Mapping vulnerability to multiple stressors: climate change and globalization in India


Abstract

There is growing recognition in the human dimensions research community that climate change impact studies must take into account the effects of other ongoing global changes. Yet there has been no systematic methodology to study climate change vulnerability in the context of multiple stressors. Using the example of Indian agriculture, this paper presents a methodology for investigating regional vulnerability to climate change in combination with other global stressors. This method, which relies on both vulnerability mapping and local-level case studies, may be used to assess differential vulnerability for any particular sector within a nation or region, and it can serve as a basis for targeting policy interventions.

1. Introduction

Vulnerability has emerged as a cross-cutting theme in research on the human dimensions of global environmental change (Downing et al., 2000; Kasperson and Kasperson, 2001; Polsky et al., 2003). Yet vulnerability to climate change has traditionally been studied in isolation from other stressors, including structural changes associated with economic globalization (O’Brien and Leichenko, 2000). It has been acknowledged that exposure to multiple stressors is a real concern, particularly in developing countries, where food security is influenced by political, economic, and social conditions in addition to climatic factors (Leichenko and O’Brien, 2002). Nevertheless, there has been no systematic methodology to operationalize vulnerability in the context of multiple stressors. Here, we present a method for mapping vulnerability to two stressors at the sub-national level, and we apply this method to examination of vulnerability in India’s agricultural sector.

Our approach comprises four main steps: (1) developing a national vulnerability profile for climate change at the district level; (2) developing a national vulnerability profile for an additional stressor at the district level; (3) superimposing the profiles to identify districts in India that are “double exposed”; and (4) conducting case studies in selected districts. This method may be used to assess differential vulnerability for any particular sector within a nation or region, and it can serve as a basis for targeting policy interventions.

We focus on India’s agricultural vulnerability to two stressors: climate change and economic globalization. Among India’s population of more than one billion people, about 68% are directly or indirectly involved in the agricultural sector. This sector is particularly vulnerable to present-day climate variability, including multiple years of low and erratic rainfall. Scenarios generated by global circulation models show that India could experience warmer and wetter conditions as a result of climate change, particularly if the summer monsoon becomes more intense (Mitra et al., 2002; Kumar et al., 2002; McLean et al., 1998). However,
increased rates of evapotranspiration due to the higher temperatures may offset the increased precipitation, leading to negative impacts on soil moisture (Kumar and Parikh, 2001). There are also considerable uncertainties associated with climate model projections of tropical monsoon behavior, and simulations that include sulfate aerosol forcing indicate decreasing summer monsoon rainfall (Bagla, 2002; Webster et al., 1998; Lal et al., 1995). Although the direct temperature and CO₂ effects of climate change may lead to productivity increases for some irrigated crops (Aggarwal and Mall, 2002), there is general consensus that major agricultural production areas are likely to be adversely affected by climate change, particularly in areas that become increasingly water-stressed (Dinar, 1998; Kumar and Parikh, 2001; Lal et al., 1998; Gadgil, 1995).

The agricultural sector in India is influenced by more than changing climatic conditions. Widespread promotion of Green Revolution technologies during the 1960s increased agricultural yields in India for some crops and farmers by introducing high-yielding varieties that depend on inputs, including irrigation, chemical fertilizers, and pesticides (Goldman and Smith, 1995; Freebairn, 1995). In recent years, national and state agricultural policies have emphasized decentralized and participatory natural resource management, particularly for practices such as watershed development and agroforestry (Sanyal, 1993). At same time, rapid liberalization of the Indian economy has had significant structural effects on Indian agriculture (Bhalla, 1994; Chaudhury, 1998; Gulati, 1999; Gulati and Kelley, 1999; Sen, 1999). Since 1991, economic reforms have included reductions and changes in import and export restrictions and tariffs, changes in access to agricultural credit, and reductions of production subsidies (UNIDO, 1995; Rajan and Sen, 2002). Although liberalization of agricultural trade has been limited relative to other sectors of the Indian economy, India’s potential participation in the WTO Agreement on Agriculture suggests that greater changes are forthcoming (Gulati et al., 1999; Rajan and Sen, 2002). The effects of these economic changes are expected to be uneven, with some regions and farmers benefiting from market liberalization and from new inflows of investments and technology, while others may have difficulty adjusting to a more open economy, particularly to the effects of increasing competition from agricultural imports (Gulati and Kelley, 1999; Mittelman, 2000).

