir	1778	2874	3099	2954	3517	3618	3816	4457	5400	5860	6231	6658	-	-
Karnataka	1520	2495	2837	3186	3652	4124	4598	6321	7242	8504	9359	10504	11693	-
Kerala	1508	2398	2676	2937	3233	3718	4200	5768	6524	7578	9004	10809	11936	-
Madhya Pradesh	1358	2085	2106	2648	3027	3311	4049	4544	5516	6034	6775	7571	8114	-
Maharashtra	2435	3826	3995	4638	5364	6353	7439	10080	12010	13368	15770	17666	18365	-
Manipur	1419	2322	2590	3211	3502	3575	3976	5023	5929	6542	6914	7510	8194	-
Meghalaya	1381	2250	2479	2955	3118	3863	4375	5272	5934	6402	7862	8474	-	-
Mizoram	1289	2658	3165	4077	4026	4135	4474	6599	7517	7743	9570	13360	-	-
Nagaland	1361	2576	2781	3385	3706	4333	4990	6273	7730	8550	9758	11174	-	-
Orissa	1314	2175	2315	2308	2871	3218	3077	4114	4662	5369	6236	5893	6767	-
Pondicherry	2794	4475	NA	NA	NA	NA	6683	7584	8537	10489	11512	11677	-	-
Punjab	2674	4578	4940	5719	6487	7674	8318	11140	12934	14534	16053	18006	19500	-
Rajasthan	1222	1978	2095	2310	3089	3241	4191	5197	5315	6951	7523	8974	9356	9819
Sikkim	1571	3023	3472	3886	4241	4686	5302	5722	7679	8869	9472	-	-	-
Tamil Nadu	1498	2620	2885	3374	3782	4370	4983	6680	8051	9353	10222	11708	12989	-
Tripura	1307	2025	2174	2403	3011	3190	3370	3773	4252	4366	5083	5432	5804	6200
Uttar Pradesh	1278	1999	2157	2360	2724	3031	3590	4335	4794	5339	5872	6713	7263	-
West Bengal	1773	2893	2834	3192	3691	4138	4673	5541	6247	7436	8491	9579	10636	-

Table 7 Decennial growth of the Indian population from 1901 through 1991

000 numbers[91]	**1901**	**1911**	**1921**	**1931**	**1941**	**1951**	**1961**	**1971**	**1981**	**1991**
India total		238396	252093	251321	278977					
Andhra Pradesh	19066	21447	21420	24204	27289	31115	35983	43503	53551	66508
Arunachal Pradesh	-	-	-	-	-	-	337	468	632	865
Assam	3290	3849	4637	5560	6695	8029	10837	14625	18041	22414
Bihar	27312	28314	28127	31347	35171	38782	46447	56353	69915	86374
Goa	476	487	469	505	541	547	590	795	1008	1170
Gujarat	9095	9804	10175	11490	13702	16263	20633	26697	34086	41310
Haryana	4623	4175	4256	4560	5273	5674	7591	10036	12922	16464
Himachal Pradesh	1920	1897	1928	2029	2263	2386	2812	3460	4281	5171
JammuKashmir	2139	2293	2424	2670	2947	3254	3561	4617	5987	7719
Karnataka	13055	13525	13378	14633	16255	19402	23587	29299	37136	44977
Kerala	6396	7175	7802	9507	11032	13549	16904	21347	25454	29099
Madhya Pradesh	16861	19441	19172	21356	23991	26072	32372	41654	52179	66181
Maharashtra	19392	21475	20850	23959	26833	32003	39554	50412	62783	7897

[91] http://www.economywatch.com/database/population4.htm

Manipur	284	346	384	446	512	578	780	1073	143	1837
Meghalaya	341	394	422	480	556	606	769	1012	1336	1775
Mizoram	82	91	98	124	153	196	266	332	494	690
Nagaland	102	149	159	179	190	213	369	516	775	1210
Orissa	10303	11379	11159	12491	13768	14646	17549	21945	23670	31660
Punjab	7545	6732	7153	8012	9600	9161	11135	13551	16789	20282
Rajasthan	10294	10984	10293	11748	13864	15971	20156	25766	34262	44006
Sikkim	59	88	82	110	122	138	162	210	316	406
Tamil Nadu	19253	20903	21629	23472	26268	30119	33687	41199	48408	55859
Tripura	173	230	304	382	513	639	1142	1556	2053	2757
Uttar Pradesh	48628	48155	46672	49780	56535	63220	73755	88342	110863	139112
West Bengal	16940	17999	17474	18897	23230	26300	34926	44312	54581	68078

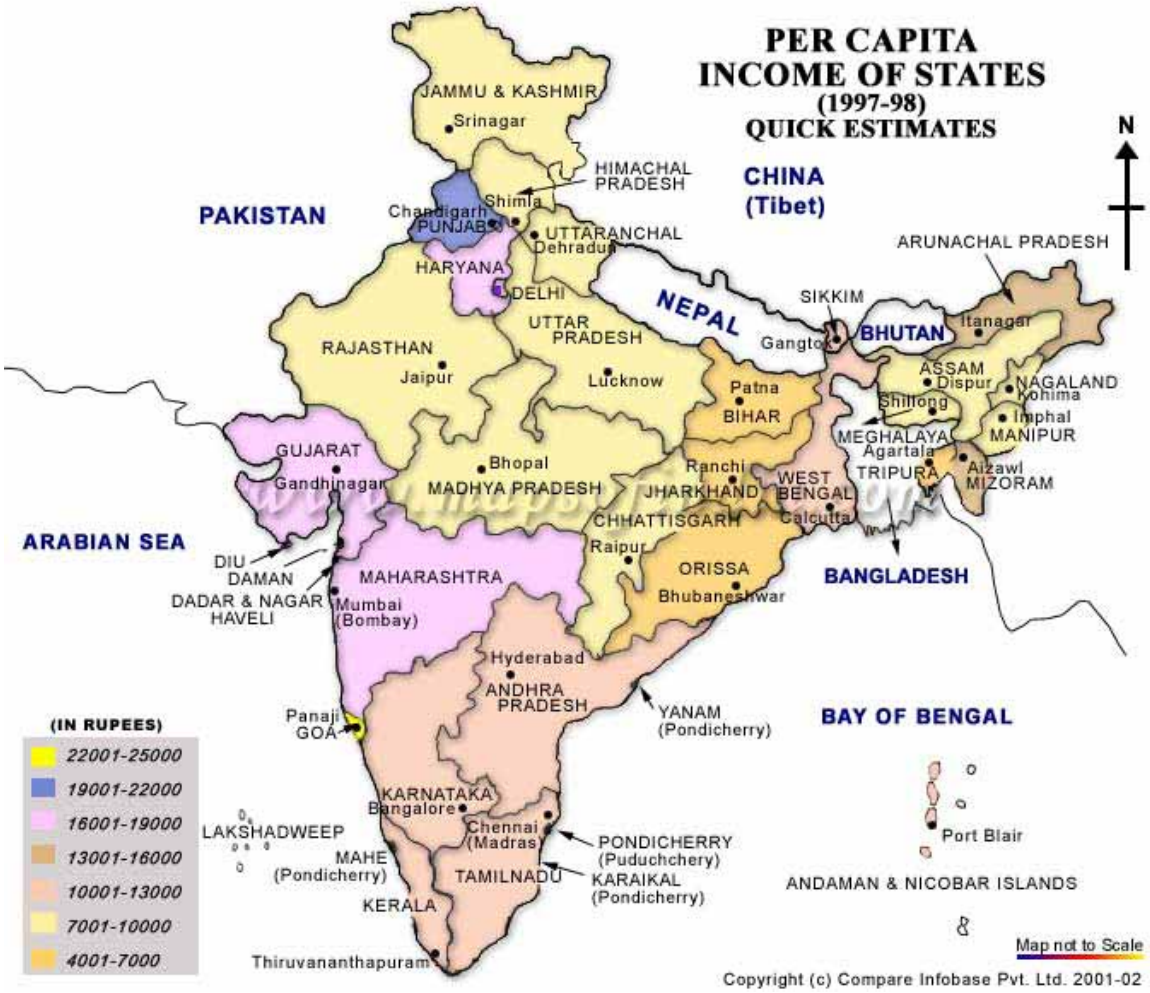

Figure 18 Map of income estimates by state (http://www.mapsofindia.com/maps/india)

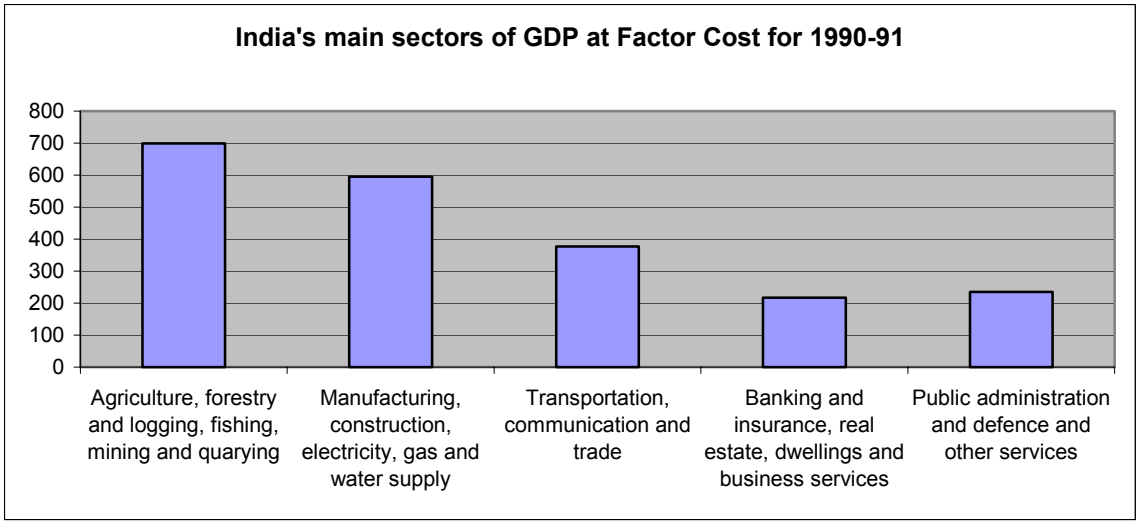

Figure 19 India's main sectors of GDP at Factor cost for 1990-1991 (generated from http://www.indiainfoline.com/econ/andb/nia/nia3.html)

Inequity

Table 8 Poverty and inequity information (Deaton and Dreze)

[92]	Poverty and Inequity in India; previously Gini (total inequality)	Urbanization ratio (%) Calculated[93]
India (b)	0.19	
Andhra Pradesh	0.095	26.89
Arunachal Pradesh	0	12.80
Assam	0	.
Bihar	0.092	13.14
Goa	0	41.00
Gujarat	0.120	34.49
Haryana	0.210	24.63
Himachal Pradesh	0.164	8.69
JammuKashmir	0	.
Karnataka	0.135	30.92
Kerala	0.176	26.31
Madhya Pradesh	0.134	23.18
Maharashtra	0.179	38.69
Manipur	0	27.52
Meghalaya	0	18.60
Mizoram	0	46.10
Nagaland	0	17.21
Orissa	0.125	13.38
Punjab	0.140	29.55
Rajasthan	0.109	22.88
Sikkim	0	9.10
Tamil Nadu	0.167	34.15

[92] http://www.wws.princeton.edu/~rpds/Downloads/poverty_inequality_india_july8_2002.pdf (table 5)
[93] from: http://www.cs.colostate.edu/~malaiya/india.html
http://www.indiainfoline.com/econ/andb/pop/pop12.html

Tripura	0.029	15.30
Uttar Pradesh	0.134	19.84
West Bengal	0.140	27.48

Human resources

Percentage people in the work force

Table 9 Urban and rural workforce participation rates

Statewise Workforce Participation Rate by Rural/Urban (1993-94)[94]				
States/UTs	Rural		Urban	
	Male	Female	Male	Female
Andhra Pradesh	63.1	52.1	54.4	19.9
Arunachal Pradesh	49.7	40.9	51.5	10.1
Assam	51.6	15.9	52.8	9.2
Bihar	51.1	17.2	43.9	6.9
Delhi	58.6	9.8	53.8	9.6
Goa	57.9	26.9	50.7	19.9
Gujarat	57.4	39.6	53.5	14.2
Haryana	46.3	27.1	51.9	15.2
Himachal Pradesh	59	52	48.8	20.1
Jammu & Kashmir	51.9	39.1	49.1	13
Karnataka	60.4	43	54.2	18.1
Kerala	53.7	23.8	55.9	20.3
Madhya Pradesh	57.2	41	47.1	14.2
Maharashtra	55.1	47.7	52.6	16.9
Manipur	47.7	30.8	43.4	22.3
Meghalaya	61.9	49.3	50	18.9
Mizoram	52.9	31.7	48.4	26.4
Nagaland	43.9	21.6	37.8	9.9
Orissa	56.6	31.7	51	15.1
Punjab	54.6	22	55.3	9.3
Rajasthan	54	45.7	49	16.3
Sikkim	56.3	19.1	58	13.6
Tamil Nadu	60.2	47.8	57.5	23
Tripura	52.2	12.8	49.7	12.4
Uttar Pradesh	52.2	21.9	48.2	10.2
West Bengal	55.7	18.5	55	14.3
India	55.3	32.8	52.1	15.5

[94] Table: "Statewise workforce participation Rate by Rural/Urban," http://www.Indiastat.com

Table 10 Calculated dependency ratios from Table 9 information

	Dependency ratio	Calculated work age population (16-55) % of total
India	61.08	38.92
Andhra Pradesh	52.63	47.375
Arunachal Pradesh	61.95	38.05
Assam	67.63	32.375
Bihar	70.23	29.775
Goa	61.15	38.85
Gujarat	58.83	41.175
Haryana	64.88	35.125
Himachal Pradesh	55.03	44.975
Jammu and Kashmir	61.73	38.275
Karnataka	56.08	43.925
Kerala	61.58	38.425
Madhya Pradesh	60.13	39.875
Maharashtra	56.93	43.075
Manipur	63.95	36.05
Meghalaya	54.98	45.025
Mizoram	60.15	39.85
Nagaland	71.70	28.3
Orissa	61.40	38.6
Punjab	64.70	35.3
Rajasthan	58.75	41.25
Sikkim	63.25	36.75
Tamil Nadu	52.88	47.125
Tripura	68.23	31.775
Uttar Pradesh	66.88	33.125
West Bengal	64.13	35.875

Literacy rates

Table 11 Adult illiteracy rates

[95]	LITERACY RATE (2001 Census) (in %)		LITERACY RATE		CHANGE IN LITERACY RATE (1991 -2001)
	Total	MALES	FEMALES	(1991 Census)	
India	65.38	75.96	54.28	51.63	13.75
Andaman & Nicobar Is.*	81.18	86.07	75.29	73.02	8.17
Andhra Pradesh	61.11	70.85	51.17	44.09	17.02
Arunachal Pradesh	54.74	64.07	44.24	41.59	13.15
Assam	64.28	71.93	56.03	52.89	11.52
Bihar	47.53	60.32	33.57	37.49	10.04
Chandigargh*	81.76	85.65	76.65	77.81	3.94
Chhatisgarh	65.18	77.86	52.4	42.91	22.27
Dadra & Nagar Haveli*	60.03	73.32	42.99	40.71	19.33

[95] http://www.censusindia.net/results/provindia3.html

Daman & Diu*	81.09	88.4	70.37	71.2	9.89
Delhi*	81.82	87.37	75	75.29	6.53
Goa	82.32	88.88	75.51	75.51	6.81
Gujarat	69.97	80.5	58.6	61.29	8.68
Haryana	68.59	79.25	56.31	55.85	12.74
Himachal Pradesh	77.13	86.02	68.08	63.86	13.27
Jammu & Kashmir	54.46	65.75	41.82	NA	NA
Jharkhand	54.13	67.94	39.38	41.39	12.74
Karnataka	67.04	76.29	57.45	56.04	11
Kerala	90.92	94.2	87.86	89.81	1.11
Lakshadweep *	87.52	93.15	81.56	81.78	5.74
Madhya Pradesh	64.11	76.8	50.28	44.67	19.41
Maharashtra	77.27	86.27	67.51	64.87	12.39
Manipur	68.87	77.87	59.7	59.89	8.97
Meghalaya	63.31	66.14	60.41	49.1	14.21
Mizoram	88.49	90.69	86.13	82.27	6.22
Nagaland	67.11	71.77	61.92	61.65	5.45
Orissa	63.61	75.95	50.97	49.09	14.52
Pondicherry*	81.49	88.89	74.13	74.74	6.74
Punjab	69.95	75.63	63.55	58.51	11.45
Rajasthan	61.03	76.46	44.34	38.55	22.48
Sikkim	69.68	76.73	61.46	56.94	12.61
Tamil Nadu	73.47	82.33	64.55	62.66	10.81
Tripura	73.66	81.47	65.41	60.44	13.22
Uttar Pradesh	57.36	70.23	42.98	40.71	16.65
Uttaranchal	72.28	84.01	60.26	57.75	14.53
West Bengal	69.22	77.58	60.22	57.7	11.52

Table 12 Literacy and population 1991

State[96]	**Population:**	**Literates%:**
Andhra Pr	66,508,008	44.09
Arunachal	864,558	41.59
Assam	22,414,322	52.89
Bihar	86,374,465	38.48
Goa	1,169,793	75.51
Gujarat	41,309,582	61.29
Haryana	16,463,648	55.85
Himachal P	5,170,877	63.86
JammuKashmir	7,718,700*	
Karnataka	44,977,201	56.04
Kerala	9,098,518	89.81
Madhya Pr	66,181,170	44.2
Maharashtra	78,937,187	64.87
Manipur	1,837,149	59.89
Meghalaya	1,774,778	49.1

[96] "States: Literacy & Population by Religion," http://w ww.cs.colostate.edu/~malaiya/india.html#

Mizoram	689,756	82.27
Nagaland	1,209,546	61.65
Orissa	31,659,736	49.09
Punjab	20,281,969	58.51
Rajasthan	44,005,990	38.55
Sikkim	406,457	56.94
TamilNadu	55,858,946	62.66
Tripura	2,757,205	60.44
Uttar Pr	139,112,287	41.6
West Bengal	68,077,965	57.7
Andaman-Nicobar	241,453	63.08

Environmental capacity

Land use

For land use information see Tables 19. Land use and land management, parklands and protected areas like nature reserves are crucial for future vulnerability and resilience to climate change. Detailed analyses will be required by state, and/or by the major watersheds for insights into how climate change might affect clean water availability, maintain biodiversity and ecosystem integrity and how environmental coping and adaptive capacity can be enhanced.

Sulfur emissions

State information was generated from gridded (1 degree latitude by 1 degree longitude) emission information from GEIA[97] and 1 degree gridded information on state boundaries from CDIAC[98] and state areas from the land use information (see Table 19 in this report). The type of rather rough information on sulfur emissions, representing a proxy for (negative) human impact on environmental capacity, calculated as emissions per unit land area, is not necessarily accurate for small states.

Table 13 Sulfur emissions

	Sulfur dioxide emissions/area = kg/km2	**SO_2**
India (b)	4.41	1443875
Andhra Pradesh	5.24	144053
Arunachal Pradesh	1.64	13700
Assam	5.14	40299
Bihar	9.14	158880
Goa	9.09	35308

[97] http://weather.engin.umich.edu/geia/
[98] http://cdiac.esd.ornl.gov/home.html

Gujarat	9.26	181545
Haryana	3.75	16560
Himachal Pradesh	1.60	8900
JammuKashmir	0.20	4500
Karnataka	1.53	29302
Kerala	9.09	35308
Madhya Pradesh	3.94	174885
Maharashtra	3.45	106019
Manipur	0.31	700
Meghalaya	1.43	3200
Mizoram	0.43	900
Nagaland	1.33	2200
Orissa	1.43	22272
Punjab	10.76	54200
Rajasthan	1.50	51216
Sikkim	0.14	100
Tamil Nadu	9.13	118730
Tripura	0.67	700
Uttar Pradesh	4.93	145070
West Bengal	10.74	95328

Population density

Population densities were calculated from reported state populations and reported state land-areas and compared with independently reported state population densities. Corrections were made where necessary before incorporation into the VRIP input stream.

Table 14 Population density

India/ States/Union Territories[99]	1991	2001
India	267	324
Jammu and Kashmir	74	99
Himachal Pradesh	93	109
Punjab	403	482
Chandigarh	5632	7903
Uttaranchal	133	159
Haryana	372	477
Delhi	6352	9294
Rajasthan	129	165
Uttar Pradesh	548	689
Bihar	685	880
Sikkim	57	76
Arunachal Pradesh	10	13
Nagaland	73	120
Manipur	82	107
Mizoram	33	42
Tripura	263	304

[99] http://www.cyberjournalist.org.in/census/cenden0.html

Meghalaya	79	103
Assam	286	340
West Bengal	767	904
Jharkhand	274	338
Orissa	203	236
Chhatisgarh	130	154
Madhya Pradesh	158	196
Gujarat	211	258
Daman & Diu	907	1411
Dadra & Nagar Haveli	282	449
Maharashtra	257	314
Andhra Pradesh	242	275
Karnataka	235	275
Goa	316	363
Lakshadweep	1616	1894
Kerala	749	819
Tamil Nadu	429	478
Pondicherry	1683	2029
Andaman & Nicobar Islands*	34	43

Settlement/infrastructure sensitivity

Sea level rise

Various studies on sea level rise and its impacts on land inundation, sea salt infiltration, and settlement displacements can be found. We found, for the present the information listed in the table below directly useful for our VRIP model. We scaled the percentage of the population projected as expected to be impacted by 1-meter sea level rise to the national data listed in Table 1.

Table 15 Estimates of coastal areas inundated and population affected under one meter sea level rise

[100]	**Coastal area (million hectares)**			**Population (millions)**		
State/Union	Total	Inundated	Percentage	Total	Affected	Percentage
Andhra Pradesh	27.504	0.055	0.19	66.36	0.617	0.93
Goa	0.37	0.016	4.34	1.17	0.085	7.25
Gujarat	19.602	0.181	0.92	41.17	0.441	1.07
Karnataka	19.179	0.029	0.15	44.81	0.25	0.56
Kerala	3.886	0.012	0.3	29.08	0.454	1.56
Maharashtra	30.771	0.041	0.13	78.75	1.376	1.75
Orissa	15.571	0.048	0.31	31.51	0.555	1.76
Tamil Nadu	13.006	0.067	0.52	55.64	1.621	2.91
West Bengal	8.875	0.122	1.38	67.98	1.6	2.35
Nicobar Islands	0.825	0.006	0.72	0	0	0
India	139.594	0.571	0.41	416.74	7.1	1.68
http://www.teriin.org/climate/impacts.htm						

[100] from http://www.teriin.org/climate/impacts.htm#tab1

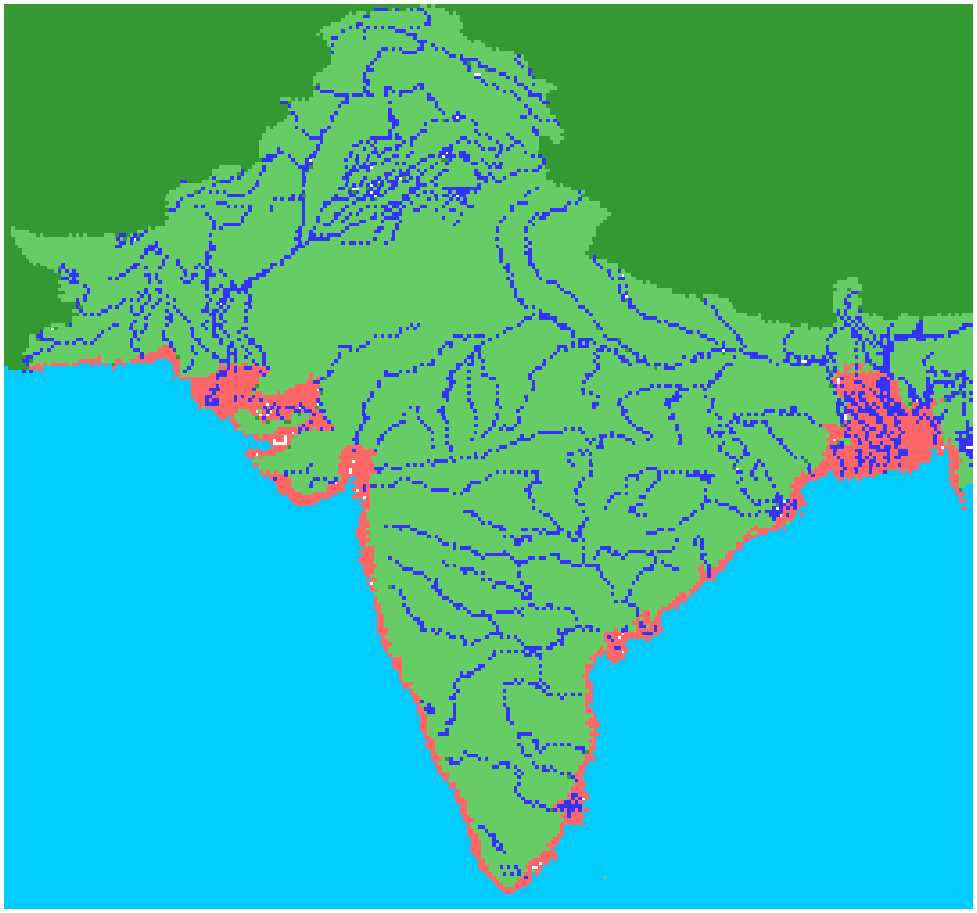

Figure 20 Map of areas potentially impacted by sea level rise (from http://www.teriin.org/climate/impacts.htm)