In the remainder of the paper, we illustrate our four-step approach to assessment of regional vulnerability in the context of multiple stressors. In Section 2, we present a profile of regional agricultural vulnerability to climate change in India. Our profile focuses on sensitivity to dry conditions because a greater part of the Indian subcontinent is located in the semi-arid tropics, where rainfall is the key limiting factor in agriculture.² Section 3 presents a profile of India’s regional agricultural vulnerability to economic globalization. Using a representative basket of crops that are likely to be affected by competition from agricultural imports, we evaluate sensitivity to international trade as a function of crop productivity and distance to major ports. Those regions that have low crop productivity and/or are very close to international ports are considered more vulnerable to competition from international imports than those regions that have high productivity and/or are located farther from international ports. Trade sensitivity thus provides insight into which regions are vulnerable to the negative effects of economic globalization.³ In Section 4, we combine the climate change and globalization assessments to identify districts in India that are likely to be “double exposed” to both processes. These areas can be considered critical areas or “hot spots” in terms of vulnerability. In Section 5, we present and discuss the role of case studies in this methodology for assessing vulnerability. Case studies provide a means of “ground truthing” the macro-level vulnerability profiles. In addition, they can be used to identify local circumstances and institutional factors that are important in terms of vulnerability, yet do not come across in the macro-indicators. In the concluding section, we discuss some of the strengths and weaknesses of our approach, and identify some challenges for future research on vulnerability to multiple stressors.

2. Vulnerability to climate change

The first step in our approach involves the creation of a climate change vulnerability profile. Vulnerability to climate change is generally understood to be a function of a range of biophysical and socioeconomic factors. The most recent report of the Intergovernmental Panel on Climate Change (IPCC) provides a useful typology suggesting that vulnerability may be characterized as a function of three components: adaptive capacity, sensitivity, and exposure (McCarthy et al., 2001). Adaptive capacity describes the ability of a system to adjust to actual or expected climate stresses, or to cope with the consequences. It is considered “a function of wealth, technology, education, information, skills, 

²Although agricultural sensitivity to storms and flooding may also be altered under climate change, the nature of the changes remains highly uncertain.

³We focus on agricultural imports as a key indicator of the effects of globalization on agriculture because competition from agricultural imports represents an issue of critical concern to developing countries, as witnessed by the recent collapse of the WTO negotiations in Cancun, Mexico in September 2003. These talks collapsed largely as the result of disagreement between representatives of advanced and developing countries over agricultural trade issues.
infrastructure, access to resources, and stability and management capabilities” (McCarthy et al., 2001, p. 8). Sensitivity refers to the degree to which a system will respond to a change in climate, either positively or negatively. Exposure relates to the degree of climate stress upon a particular unit of analysis; it may be represented as either long-term changes in climate conditions, or by changes in climate variability, including the magnitude and frequency of extreme events. In this study we focus on exposure to long-term climate change as projected by global climate models. Nevertheless, our measures of sensitivity and adaptive capacity can also be used to represent vulnerability to climate variability, as farmers will be adapting to changes in extreme temperatures and monsoon variability as much as to changes in mean conditions.

Our approach applies the IPCC typology to develop measures of adaptive capacity, sensitivity and exposure. In effect, we are operationalizing the IPCC definition of vulnerability in a sub-national assessment to show how different factors that shape vulnerability vary within one country. While our approach represents only one interpretation of the IPCC typology, it does provide an important entry point for discussions and debates related to the utility of vulnerability mapping at sub-national levels.

In developing our climate change vulnerability profile, we assumed that climate change exposure (i.e., ongoing and future exposure) will affect current sensitivity, either positively or negatively, and that farmers will respond to these changes in climate sensitivity if they have sufficient adaptive capacity. Thus the vulnerability profile is constructed by combining indices for adaptive capacity with sensitivity indices that take into account exposure to climate change.