Access to clean water and sanitation

Table 16 Access to clean water and sanitation

	Percentage of the population with access to clean water[101]	Expenditure on health (medical/public) incl water &sanitation [102]
India	62.3	69.85
Andhra Pradesh	55.08	40.17
Arunachal Pradesh	70.02	378.18
Assam	45.86	65.4
Bihar	58.76	35.66
Goa	43.41	490.22
Gujarat	69.78	54.03
Haryana	74.32	96.93

[101] htpp://www.rainwatewrharvesting.org/resources/statistics/stat531.htm
[102]Table: "Statewise per capita (Public sector) expenditure on health (Medical and Public Health) including water supply and sanitation and family welfare (during 1985-86 to 1989-90)," http://www.Indiastat.com

Himachal Pradesh	77.34	184.57
JammuKashmir		238.34
Karnataka	71.68	54.15
Kerala	18.89	70.66
Madhya Pradesh	53.41	58.1
Maharashtra	68.49	78.13
Manipur	38.72	188.73
Meghalaya	36.16	229.2
Mizoram	16.21	434.7
Nagaland	53.37	577.38
Orissa	39.07	47.14
Punjab	92.74	98.59
Rajasthan	58.96	96.17
Sikkim	73.05	419.47
Tamil Nadu	67.42	77.35
Tripura	37.18	152.18
Uttar Pradesh	62.24	43.11
West Bengal	81.98	54.92

Food sensitivity

Agriculture

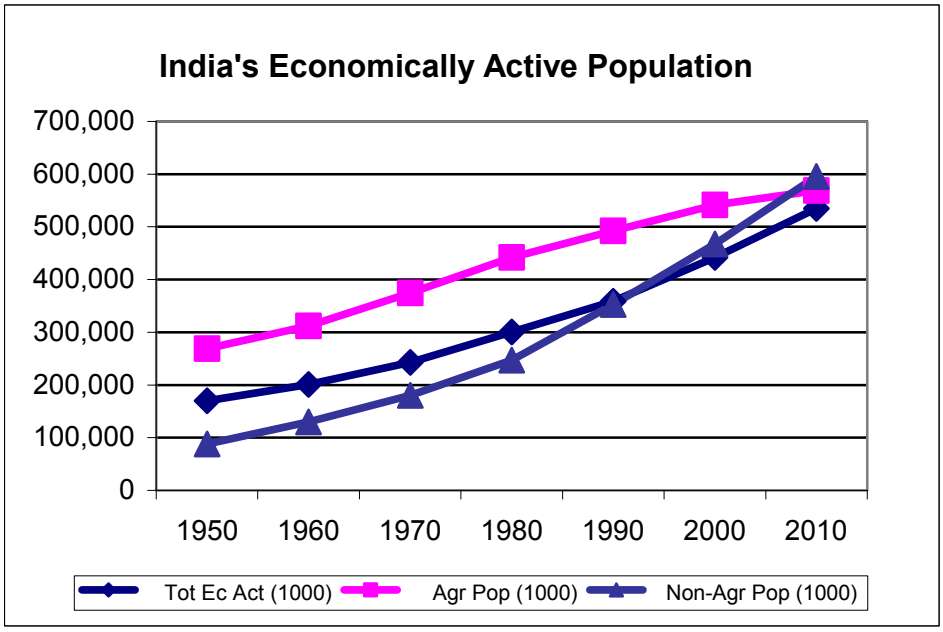

Figure 21 India's economically active population: its agrarian, and non-agrarian population (generated from information in http://www.teriin.org/climate/impacts.htm)

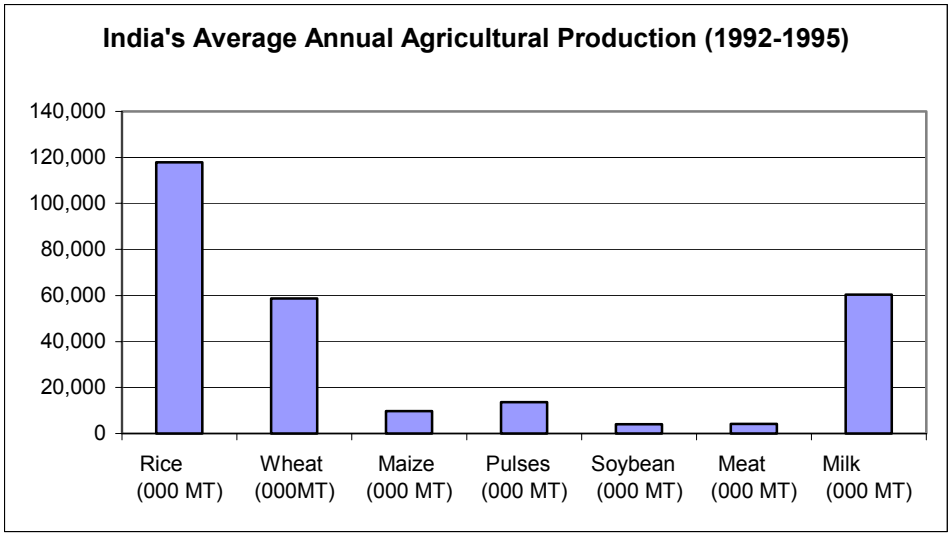

Figure 22 India's average annual agricultural production of main crops (generated from information in http://www.teriin.org/climate/impacts.htm)

Note that rice production in India accounts for 50% of the cereal produced. Also note that in eastern India, approximately 80% of the 20 million ha of rice is grown in rain-fed lowlands. Figure 28 shows a map of India with irrigation canals.[103]

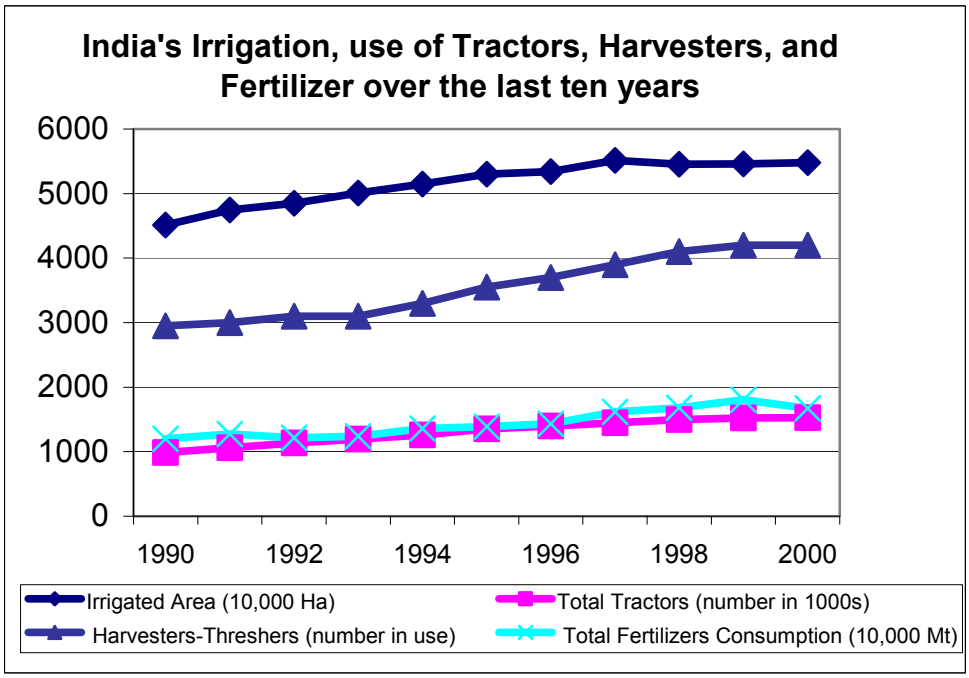

Figure 23 Changes in the last ten years in the amount of irrigated land, availability of tractors and harvesters, and fertilizer consumption (generated from http://www.teriin.org/climate/impacts.htm)

[103] See also http://www.grida.no/climate/ipcc/regional/296.htm

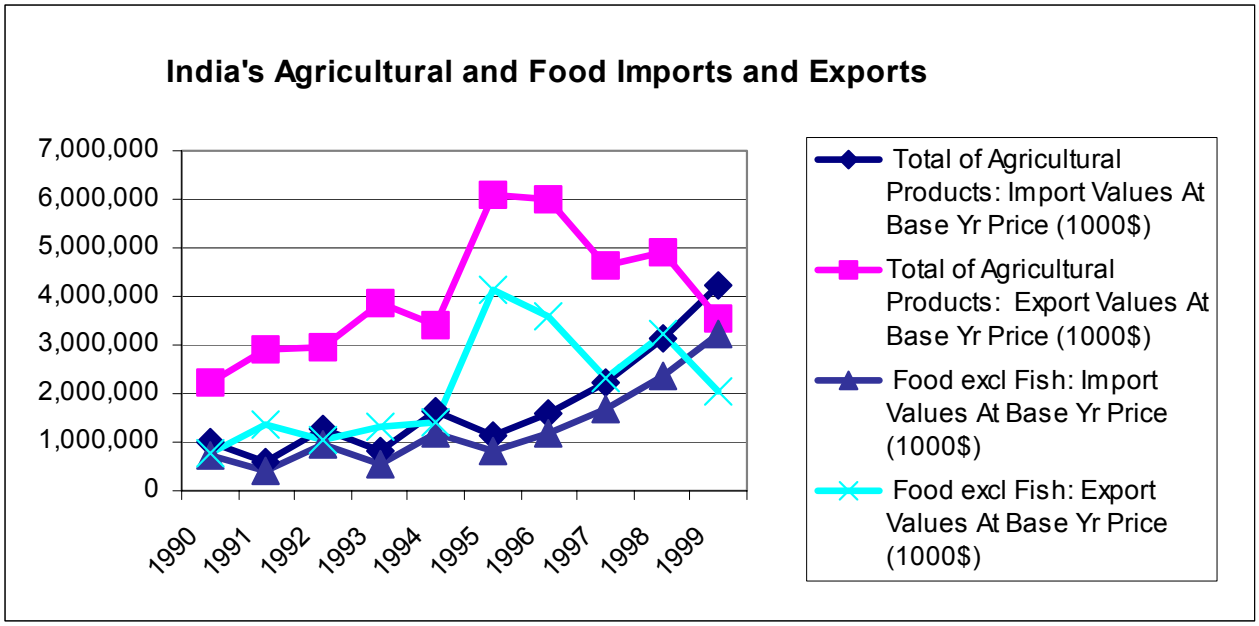

Figure 24 India's agricultural and food imports and exports over the last ten years (generated from http://www.teriin.org/climate/impacts.htm)

Note that exports have been steadily increasing, but that imports have been much more variable, especially over the last 5 years.

Table 17 Crop production

[104]	1998-99: Total cereals (000 ha)	Production (000 tonnes)
India (b)	101539	188188
Andhra Pradesh	5620	13632
Arunachal Pradesh	174	181
Assam	2541	3364
Bihar	8047	12210
Goa	58	154
Gujarat	3042	4934
Haryana	4063	11770
Himachal Pradesh	809	1477
JammuKashmir	844	1498
Karnataka	5570	9254
Kerala	357	664
Madhya Pradesh	12746	16224
Maharashtra	9595	10496
Manipur	170	392
Meghalaya	129	184
Mizoram	78	131
Nagaland	191	268

[104] "Table 28: Comparative Statistics," http://www.andhrapradesh.com/apwebsite/tables/statisticsstate/table-4.htm

Orissa	4640	5540
Punjab	6046	22856
Rajasthan	8818	10497
Sikkim	69	85
Tamil Nadu	3433	9634
Tripura	259	499
Uttar Pradesh	17798	37870
West Bengal	6336	14240

Background information for cereal production in the different states is listed in Table 18.

Table 18 Areas cropped with different cereals, 1997-98 & 1998-99

AREA UNDER CROPS IN INDIA, 1997-98 & 1998-99.[105]									
(Provisional)									
(**Thousand hectares**)									
FOOD CROPS									
C E R E A L S									
State/ Union-Territory/ Year	**Rice**	**Jowar**	**Bajra**	**Maize**	**Ragi/ Marua**	**Wheat**	**Barley**	**Other Cereals & Millets**	**Total Cereals & Millets**
ANDHRA PRADESH									
1997-98	3500	789	96	396	98	11	-	66	4956
1998-99	4317	752	127	399	103	11	-	74	5783
ARUNACHAL PRADESH (b)									
1997-98	120	-	-	35	-	4	-	19	177
1998-99	116	-	-	36	-	4	-	18	173
ASSAM									
1997-98	2526	-	-	19	-	85	-	10	2640
1998-99	2454	-	-	20	-	90	-	10	2574
BIHAR									
1997-98	5112	3	6	705	74	2088	43	40	8071
1998-99	5087	3	6	711	72	2121	41	32	8073
GOA									
1997-98	56	-	-	(a)	3	-	-	-	59
1998-99	56	-	-	(a)	3	-	-	-	59
GUJARAT									
1997-98	744	383	1281	430	11	697	12	26	3585
1998-99(b)	622	239	1038	408	20	701	12(p)	14	3054
HARYANA									
1997-98	914	131	584	26	-	2057	42	1	3755
1998-99	1087	130	613	20	-	2186	36	1	4073
HIMACHAL PRADESH									
1997-98	86	-	(a)	312	5	377	28	11	820
1998-99	82	-	(a)	301	5	380	27	12	806
JAMMU & KASHMIR									
1997-98	276	(a)	10	311	8	245	7	5	862
1998-99	270	(a)	11	311	9	243	9	5	858
KARNATAKA									
1997-98	1343	1895	302	547	911	251	-	74	5323

[105] http://agricoop.nic.in/statistics/st3.htm

1998-99	1416	1845	417	505	998	269	-	88	5538
KERALA									
1997-98	387	3	-	-	2	-	-	3	395
1998-99	353	2	-	-	1	-	-	2	358
MADHYA PRADESH									
1997-98	5387	834	142	851	12	4582	91	849	12748
1998-99	5440	754	146	843	12	4654	93	824	12765
MAHARASHTRA									
1997-98	1477	5500	1671	241	157	747	2	112	9907
1998-99	1483	4775	1760	270	157	1016	2	144	9606
MANIPUR									
1997-98	158	-	-	3	-	-	-	-	161
1998-99	167	-	-	3	-	-	-	-	170
MEGHALYA									
1997-98	105	-	-	17	-	5	-	3	130
1998-99	105	-	-	17	-	4	-	3	130
MIZORAM									
1997-98	68	-	-	8	-	-	-	-	76
1998-99	68	-	-	9	-	-	-	-	77
NAGALAND									
1997-98	145	-	-	30	-	2	(a)	12	189
1998-99	145	1	1	32	-	4	1	10	193
ORISSA									
1997-98	4497	14	4	169	198	17	-	43	4942
1998-99	4447	14	3	164	198	17	-	46	4889
PUNJAB									
1997-98	2281	(a)	8	165	-	3300	37	101	5891
1998-99(b)	2519	(a)	4	154	-	3338	37(p)	101(p)	6153
RAJASTHAN									
1997-98	164	561	4703	969	-	2680	263	18	9358
1998-99	168	535	4184	946	-	2766	216	17	8832
SIKKIM(b)									
1997-98	16	-	-	39	5	8	1	-	70
1998-99	16	-	-	39	5	8	1	-	69
TAMIL NADU									
1997-98	2261	380	169	58	107	-	-	76	3051
1998-99	2275	365	154	56	120	(a)	-	69	3039
TRIPURA(b)									
1997-98	258	-	-	2	-	2	-	-	262
1998-99	256	-	-	2	-	1	-	-	259
UTTAR PRADESH									
1997-98	5733	398	864	1028	132	9153	340	146	17794
1998-99(b)	5881	354	843	996	135	9318	331	112	17969
WEST BENGAL									
1997-98	5900	1	(a)	43	13	367	6	5	6336
1998-99	5904	1	(a)	39	13	367	6	5	6335
ALL INDIA									
1997-98	43577	10899	9842	6406	1736	26712	873	1619	101664
1998-99	44796	9780	9309	6284	1851	27530	810	1587	101946

Table 19 Land use in Indian states, presently used in VRIP

[106]	State land	State cropland http://agricoop.nic.in/statistics/stpart3d.htm	Percentage managed land Calculated from information from Table 17	Percentage crop land calculated from this table's information	Percentage unmanaged land (100-percentage managed)
India	327631000	140594000	62.83	42.77	39.96
Andhra Pradesh	27507000	7990000	57.89	29.05	42.22
Arunachal Pradesh	8374000	228000	37.88	2.72	94.67
Assam	7844000	3243000	41.45	41.34	58.51
Bihar	17388000	9571000	62.78	55.04	37.34
Goa	370000	143000	55.95	38.65	45.15
Gujarat	19602000	5179000	67.08	26.42	34.30
Haryana	4421000	4389000	86.86	99.28	13.20
Himachal Pradesh	5567000	952000	38.42	17.10	80.34
JammuKashmir	22224000	962000	84.45	4.33	76.69
Karnataka	19179000	7981000	67.92	41.61	32.30
Kerala	3886000	1346000	62.92	34.64	37.09
Madhya Pradesh	44344000	18433000	51.38	41.57	48.62
Maharashtra	30771000	14397000	68.63	46.79	31.39
Manipur	2233000	205000	8.33	9.18	92.58
Meghalaya	2243000	225000	48.33	10.03	51.72
Mizoram	2108000	104000	21.11	4.93	78.85
Nagaland	1658000	230000	44.21	13.87	59.26
Orissa	15571000	7606000	51.22	48.85	48.78
Punjab	5036000	6256000	86.04	124.23	13.97
Rajasthan	34224000	14370000	74.95	41.99	25.02
Sikkim	710000	122000	16.06	17.18	83.94
Tamil Nadu	13006000	4587000	63.89	35.27	36.14
Tripura	1049000	382000	29.55	36.42	70.45
Uttar Pradesh	29441000	23663000	69.24	80.37	30.39
West Bengal	8875000	7886000	67.88	88.86	32.82

Table 20 Background information on land use in India's states

State/Union/Territory/Year[107]	Geographical area	Reporting area for land utilization statistics	Forests	Not available for cultivation	Barren & uncultur-able	Other uncultivated land excluding fallow land, permanent pasture & other grazing land	Land under misc. tree crops, groves; not including sown lands	Cultur-able waste land	Fallow land other than current fallows	Current fallows	Net area sown	Total cropped area	Net irrigated area	Gross irrigated area
ANDHRA PRADESH														
1997-98	27507	27440	6199	2583	2109	693	246	752	1620	3392	9846	12135	3945	5158
1998-99		27440	6199	2593	2108	686	241	774	1528	2333	10978	13625	4538	6092
ARUNACHAL PRADESH (r)														
1997-98	8374	5495	5154		48	(n)	44	(n)	36	28	185	252*	36(v)	36(v)
1998-99		5495	5154		48	(n)	44	(n)	36	28	185	250*	36(v)	36(v)

[106] Units were converted when comparisons were necessary.
[107] http://agricoop.nic.in/statistics/st3.htm

ASSAM														
1997-98	7844	7850	1930	1045	1448	170	243	86	67	110	2751	3994	572(b)	572(b)
1998-99		7850	1930	1051	1459	167	236	80	82	144	2701	3941	572(b)	572(b)
BIHAR														
1997-98	17388	17330	2949	2405	1010	107	343	328	931	1845	7411	10015	3508	4579
1998-99		17330	2949	2428	1010	106	344	323	926	1814	7431	10053	3682	4752
GOA														
1997-98	370	361	125	37		1	1	56	(m)	(m)	141	169	24	36
1998-99		361	125	37		1	1	55	(m)	(m)	142	171	22	34
GUJARAT														
1997-98	19602	18812	1859	1140	2604	849	4	1980	26	676	9674	11157	3058	3779
1998-99(t)		18812	1859	1140	2604	849	4	1980	26	676	9674	10702*	3058	3779
HARYANA														
1997-98	4421	4402	115	355	86	25	5	37	-	144	3635	6143	2793	4829
1998-99		4394	115	350	89	24	5	37	2	143	3628	6320	2842	5042
HIMACHAL PRADESH														
1997-98	5567	4267	1087	225	776	1340	98	104	23	55	560	986	103	180
1998-99		4531	1077	239	910	1493	71	107	28	57	549	970	103	183
JAMMU & KASHMIR														
1997-98	22224	4505(o)	2747(k)	291	291	126	72	140	8	94	736	1083	309	446
1998-99		4505(o)	2747(k)	291	291	126	72	140	8	97	733	1081	309	447
KARNATAK														
1997-98	19179	19050	3063	1284	801	1005	313	439	399	1671	10075	11695	2363	2912
1998-99		19050	3063	1295	799	987	312	435	401	1266	10489	12312	2492	3118
KERALA														
1997-98	3886	3885	1081	320	39	1	22	65	28	58	2271	2969	350	417
1998-99		3885	1082	334	28	1	20	63	32	68	2259	2917	375	421
MADHYA PRADESH														
1997-98	44344	44346	14712	2515	1713	2621	20	1456	764	719	19826	25956	6304	6527
1998-99		44349	14708	2518	1699	2568	18	1505	761	733	19839	26011	6560	6814
MAHARASHTRA														
1997-98	30771	30758	5366	1238	1703	1347	223	884	1131	1105	17761	21740	2936	3352(w)
1998-99		30758	5366	1239	1702	1341	222	888	1139	1132	17732	22155	2946	3422(w)
MANIPUR(j)														
1997-98	2233	2211	602	26	1419	(n)	24	(n)	-	-	140	207	65	75
1998-99		2211	602	26	1419	(n)	24	(n)	-	-	140	216	65	75
MEGHALAYA														
1997-98	2243	2241(f)	932	86	141	-	161	482	164	68	207	251	47	54
1998-99		2241(f)	932	85	140	-	158	470	166	69	221	266	48	55
MIZORAM(p)														
1997-98	2108	2109	1598		65	-		174	163	-	109	113	8	10
1998-99		2109	1598		65	-		174	163	-	109	116	9	10
NAGALAND														
1997-98	1658	1561	863	62		-	130	69	83	103	251	260	62	70
1998-99		1560	875	65		-	124	65	77	92	261	286	63	73
ORISSA														
1997-98	15571	15571	5606	866	590	534	774	445	336	298	6122	8645	2090(e)	2318
1998-99		15571	5606	838	618	534	774	445	336	372	6048	8425	2090(e)	2358
PUNJAB														
1997-98	5036	5033	305	57	337	4	5	37	5	44	4238	7833	4004	7487
1998-99(t)		5033	305	57	337	4	5	37	5	44	4238	8117*	4004	7487
RAJASTHAN														
1997-98	34224	34264	2528	1699	2622	1723	15	5017	1988	1597	17075	22325	5421	6676
1998-99		34265	2557	1705	2603	1718	14	5069	2287	2238	16073	21401	5499	6809
SIKKIM(d)														
1997-98	710	710	257	97	173	69	5	1	9	4	95	140*	16(g)	16(g)
1998-99		710	257	97	173	69	5	1	9	4	95	127*	16(g)	16(g)
TAMIL NADU														
1997-98	13006	12998	2140	1952	481	124	230	344	1162	984	5581	6558	2945	3519
1998-99		12998	2140	1968	478	123	240	348	1111	956	5635	6627	3019	3635
TRIPURA (e)														
1997-98	1049	1049	606	133		(n)	27	1	1	4	277(c)	451*	35(h)	60(h)
1998-99		1049	606	133		(n)	27	1	1	4	277(c)	444*	35(h)	60(h)

UTTAR PRADESH														
1997-98	29441	29794	5281	2539	941	294	516	909	760	1041	17513	26045@	12012	17322
1998-99		29794	5213	2556	930	296	547	896	742	1029	17585	26609@*	12691	17676
WEST BENGAL														
1997-98	8875	8687	1192	1621	30	8	77	46	30	219	5465	9259	1911(d)	2491(q)
1998-99		8687	1192	1638	30	7	73	45	33	229	5440	9290	1911(d)	2491(q)
ALL INDIA														
1997-98	328726+	305786	69012	22695	19441	11046	3616	13880	9748	14265	142083	190570	54985	73007
1998-99		306044	68973	22802	19554	11104	3598	13967	9913	13532	142600	192619	57053	75546