To measure adaptive capacity, we identified significant biophysical, socioeconomic, and technological factors that influence agricultural production.4 The biophysical indicators used in the profile consisted of soil conditions (quality and depth) and ground water availability. We selected these indicators based on the assumption that areas with more productive soil and more groundwater available for agriculture will be more adaptable to adverse climatic conditions and better able to compete and utilize the opportunities of trade.5 Indicators for soil quality include the depth of the soil cover and severity of soil degradation, while indicators of groundwater availability are based on estimates of the total amount of replenishable groundwater available annually.6

Socioeconomic factors consisted of levels of human and social capital, and the presence or lack of alternative economic activities. Levels of human and social capital provide basic indicators of the economic endowments of the district and of the capacity for the communities in a district to engage in collective economic and social activities. Human capital was represented by adult literacy rates, while social capital was measured by degree of gender equity in a district.7 The presence of alternative economic activities provides an indicator of the ability of farmers in a district to shift to other economic activities in response to reduced agricultural income resulting from adverse climatic conditions such as drought. Presence of alternative economic activities is measured by the percentage of the district workforce that is employed in agriculture and by the percentage of landless laborers in the agricultural workforce.8

Technological factors consisted of the availability of irrigation and quality of infrastructure. Districts with higher irrigation rates and/or better infrastructure are expected to have a higher capacity to adapt to climate fluctuations and other economic shocks. Irrigation rates are measured by net irrigated area as percentage of net sown area.9 Quality of infrastructure is measured using

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6Data for depth of soil cover was obtained from a digitized soil cover map of India from the Atlas of Agricultural Resources of India (NATMO, 1980). Data for the severity of soil degradation was obtained from a digitized map “India Soil Degradation—Human Induced” from the National Bureau of Soil Survey and Land Use Planning (NBSS-LUP, 1994) This composite map is based on three indices: (1) types of soil degradation; (2) degree of degradation; and (3) extent of degradation. Types of degradation include water erosion, wind erosion, chemical deterioration (salinization, loss of nutrients), physical deterioration (water logging), stable terrain (with slight water erosion), and soil not fit for agriculture. Data on replenishable ground water resources is taken from Central Ground Water Board, Ministry of Water Resources (CGWB (Groundwater Statistics), 1996). It is calculated as the total amount of groundwater which is replenishable annually, depending upon the amount of rainfall, recharge from the canals, surface water bodies and change in land cover.

7Gender equity is calculated based on indicators of female child mortality rates and female literacy rates. Districts with female child mortality rates that are in excess of natural rates and/or lower female literacy rates have lower values for gender equity (Drèze and Sen, 2002, pp. 88–99).

8Landless laborers are generally poor and have little security of income: in times of agricultural distress, laborers are the first to lose their income. The share of landless laborers in a district also provides an indirect indicator of population pressures on available land in a district.

9Water scarcity is the main productivity constraint for Indian agriculture. Irrigation data was available for most of the districts of India in 1991 from the Agricultural Census. However, a total of 63 districts (many in the northeast) were missing irrigation data in the Agricultural Census. These data were consequently gathered from the following data sources: Sanghi et al. (1998); Indian Agricultural

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4Our adaptive capacity profile is based on conditions in 1991 because this is the most recent year in which there is comprehensive social, infrastructure, and agricultural data available at the district level in India. The 2001 Census was recently released, and we will be incorporating these new social and economic data in our future analyses.

5We do not include indicators of evaporation or soil moisture in the biophysical index because these factors are already captured via the evapotranspiration measures that are included in the climate sensitivity index.

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the Infrastructure Development Index of the Centre for Monitoring of Indian Economy (CMIE, 2000). The CMIE index is published as a single composite index number for each district-based availability of facilities for transport energy, irrigation, bunking, communication, education, and health.10

Based on the above biophysical, social, and technological indicators, Fig. 1 depicts adaptive capacity in 1991 across India’s 466 districts.11 This map shows higher degrees of adaptive capacity in districts located along the Indo-Gangetic Plains (except Bihar) and lower adaptive capacity in the interior portions of the country, particularly in the states of Bihar, Rajasthan, Madhya Pradesh, Maharashtra, Andhra Pradesh, and Karnataka.