Table 21 Different wasteland categorizations by state

Statewise Comparative Estimates of Wastelands			[108]	**State-wise Estimated Forest Wasteland**		
(Area in Lakh Hectares)				(As on 1997 & 1998)		
States	**As per SPWD's**	**As per Wasteland**		**State/Uts**	**Estimated Forest Wasteland**	
	Estimate, 1984	**Atlas, 2000**			**1997**	**1998**
Andhra Pradesh	114.16	51.75		Andhra Pradesh	114.16	114.16
Arunachal Pradesh	-	18.33		Arunachal Pradesh	0.014	0.004
Assam	17.3	20.02		Assam	N.A.	N.A.
Bihar	54.58	21		Bihar	N.A.	N.A.
Goa	-	0.61		Goa	N.A.	N.A.
Gujarat	78.36	43.02		Gujarat	0.008	0.008
Haryana	24.78	3.73		Haryana	Nil	Nil
Himachal Pradesh	19.58	31.66		Himachal Pradesh	16.38	16.38
Jammu & Kashmir	15.65	65.44		Jammu & Kashmir	1.47	1.4
Karnataka	91.65	20.84		Karnataka	N.A.	N.A.
Kerala	12.79	1.45		Kerala	1.88	-
Madhya Pradesh	201.42	69.71		Madhya Pradesh	N.A.	N.A.
Maharashtra	144.01	53.49		Maharashtra	17.8	17.8
Manipur	14.38	12.95		Manipur	N.A.	N.A.
Meghalaya	19.18	9.9		Meghalaya	N.A.	N.A.
Mizoram	-	4.07		Mizoram	N.A.	N.A.
Nagaland	13.86	8.4		Nagaland	N.A.	N.A.
Orissa	63.84	21.34		Orissa	N.A.	N.A.
Punjab	12.3	2.23		Punjab	N.A.	N.A.
Rajasthan	199.34	105.64		Rajasthan	15	15
Sikkim	2.81	3.57		Sikkim	N.A.	Nil
Tripura	9.73	1.28		Tamil Nadu	6.42	6.42
Tamil Nadu	44.01	23.01		Tripura	0.81	0.81
Uttar Pradesh	80.61	38.78		Uttar Pradesh	N.A.	N.A.
West Bengal	25.36	5.72		West Bengal	1.68	1.68
Total	1295.74	638.51		India	175.622	180.322

Food consumption

Total protein consumption per capita was substituted for animal protein per capita. Data are listed below showing clearly the mostly vegetarian diets in India.

[108] Table: "Statewise comparative estimates of wastelands & Statewise estimated forest wasteland (as on 1997-1998)," http://www. Indiastat.com

Table 22 Protein consumption

[109]	GTPCAP/DAY CALORIES	GTPCAP/DAY PROTEINS(GR)	VPPCAP/DAY PROTEINS(GR)	APPCAP/DAY PROTEINS(GR)
India (b)	2275.34	55.15	46.18	8.97
Andhra Pradesh	2,340	55.7	51.4	2.8
Arunachal Pradesh	N.A			
Assam	N.A			
Bihar	2,055	55.5	54.7	1.6
Goa	2,129	63.3	53.7	1.9
Gujarat	2,375	69.3	60.4	4.7
Haryana	N.A			
Himachal Pradesh	N.A			
JammuKashmir	2,259	64.3	58.0	4.5
Karnataka	2,431	65.4	60.2	3.1
Kerala	2,140	52.9	44.2	3.0
Madhya Pradesh	2,614	82.5	75.9	4.0
Maharashtra	2,211	61.7	56.0	2.9
Manipur	N.A			
Meghalaya	2,018	66	53.9	0.6
Mizoram	N.A			
Nagaland	N.A			
Orissa	2,700	61.4	59.6	0.8
Punjab	2,760	85	65.7	13.5
Rajasthan	2,115	71	62.6	6.9
Sikkim	2,051	54	48.0	3.3
Tamil Nadu	1,871	45.6	35.6	2.4
Tripura	1,967	45.1	42.2	1.8
Uttar Pradesh	2,115	69.6	66.2	3.0
West Bengal	2,426	53.4	51.2	0.8

Human population health sensitivity

Fertility and life expectancy

Table 23 Fertility rates and life expectancy

	Birth rates[110]		Fertility rates[111]	Life expectancy:[112]
India	2.75	2.74	3.5	60
Andhra Pradesh	2.28	2.27	2.7	61.2
Arunachal Pradesh	2.19			
Assam	2.76			55.1
Bihar	3.21	3.21	4.6	58.9

[109] http://www.unu.edu/unupress/food/8F173e/8F173E08.htm
[110] 9th Five Year Plan, vol 1, Population, growth and demographic profile: Perspective, Table 1-3 Important social & demographic indicators – major states. http://www.censusindia.net/srs1.html & http://planningcommission.nic.in/fiveyr/9th/vol1/v1c1-3.htm1994
[111] http://planningcommission.nic.in/fiveyr/9th/vol1/v1c1-3.htm1994
[112] http://www3.who.int/whosis/hale/hale.cfm?path=whosis,hale&language=english

Goa	1.44			
Gujarat	2.57	2.55	3.1	60.5
Haryana	2.88	2.88	3.7	63.2
Himachal Pradesh	2.3			64.2
JammuKashmir	0			
Karnataka	2.3	2.3	2.8	62.3
Kerala	1.8	1.78	1.7	72.7
Madhya Pradesh	3.23	3.24	4.2	54.5
Maharashtra	2.34	2.32	2.9	64.5
Manipur	1.96			
Meghalaya	3.04			
Mizoram	1.51			
Nagaland	0			
Orissa	2.7	2.68	3.3	55.9
Punjab	2.37	2.35	2.9	67
Rajasthan	3.24	3.23	4.5	58.6
Sikkim	2			
Tamil Nadu	1.95	1.92	2.1	62.9
Tripura	1.84			
Uttar Pradesh	3.4	3.4	5.1	56.5
West Bengal	2.28	2.28	5	61.6

Ecosystem sensitivity

Land use

Land use tables are listed above. Additional insight into forest cover in India is provided in the forest map shown below.

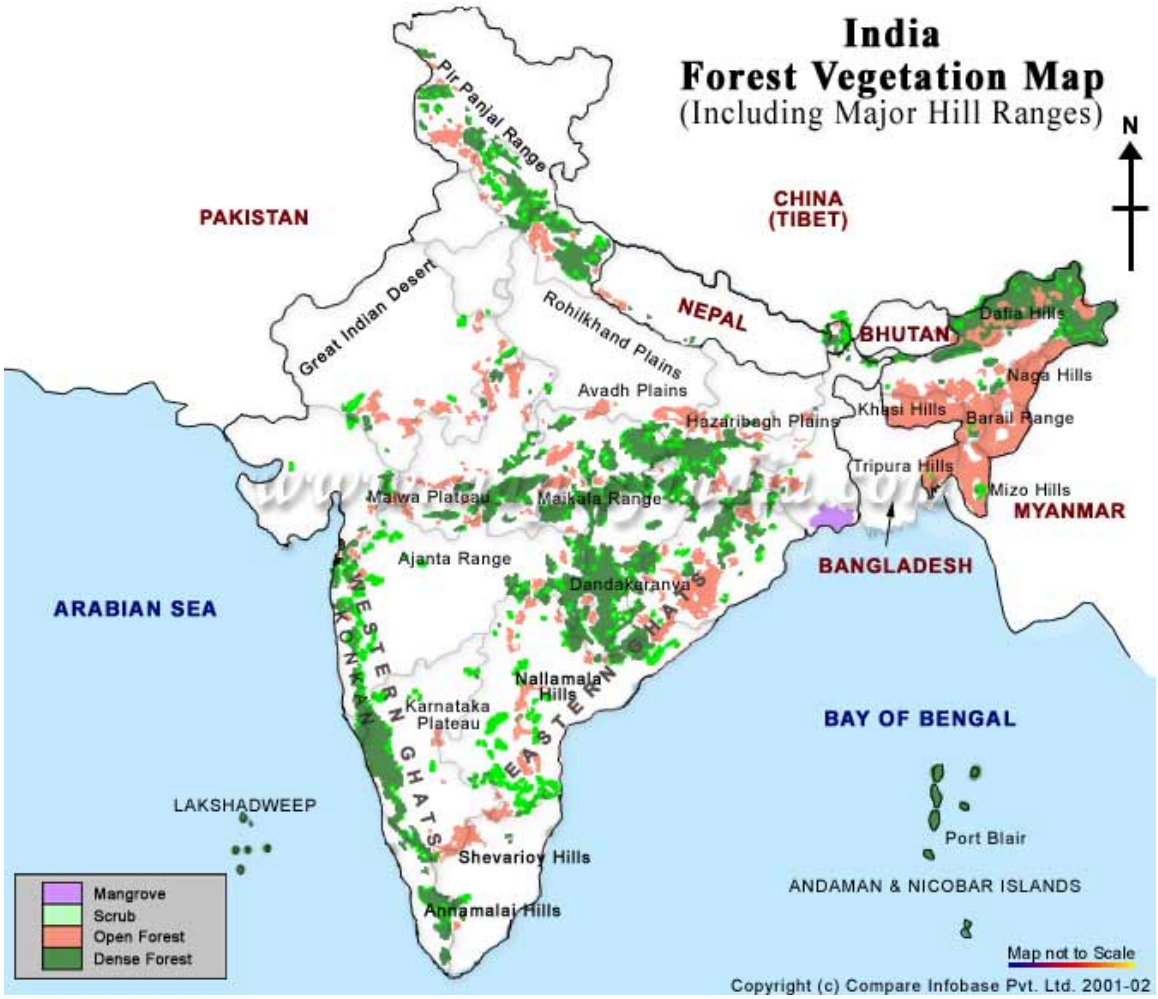

Figure 25 Forest vegetation map of India (http://www.mapsofindia.com/maps/india)

Fertilizer use

Availability of affordable fertilizer impacts agricultural yields, but also water quality and surrounding ecosystems. Table 23 lists the states' fertilizer use, data that were used in the calculation of fertilizer use per ha of cropland.

Table 24 Fertilizer use

State-wise Consumption of Fertilizers during 1998-99 and 1999-2000[113]	N 1998-99 (Estimated)	P 1998-99 (Estimated)	K 1998-99 (Estimated)	FAO 1990: tonnes< > **Total tonnes** rescaled
All India	11353799	4112148	1331536	16797483
Andhra Pradesh	1284255	560463	163193	2007911
Arunachal Pradesh	352	149	103	604
Assam	47690	20556	9856	78102
Bihar	666481	172663	55847	894991
Goa	3386	1612	1932	6930
Gujarat	690728	267569	61358	1019655
Haryana	662679	171768	3950	838397
Himachal Pradesh	29140	5219	4198	38557
Jammu & Kashmir	51293	17403	2142	70838
Karnataka	638632	335955	174211	1148798
Kerala	86042	42528	52917	181487
Madhya Pradesh	738167	448369	39214	1225750
Maharashtra	1025000	458000	178000	1661000
Manipur	15386	1498	201	17085
Meghalaya	2808	1379	155	4342
Mizoram	245	527	370	1142
Nagaland	390	355	54	799
Orissa	194577	60380	44214	299171
Punjab	1081064	275464	18738	1375266
Rajasthan	532520	188480	6128	727128
Sikkim	568	306	54	928
Tamil Nadu	518619	202066	230201	950886
Tripura	6969	1807	985	9761
Uttar Pradesh	2447869	557571	86088	3091528
West Bengal	579698	305769	192483	1077950

Water

Although India is listed under the water-abundant category of countries with 2,464 cubic meters of renewable annual fresh water available per person in 1990[114] water availability is a regional phenomena and, according to long-range United Nations population projections, India's population could, under the low-growth projection, stabilize and eventually shrink in size after 2025, which would actually increase per capita water availability. Under the medium and high projections, however, the country would move into conditions of water stress and water scarcity, respectively (see Figure 26).

[113] http://agricoop.nic.in/statistics/consum4a.htm
[114] http://www.cnie.org/pop/pai/water-30.html

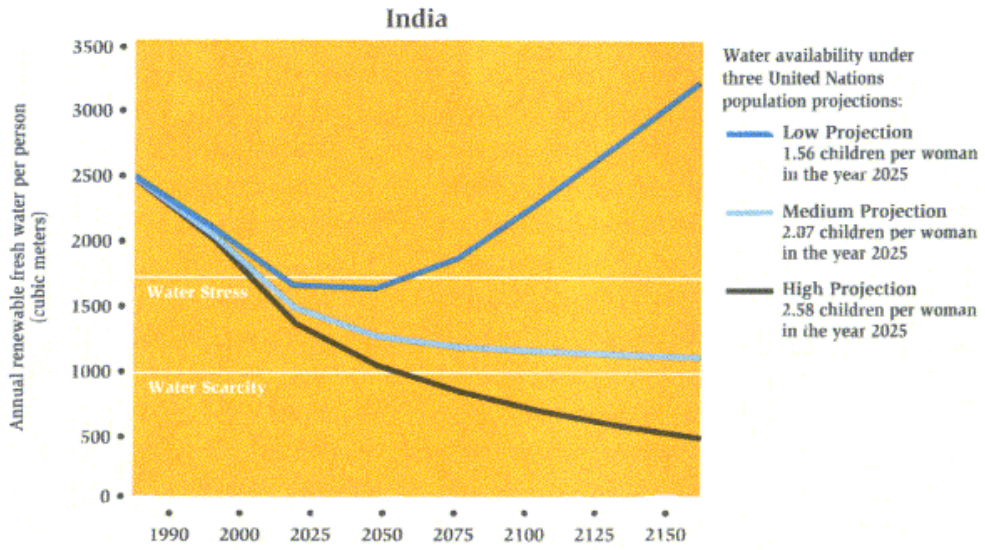

Figure 26 The future of renewable water supplies (http://www.cnie.org/pop/pai/water-14.html)

We have not been able to integrate the diverse pieces of information on water sources, water availability and water renewability into state-specific water availability, within the present timeframe of this report. Given that a very large percentage of the presently available water in India is used for agriculture, which might shift locally when industrial development requires more intense water use, and people require more water for personal use, water availability paired with climate change requires more of an in depth study then can be presently delivered. Some essential background information is listed below, however.

Table 25 India's Pakistan's, Bangladesh's, and Nepal's water budgets

		India	Pakistan	Bangladesh	Nepal
Annual Internal Renewable (km3)		1850	298	1357	170
Annual Withdrawal (km3)		380	153.4	22.5	2.68
From outside the country borders		235	170	1000	0
Sectoral Withdrawal (%)	Domestic	3	2	3	4
	Industry	4	2	1	1
	Agriculture	93	97	96	96
http://www.grida.no/climate/ipcc/regional/293.htm &WRI, 2000					

Table 26 Water resources in Indian states

	Rivers & Canals (Length, in Kms.)[115]	Reservoirs (in Lakh - 100,000 - Ha.)	Tanks & Ponds (in Lakh - 100,000 Ha.)	Floodplain Lakes & Derelict Water (in Lakh- 100,000 Ha.)	Brackish Water (in Lakh- 100,000 Ha.)	Beels, Oxbow Lakes & Derelict Water	Brackish Water	statewide annual requirement of water for domestic purposes (in 1.e-3 km3) 1991	statewide annual requirement of water for domestic purposes (in 1.e-3 km3) 2001:
India (b)	191024	20.41	28.55	7.98	14.37	5.45	-	31949	38263
Andhra Pradesh	11514	2.34	5.17	-	0.79	-	-	2548	2927
Arunachal Pradesh	2000	-	2.76	0.42	-	0.03	-	0.027	0.038
Assam	4820	0.02	0.23	1.1	-	1.1	3.76	0.691	0.817
Bihar	3200	0.6	0.95	0.05	-	0.05	-	2746	3237
Goa	250	0.03	0.03	-	-	-	-	0.053	0.074
Gujarat	3865	2.43	0.71	0.12	3.76	0.12	0.08	1731	2052
Haryana	5000	Neg	0.1	0.1	-	0.1	2.43	613	749
Himachal Pradesh	3000	0.42	0.01	-	-	-	-	153	201
Jammu Kashmir	27781	0.07	0.17	0.06	-	0.06	0.1	284	371
Karnataka	9000	2.11	2.9	-	0.08	-	-	1809	2120
Kerala	3092	0.3	0.3	2.43	2.43	*	-	1108	1239
Madhya Pradesh	20661	2.94	1.19	-	-	-	-	2419	2968
Maharashtra	16000	2.79	0.59	-	0.1	-	-	3466	4044
Manipur	3360	0.01	0.05	0.04	-	0.4	4.17	71	99
Meghalaya	5600	0.08	0.02	Neg	-	Neg	-	61	85
Mizoram	1395	-	0.02	-	-	-	-	33	46
Nagaland	1600	0.17	0.5	Neg	-	Neg	-	41	58
Orissa	4500	2.56	1.14	1.8	4.17	1.8	0.56	1010	1153
Punjab	15270	Neg	0.07	-	-	-	-	803	942
Rajasthan	5290	-	1.8	-	-	-	-	1602	1984
Sikkim	900	1.2	-	0.03	-	0.03	2.1	12	17
Tamil Nadu	7420	0.52	0.56	0.07	0.56	N.A.		2332	2599
Tripura	1200	0.05	0.13	-	-	-	14.22	90	126
Uttar Pradesh	31200	1.5	1.62	1.33	-	1.33		4864	6094
West Bengal	2526	0.17	2.76	0.42	2.1	0.42		2627	3087

[115] Table: "Statewise details of inland water resources of various types (during 2000-2001)," http://www.Indiastat.com

Table 27 Statewise ground water resources and irrigation potential

Statewise Ground Water Resource and Irrigation Potential (Indiastat.com)										
	Total Replenishable Ground Water Resource (m.ha.m/yr[116])	Provision for Domestic, Industrial &Other Uses (m.ha.m/yr)	Available Ground Water Resource for Irrigation in Net Terms (m.ha.m/yr)	Utilisable Ground Water Resource for Irrigation in Net Terms (m.ha.m/yr)	Gross Draft Estimated on Prorata Basis (m.ha.m/yr)	Net Draft (m.ha.m/yr)	Balance Ground Water Resource for Future use in net terms (m.ha.m/yr)	Level of Ground Water Development (%)	Weighted Average Delta (m)	Utilisable Irrigation Potential for Development (m.ha)
Andhra Pradesh	3.52916	0.52938	2.99978	2.69981	1.01318	0.70922	2.29056	23.64	0.047-1.472	3.96008
Arunachal Pradesh	0.14385	0.02158	0.12227	0.11005	-	-	0.12227	-	-	0.018
Assam	2.47192	0.37079	2.10113	1.89102	0.13455	0.09418	2.00695	4.48	1.283	0.9
Bihar	3.35213	0.50282	2.84931	2.56439	0.78108	0.54676	2.30255	19.19	0.40-0.65	4.94763
Goa	0.02182	0.00327	0.01855	0.0167	0.00219	0.00154	0.01701	8.3	0.87	0.02928
Gujarat	2.03767	0.30565	1.73202	1.55881	1.02431	0.71702	1.015	41.45	0.45-0.714	2.7559
Haryana	0.85276	0.12792	0.72484	0.65236	0.86853	0.60798	0.11686	83.88	0.385-0.6	1.4617
Himachal Pradesh	0.0366	0.00731	0.02929	0.02637	0.00757	0.0053	0.02399	18.1	0.385	0.0685
Jammu & Kashmir	0.44257	0.06639	0.37618	0.33858	0.00713	0.005	0.37118	1.33	0.385-0.6	0.70795
Karnataka	1.61857	0.24279	1.37578	1.23821	0.61443	0.4301	0.94568	31.26	0.18-0.74	2.57281
Kerala	0.79003	0.13135	0.65868	0.59281	0.14374	0.10062	0.55806	15.28	0.53-0.83	0.87925
Madhya Pradesh	5.08892	0.76332	4.3256	3.89298	1.01866	0.71312	3.61248	16.49	0.4	9.73249
Maharashtra	3.78673	1.23972	2.54701	2.29231	1.10576	0.77403	1.77298	30.39	0.43-1.28	3.65197
Manipur	0.3154	0.0473	0.2681	0.24129	Neg.	Neg.	0.2681	Neg.	0.65	0.369
Meghalaya	0.05397	0.0081	0.04587	0.04128	0.0026	0.00182	0.044.05	Neg.	0.65	0.06351
Mizoram*										
Nagaland	0.0724	0.0109	0.0615	0.05535	Neg.	Neg.	0.0615	Neg.	-	-
Orissa	2.00014	0.30002	1.70012	1.53009	0.20447	0.14313	1.55699	8.42	0.34-0.44	4.20258
Punjab	1.8655	0.18652	1.67898	1.51109	2.25109	1.57576	0.10322	93.85	0.518	2.91715
Rajasthan	1.27076	0.19945	1.07131	0.96418	0.77483	0.54238	0.52893	50.63	0.457-0.6	1.77783
Sikkim*										
Tamil Nadu	2.63912	0.39586	2.24326	2.01892	1.93683	1.35578	0.87875	60.44	0.37-0.93	2.83205
Tripura	0.06634	0.00995	0.05639	0.05076	0.02692	0.01885	0.03754	33.43	0.63	0.08056
Uttar Pradesh	8.3821	1.25743	7.12467	6.41233	3.83364	2.68354	4.44113	37.,97	0.20-0.50	16.79896
West Bengal	2.30923	0.34642	1.96281	1.76653	0.67794	0.47452	1.48829	24.18	0.33-0.75	3.31794
Total States	43.14769	7.07414	36.07355	32.46621	16.42936	11.50055	24.573	31.88	-	64.04513
India	43.1885	7.09334	36.0807	32.4726	16.4527	11.5169	24.5788	31.92	-	64.0502
Note: * Not Assessed.										
Source: Annual Report 1999-2000, Ministry of Water Resources, Govt. of India										

[116] m.ha.m is a volume measure of a million ha surface area that is 1 m high

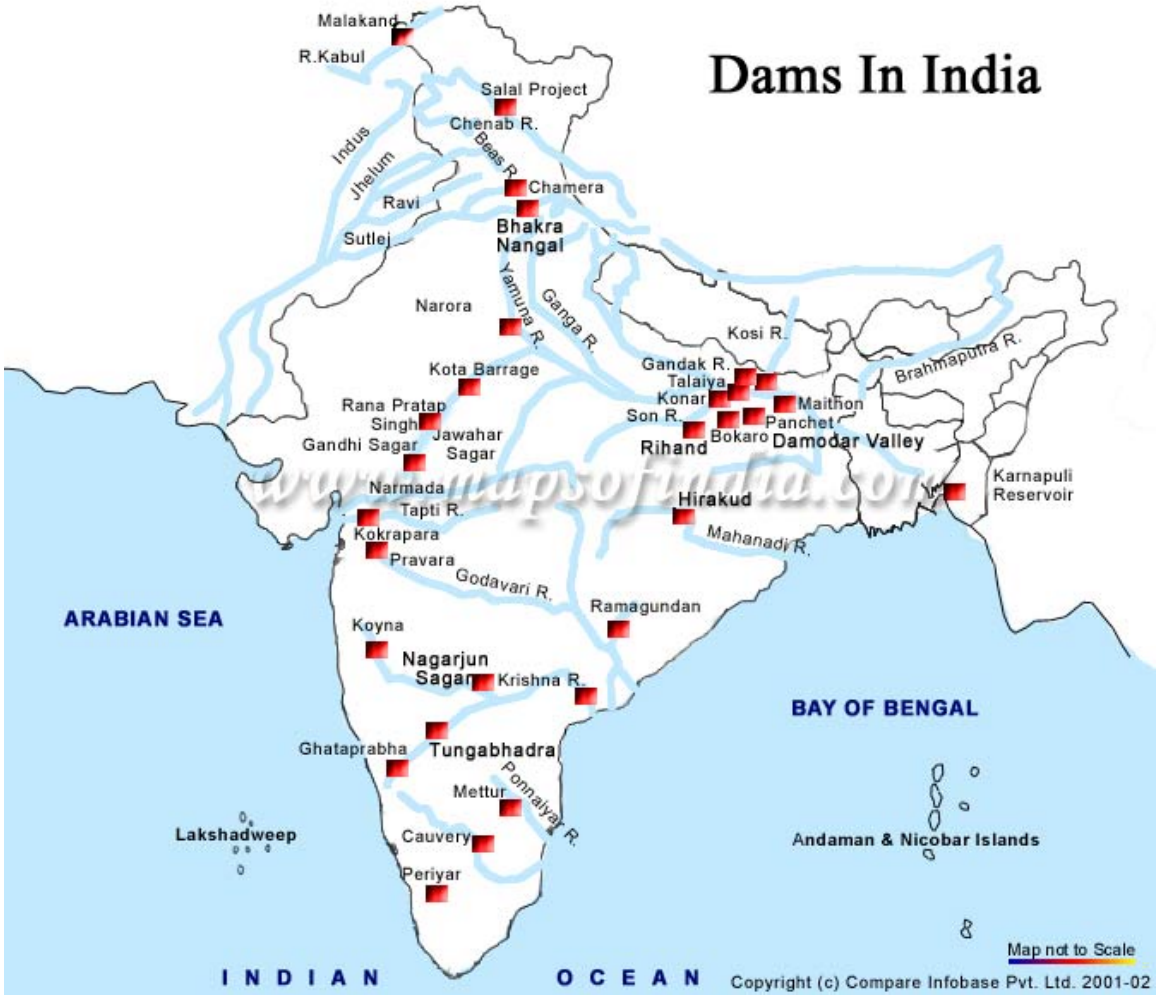

Figure 27 Map of major dams in India (http://www.mapsofindia.com/maps/india)

Figure 28 Main watersheds and irrigation canal system in India (http://www.mapsofindia.com/maps/india)

State descriptions

Table 28 State descriptions

	Descriptions [117]
Andhra Pradesh	Located in the southern part of India, Andhra Pradesh is bound in the north by Orissa and Madhya Pradesh, in the west by Maharashtra and Karnataka, in the south by Tamil Nadu and in the east by the Bay of Bengal. The state has a coastline of 974 kms. The state came into existence on November 1st, 1956 with the merger of Hyderabad and Andhra State. Infrastructure: Andhra Pradesh is well connected by road, rail, air and sea. Visakhapatnam is a major port. Hyderabad, Tirupati, and Visakhapatnam are air-linked. Hydro and thermal power projects meet the power requirements of the state. A number of new power projects are initiated. Agriculture: Agriculture is the main occupation and 70 percent of the population is engaged in agriculture and related activities. Rice is the major food crop and staple food. Other important crops are jowar, bajra, maize, ragi, small millets, pulses, tobacco, cotton and sugar cane. Forest covers 23 percent of the state. Industry: Several major industries are in operation around Hyderabad, which has now been nicknamed Cyberabad because of its Information Technology foray and location of major software industries in the city. Another industrial location is Visakhapatnam, which is also one of the major seaports of India. The state is promoting Information Technology in a big way and has one of the IT parks in Hyderabad, e.g., http://www.apinfrastructure.com/indexmain.html: Biotech Park: MoU with North Carolina Biotech Council and Research Triangle Park, Raleigh signed on Feb 4, 2002.
Arunachal Pradesh	Arunachal Pradesh is located in the eastern part of India. It shares international boundaries with Bhutan, Tibet, China and Myanmar and state boundaries with Assam and Nagaland. Before 1962 the state was known as North East Frontier Agency and was constitutionally part of Assam. Because of its strategic importance, it was administered by the Ministry of External Affairs until 1965 and subsequently by the Ministry of Home Affairs through the governor of Assam. In 1972, Arunachal Pradesh was constituted as a Union Territory and in 1987 it became the 24th State of the Indian Union. Agriculture: Agriculture is the main occupation of the people. Food grain production is continuously increasing and many cash crops and horticultural crops are being developed. Industry: The state has witnessed rapid progress in industrial development. Considerable efforts have been made to develop medium and small-scale industries. Local entrepreneurs are being encouraged to establish tea plantations. Resources: The important mineral in Arunachal Pradesh is petroleum. The state also has copper ore, gold and pyrites, limestone, dolomite and graphite.

[117] Almost literally adapted from http:///www.econowatch but see also: http://www.indiainfoline.com/econ/andb/states/states0.html

	Infrastructure: The state is well linked by road and has 330 km of national highway. Tourism: The tourist destinations are Tawang, Dirang, Bomdila, Tipi, Itanagar, Malinithan, Likabali, Pasighat, Along, Tezu, Miao, Roing, Daporijo,Namdapha, Bhismaknagar, Parashuram Kund and Khonsa
Assam	Assam, known during the epic period as Pragjyotisha or the place of eastern astronomy and later as Kamrupa, has been mentioned in the Allahabad pillar inscription of Samudragupta. Assam is strategically located and has international borders with China, Myanmar, Bhutan, and Bangladesh. It is surrounded on all other sides by predominantly hilly or mountainous tracts--Bhutan and Arunachal Pradesh on the north, Manipur, Nagaland and Arunachal Paradesh on the east and Meghalaya Mizoram and Tripura on the south. Agriculture: Assam is primarily an agrarian state, with more than 70 percent of the workforce engaged in agriculture and allied activities. Rice is the primary food crop; cash crops are jute, tea, cotton, oilseeds, sugarcane, potato etc. Horticulture crops like orange, citrus fruits, banana, pineapple, arecanut, coconut, guava, mango, and jackfruit are also grown in small quantities. Industry: Tea-based industry occupies an important place. Tea gardens occupy an area of about 2.31 lakh hectare. Resources: Assam is known for rich forest wealth with a large variety in flora and fauna. Coal, petroleum, natural gas, limestone, and minor minerals are produced. Infrastructure: The state is well linked by road, state highways, national highways and PWD roads. It has both broad gauge and metric gauge lines. Airports at Guwahati, Tespur, Dibrugarh, Lakhimpur, Silchar and Rowriah are civil airports. Tourism: The important places of tourist interest in the State are Kazirnaga National Park, Manas, Pobi-tora and Orang.
Bihar	Bihar was part of the Bengal presidency till 1911, when a separate province of Bihar and Orissa was created. In 1936 Bihar was made a separate province. The state is bounded in the north by Nepal, in the east by West Bengal, in the west by Uttar Pradesh and in the south by Orissa. Agriculture: Agriculture is the main occupation the people of the state. Principal foodgrain crops are paddy, wheat, maize, and pulses. Main cash crops are sugarcane, potato, tobacco, oilseeds, onion, chilies, jute and mesta. Industry: Major industries are two integrated steel plants, Bokaro steel and Tata Iron and Steel; secondary industries are steel making units, industrial alcohol and paper plants, copper concentrate expansion, granite cutting polishing, steel blast furnace, crystal glass, and steel rolling. Resources: The state is renowned for its rich mineral resources. The mineral products are coal, iron ore, bauxite, limestone, mica, pyrite, graphite, copper ore, etc. The state has a monopoly over production of uranium and pyrite. Infrastructure: The state is well linked by road, state highways, national highways, rural and

	district roads. It has a fairly good railway network. There are major airports at Patna, Ranchi, Jamshedpur, and Gaya. Tourism: The important places of tourist interest are Rajgir, Gaya, Bodh Gaya, Nalanda, Vaishali, Pawapuri, Ranchi, Hazaribagh.
Goa	Situated on the western coast of the Indian Peninsula, Goa is separated from Maharashtra by the Terekhol river in the north, and bordered by Karnataka in the south, the western Ghats in the east and the Arabian Sea in the west. Goa was a Portuguese colony until 1961 when it merged with India as a union territory along with Daman and Diu. In 1987, Goa was conferred statehood, and Daman and Diu were made a separate union territory. Agriculture: Rice is the main food crop. Pulses, ragi and other food crops are also grown in the state. Main cash crops are coconut, cashewnut, arecanut, sugarcane and fruits like pineapple, mango and banana. Industry: Goa has a number of large and medium sector units, and around 6000 small-scale units. There are 16 industrial estates besides the electronic city. Resources: Goa has vast resources of minerals. The major minerals are ferro-manganese, bauxite, and iron ore, which contribute substantially to the state's economy. Infrastructure: The state is well linked with roads, railways, air and seaports. Tourism: Important tourist centers are Colva, Calangute, Vagator, Baga, Harmaul, and Miramar beaches. It also has the oldest church in the country, which is a tourist attraction.
Gujarat	Situated on the western coast of the Indian Peninsula, the history of the state goes back to 200 BC. Gujarat is bound by the Arabian Sea in the west, Pakistan and Rajasthan in the north and northeast, Madhya Pradesh in the southeast and Maharashtra in the south. Agriculture: Gujarat is the main producer of tobacco, cotton, and groundnut in the country. It also contributes inputs to industries like textiles, oil and soap. Industry: One of the top most industrialized states in India, Gujarat attracts the cream of domestic and multinational investments. Resources: The important minerals produced are agate, bauxite, dolomite, fireclay, fluorite, fuller's earth, kaolin, lignite, limestone, chalk, calcareous seasand, perlite, petroleum and natural gas, silica sand and mouling sand. Infrastructure: Gujarat is well connected by roads, rail, air and seaports. Tourism: Religion, beaches, monuments and hill stations attract tourists.
Haryana	Located in the northern part of India, Haryana is bound by Uttar Pradesh in the east, Punjab in the west, Himachal Pradesh in the north and Rajasthan in the south. The national capital territory of Delhi is located just into Haryana. Agriculture: Agriculture forms the main occupation of the population. Rice, wheat, jowar, bajra, maize, barley and pulses, sugarcane, cotton, oil seeds and potato are the major crops.

	Industry: The location, that is, being near the National Capital Territory of Delhi and the abundance of resources, has helped Haryana to achieve the status of being the leading industrialized state in India. Resources: Principal minerals produced are kaolin, limestone, lime-kankar, saltpeter, tin and tungsten. Infrastructure: All the villages are well connected by road. The state is well connected by a rail and air network. Tourism: The major tourist attraction is the Surajkund Crafts Mela besides the Mori hill, Pinjore gardens etc.
Himachal Pradesh	Located in the northern part of India, Himachal Pradesh is bound by Jammu and Kashmir in the north, Punjab in the west and south-west, Haryana in the south, Uttar Pradesh in the south-east and by Tibet in the east. Agriculture: The state is predominantly agro-pastoral economy and the majority of its population works in agro-related industry. Industry: Handloom and handicrafts are important cottage industries, as is sericulture. Resources: Principal minerals are limestone, rock-salt, gypsum, silica-sand and barite. Infrastructure: The state is well connected by road, rail and air. Himachal Pradesh has three airports at Bhuntar, Jubbarhatti, and Gaggal. Tourism: Places of tourist interest are Kullu, Manali, Dharmasalas, Shimla, Plampur, Chamaba Delhousie, Naina Devi, etc.
Jammu and Kashmir	Located in the northern tip of India, Jammu and Kashmir are bound in the north and east by China, in the west by Pakistan and in the south by Himachal Pradesh and Punjab. Agriculture: The majority of the state depends on agriculture. Paddy, wheat and maize are the major crops. Barley, baira and jowar are cultivated in some parts. Gram is grown in Ladakh. Industry: Handicrafts, the traditional industry in the state, have been receiving top priority. The handicraft products have demand both inside and outside the country. Resources: Coal, gypsum, and limestone, are the major minerals produced. Infrastructure: The state is well linked with road, rail and air. Shrinigar, Jammu, and Leh are the major airports. Tourism: Kashmir valley was the major tourist attraction.
Karnataka	Located in the southern part of India, Karnataka is bound by Goa and Maharashtra in the north, Andhra Pradesh in the east, Tamil Nadu and Kerala in the south.

	Agriculture: Agriculture is the main occupation, accounting for nearly 65 percent of the workforce. Paddy, jowar, ragi, bajara, maize, wheat and pulses are some of the important crops. Industry: Karnataka is one of the leading industrial states of the country. It has been attracting both domestic and foreign investments and is home to some of the leading Indian and multinational corporations. Resources: The state is rich in mineral resources. Important minerals are iron ore, copper, manganese, chromite, china clay, limestone and magnesite. It is the main gold producing state in India. Infrastructure: The state is well linked with road, rail, air and a seaport network. Bangalore, Belgaum, Mangalore and Hubli are the main airports. Tourism: Bangalore is known for a variety of its parks, which are the main tourist attractions, e.g., the Mysore Brindavan Gardens and Srirangapattana.
Kerala	Located in southern part of India, Kerala is bound by the high Western Ghats on the east and the Arabian Sea on the west. According to the geographical features the state can be divided into hills and valleys, midland plains and coastal belts. Agriculture: Agriculture is the main occupation of the people of the state; 50 percent of the population depends upon agriculture for their livelihood. Kerala is a major producer of coconut, rubber, pepper, cardamom, ginger, gocoa, cashew, arecanut, coffee and tea. Industry: Kerala has the highest percentage literacy rate in the country. It has a number of large, medium and small-scale industrial units. Traditional industries co-exist with modern ones. Resources: Kerala has an abundance of important minerals like limonite, rutile, monazite, zircon, sillimanite, clay and quarts sand. Infrastructure: Kerala is well linked with road, rail, air and a seaport network. Thiruvanathapuram, Kochi and Kozhikode are the important airports in the state. Tourism: Kerala has the most attractive wildlife sanctuaries at Thekkady on the banks of river Periyar. Kovalam beach, Padmanabaswami temple, and Shabarimala temple are some of the important tourist centers.
Madhya Pradesh	Madhya Pradesh is the centrally situated state of the country. It is surrounded by seven states, Rajasthan on the northwest, by Uttar Pradesh on the north, Bihar on the north-east, Orissa on the east, Andhra Pradesh and Maharashtra on the south and Gujarat on the west. Agriculture: Agriculture is the mainstay of the state's economy. It is the leading producer of oilseeds, pulses, soybeans, gram and linseed. Wheat, rice, jowar, sugarcane, cotton, tuar, and mustard are the other principal crops cultivated. Industry: The state has traditional industries coexisting with high-tech industries like petrochemicals, electronics, telecommunications, and automobiles. It also produces optical fiber for telecommunication needs.

	Resources: Madhya Pradesh is the leading state in the country in mineral production; 25 types of minerals are being mined, e.g., coal, bauxite, iron-ore, manganese-ore, rock-phosphate, dolomite, copper-ore, limestone. Infrastructure: The state is well linked with roads, rail and air. Bhopal, Gwalior, Indore, Khajuraho and Raipur are the important airports. Tourism: Ancient temples, palaces, forts and archeological cites are major tourist attractions.
Maharashtra	Located in the north center of peninsular India, Maharahtra is bordered by the Arabian Sea in the west, Gujarat and Madhya Padesh in the north, Madhya Pradesh in the east and Karnataka and Andhra Pradesh in the south. Agriculture: The state is the major producer of oilseeds, groundnut, sunflower, soybean, etc. It also produces cash crops like cotton, sugarcane, turmeric and vegetables and has a vast area under horticulture cultivation. Industry: The industrial powerhouse of India, Maharashtra occupies a prominent place in the country's economy. In Mumbai, the commercial capital of the country, all leading industrial/corporate houses of the country are represented. Resources: The important minerals produced are coal, manganese ore, bauxite, limestone, dolomite, kyanite, and silica sand. Infrastructure: The state is well linked with road, rail, air and a seaport network. It has a total of 24 air fields/airports. Of these, four are international airports. Tourism: Some important tourist places include Ajanta, Ellora, Elephanta, Kanheri and Karla caves, Mahabaleshwar, Matheran and Panchganj, Panhala Hill stations and religious places.
Manipur	Manipur, located in the eastern part of India is geographically divided into two tracts: the hills with five districts and the plains with four districts. It is bound by Myanmar in the east, Nagaland in the north, Assam in west and Mizoram in the south and southwest. Agriculture: Agriculture is the single largest source of livelihood of the majority of the rural masses and is also the mainstay of the state's economy. Industry: Manipur is making rapid strides towards industrialization and a number of small and medium scale units exist. Resources: Asbestos, chromite, copper ore, coal, bog-iron, lignite, limestone, nickel ore and petroleum are reported to be present. Infrastructure: Manipur is well connected with road, rail and air. Tourism: Temples, war memorials, parks and lakes and the picturesqueness of the location attracts tourists to the state.
Meghalaya	Meghalaya, initially created as an autonomous state within Assam, was converted to the full-

	fledged state of Meghalaya in 1972. Agriculture: Agriculture is the single largest source of livelihood of the majority of the rural masses and is also the mainstay of the state's economy. Besides the major food crops of rice and maize, Meghalaya is renowned for its oranges, pineapple, banana, jackfruits, and its temperate fruits like plum, pears and peaches. Industry: The state has a number of small and medium scale industries. Resources: Mineral wealth of Meghalaya includes coal, silimanite, limestone, dolomite, fire clay, feldspar, quartz and glass sand. Infrastructure: The state is well linked with a road network. It is not connected by a railway network. The only airport in the state is located at Umroi. Tourism: Shillong, the capital city, has a number of beautiful tourist spots: Ward's Lake, Lady Hydari Park, Polo ground, Mini Zoo, Elephant falls and Shillong peak.
Mizoram	Mizoram was one of the districts of Assam till 1972, when it became a union territory in 1987. Agriculture: Agriculture is the only occupation of the people of the state. Main horticulture crops are orange, lemon, kagzi lime, passion fruit, pineapple and papaya. Industry: The state is categorized as a backward area and has no industry. Resource: Mizoram has reported the occurrence of lignite, sandstone and pyrites in small quantities. Infrastructure: The state is well linked with roads and the state capital is air linked. Tourism: The capital attracts tourists.
Nagaland	Situated in the extreme north east of India, Nagaland is bound by Arunachal Pradesh in the north, Assam in the west, Manipur in the south and Myanmar in the east. Agriculture: Agriculture is the only occupation of the people of the state. Rice is the important food grain cultivated in the state. Industry: The process of industrialization in the state is in its infancy and the need to have more industries has been recognized. Resources: Minerals occurring in the state are limestone and chromite. Infrastructure: Nagaland is a well knit with state and district road networks. Dimarpur is the only place where rail and air services are available. Tourism: Its picturesque location attracts tourists.
Orissa	Orissa, situated in the north-eastern part of Indian peninsula is bound by the Bay of Bengal in the east, West Bengal in the east and north-east, Bihar in the north, Madhya Pradesh in

	the west and Andhra Pradesh in the south. Agriculture: Agriculture is the dominant sector in the state's economy. Rice is the main crop, and sugar cane is the main cash crop. Industry: The state has both traditional and modern industries co-existing and there are a number of small and medium scale industries. Resources: One of the mineral rich states of India, Orissa is the lead producer of chromite, graphite, bauxite, manganese ore and dolomite. Infrastructure: The state is well linked with road, rail, air and a seaport network. Tourism: Temples, palaces, historical monuments and cites are tourist attractions.
Punjab	Situated in the northwest corner of the country, Punjab is bound in the west by Pakistan, the north by Jammu and Kashmir, the northeast by Himachal Pradesh, and in the south by Haryana and Rajasthan. Agriculture: Agriculture is the mainstay of Punjab's economy. The state contributes 80 percent of wheat and 43 percent of rice to the state exchequer. Industry: The Punjab has a number of small, medium and large-scale units. Resources: Limestone, quartzite, glass sand and foundry sand and potash are some of the important resources. Infrastructure: The state is well linked by road, rail and air. Tourism: The state has a large number of places of tourist interest including the Golden Temple, Durgiana Mandir and Jallianwala Bagh.
Rajasthan	The second largest state in India in terms of area, Rajasthan is located in the western part of India. The state is flanked by Pakistan in the west, Punjab, Haryana, Utatar Pradesh and Madhya Pradesh in the north, northeast and southeast and Gujarat in the southwest. Agriculture: The major crops are rice, barley, jowar, millet, maize, gram, wheat, oilseeds, pulses, cotton and tobacco. Industry: Rajasthan, as mineral rich state has a number of mineral based industries besides textile, chemicals etc. Resources: Rajasthan has rich deposits of zinc concentrates, emerald, garnet, gypsum, silver ore, asbestos, felspar and mica. It is also abundant in salt rock phosphate, marble and red stone deposits. Infrastructure: The state is well linked by road, rail and air. Tourism: Forts, palaces, and a Tiger Sanctuary attract tourists. Jaipur is the main tourism destination of most of the foreign tourists visiting the state.

Sikkim	Sikkim is bound by Bhutan in the east, Tibet in the north, Nepal in the west and West Bengal in the south. Agriculture: The state's economy is basically agrarian. Maize, rice, wheat, potato, large cardamom, ginger and orange are the principal crops. Industry: The state has been declared as industrially backward. New industrial policies have been formulated and promotional efforts are initiated to industrialize the state. Resources: The important mineral resources are copper, lead and zinc. Infrastructure: The state is well linked by road and rail. There is no airport. Tourism: Gangtok, Bakhim, Yumthang, Dzongri, Varsey and monasteries are some of the important locations.
Tamil Nadu	Tamil Nadu located in the south of India, is the successor to the old Madras Presidency, which in 1901 covered the bulk of the southern peninsula. Tamil Nadu is bounded in the north by Andhra Pradesh and Karnataka, in the west by Kerala, in the east by the Bay of Bengal and in the south by the Indian Ocean. Agriculture: Agriculture is the major occupation in Tamil Nadu. Major crops are paddy, millets, jowar, bajra, ragi, maize and pulses. Commercial crops cultivated in the state include sugarcane, cotton, sunflower, coconut, cashew, chilies, gingelly and groundnut. Plantation crops like tea, coffee, cardamom, cashew and rubber are also grown. Industry: Tamil Nadu is one of the leading industrialized states in the Indian Union. It has been attracting investment from leading multinational giants. The state has industries in basically all sectors. Resources: The important mineral resources are lignite, limestone, magnasite, mica, quartz, salt, bauxite and gypsum. Infrastructure: Tamil Nadu is well linked by road and rail. Chennai - the International Airport, and domestic airports at Tiruchirapalli, Madurai, Coimbatore and Salem connect the state with rest of the country and the world. Tourism: Chennai, Mamallapuram, Poompuhar, Kancheepuram, Kumbakonam, Dharasuram, and Chidambaram are some of the important tourist locations.
Tripura	Tripura is strategically situated between the river valleys of Myanmar and Bangladesh. Encircled almost on three sides by Bangladesh, it is linked with Assam and Mizoram in the northeast. Tripura has a long historic past, a tribal culture and a fascinating folklore. The history of Tripura can be understood from Rajmala chronicles of king Tripura and writings of other Mohammedan historians. There are references of Tripura in the Mahabharata and Puranas. Agriculture: 24.3 percent of the area is available for agriculture use. The principal crops are paddy, wheat, jute, mesta, sugarcane, potato and oil seeds. Agriculture is being practiced in about 2.5 lakh hectare; rice production in 94-95 was 4 lakh tonnes.

	Industry: Tea is a major industry. There are 55 registered gardens covering 6045 hectares and producing 54 lakh kg of tea per year. Tripura Tea Development Corporation has started new plantations. A jute mill, set up in Agartala under the public sector, produces about 20 tonnes of jute products per day and employs about 2,000 persons. In 1994-95, 30,238 hectares were rubber plantations. Handloom weaving is the single largest industry. Tripura is abundant in natural gas and a number of gas-based industries have sprung up. Resources: Tripura is abundant in natural gas, cane, bamboo and jute. Infrastructure: The total length of road in Tripura is 12,547 km of which major district roads are 454 km and other districts roads are 1,463 km. Total length of railway lines within the state is 44 km, which has been extended up to Kumarghat in North Tripura District. Agartala is the main airport and connected with Calcutta, Guwahati and Delhi. Tourism: Important tourist centers are Nirmahal, Sipahijala, Dumboor Lake, Kamalasagar, Jumpui Hill, Unakotti and Matabari. The government has set up an advisory committee to boost tourism.
Uttar Pradesh	Uttar Pradesh, the most populous state in India and 4th in area, covers about nine per cent of the total area of the country. The state is bounded by Nepal in the north, Himachal Pradesh in the northwest, Haryana on the west, Rajasthan on the southwest, Madhya Pradesh in the south and southwest and Bihar in the east. A new state, Uttaranchal, has been carved out, which will have Nainital as its capital Agriculture: Agriculture is the main occupation of the people. Uttar Pradesh is the largest producer of foodgrains and oilseeds in the country. It leads in production of wheat, maize, barley, gram, sugarcane and potatoes. Industry: The organized industrial sector of Uttar Pradesh was, until recently, confined to agro-based industries such as sugar, cotton textiles, edible oils, miscellaneous food preparations, paper etc. Now the industrial sector produces electrical equipment, machinery and basically all industrial products. Resources: The major minerals produced in the state include coal and lignite. Infrastructure: The state is well linked by road and rail. Lucknow, the capital is linked by air. Tourism: The state is a treasure of rare scenic beauty spots and flora, ideal health resorts, high mountain peaks, fascinating rivers and captivating valleys. Besides the ancient pilgrimage places it also has world-renowned monuments like the Taj Mahal.
West Bengal	West Bengal is bound in the north by Sikkim and Bhutan, in the east by Assam and Bangladesh, in the south by the Bay of Bengal and in the west by Orissa, Bihar and Nepal. Agriculture: Agriculture is the main occupation of the people of West Bengal. The major agriculture products include rice, jute, tea, potatoes, oilseeds, tobacco, wheat, barley and maize. Industry: Major industries include engineering, automobiles, chemicals, pharmaceuticals, aluminum, ceramics, jute, cotton textiles, tea, paper, leather, footwear etc.

	Resources: Coal and china clay are the two important minerals. Infrastructure: The state is well linked by road, rail, air and sea with international airports at Dum Dum, port at Calcutta and Haldia. Tourism: Calcutta, the commercial capital of the northeastern states, attracts both national and international tourists.