To measure sensitivity under exposure to climate change, we first constructed a climate sensitivity index (CSI) that measures dryness and monsoon dependence, based on a gridded data set for 1961–1990 (New et al., 1999). A large part of India is located within the semi-arid tropics, which are characterized by low and often erratic rainfall (Gulati and Kelley, 1999; Ribot et al., 1996). Much of the country relies on tropical monsoons for approximately 80% of the total annual rainfall, and most of this falls within 3 or 4 months (Mitra et al., 2002). When the monsoons fail to deliver rain at the proper times, agriculture is adversely affected. The CSI thus includes two components that indirectly represent the influence of extreme events on Indian agriculture, averaged over the 30-year normal period. The dryness index can be considered a smoothed representation of drought sensitivity; and the measure of monsoon dependency represents an average of extreme rainfall events. Changes in the magnitude and frequency of extreme events may be evident in the CSI if time-series comparisons are made at a decadal scale. Indeed, it is likely that the CSI will not change as a continuous

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(footnote continued)

10Since the CMIE publishes the data as one composite index figure and irrigation rate is part of their index, irrigation is counted twice in the technological vulnerability index. In practice this does not have much of an influence on the final index, given the importance of irrigation and the fact that the CMIE gives irrigation only 20% weight. The formula and detailed data that the CMIE uses in the calculation of the index is described at [http://www.cmie.com/products/eis/index.htm](http://www.cmie.com/products/eis/index.htm).

11In the 2001 Census, there are 592 districts in India.
function, but instead vary as a response to transient changes in climate.

Climate sensitivity for India in the period 1961–1990 is shown in Fig. 2a. The areas with high to very high climate sensitivity for agriculture are located in the semi-arid regions of the country, including major parts of the states of Rajasthan, Gujarat, Punjab, Haryana, Madhya Pradesh, and Uttar Pradesh.

We then incorporated the exposure component into the CSI using results from the HadRM2 model, a regionally downscaled general circulation model (Turnpenny et al., 2002) (Fig. 2b). The CSI was recalculated using the temperature differential and the ratio of precipitation changes between the control and 2 × CO2 model runs. Although the HadRM2 model represents only one possible scenario of climate change, it nonetheless shows that potential shifts in regional climate sensitivity may occur as the result of exposure to climate change. To illustrate the uncertainty associated with climate change exposure, a range of model results would have to be presented and compared (Mears et al., 2001). Under the HadRM2 scenario, district climate sensitivity noticeably increases in Uttar Pradesh, Madhya Pradesh, and Maharashtra.

Finally, to depict climate change vulnerability in India, we summed the district-level index of adaptive capacity with the index of climate sensitivity under exposure. The resulting climate vulnerability map (Fig. 3) represents current vulnerability to future climate change across districts. The map depicts the range of relative climate vulnerability at the district level in India. It is important to note that the districts with the highest (or lowest) climate sensitivity under the scenario of climate change used here are not necessarily the most (or least) vulnerable. For example, most districts in southern Bihar have only medium sensitivity to climate change, yet are still highly vulnerable to climate change as the result of low adaptive capacity. By contrast, most districts in northern Punjab have very high sensitivity to climate change, yet are found to be only moderately vulnerable as the result of high adaptive capacity. Assessment of both adaptive capacity in combination with climate change sensitivity and exposure is thus
crucial for differentiating relative vulnerability to climate change.

3. Vulnerability to globalization

Climate variability and change is a concern to farmers in India, where agricultural productivity is closely related to the timing and strength of the northeast and southwest monsoons. However, Indian farmers have also been exposed to structural changes in the agricultural sector resulting from trade liberalization and related policies pursued by the Indian government since 1991 (Gulati and Kelley, 1999; Bhalla, 1994). Liberalization of agricultural trade may provide new opportunities for some Indian farmers to engage in production for export markets, but at the same time, it may expose many other farmers to competition from imported agricultural products. One example of these potential negative effects is the liberalization of trade in edible oils and oilseeds which led to a crash in domestic oilseeds prices in the late 1990s due to imports of inexpensive Malaysian palm oil (Shiva, 2000). For farmers in southern India, particularly in the state of Andhra Pradesh, this price crash proved devastating and is associated with the beginning of a long wave of suicides by bankrupt farmers (Menon, 2001).

The second step in our approach entails mapping vulnerability to globalization (i.e., liberalization of agricultural trade). Although a vulnerability framework is not typically applied to economic studies, a growing literature shows that some regions and social groups are likely to be disproportionately vulnerable to the negative effects of globalization (Conroy and Glasmeier, 1993; Mittelman, 1994, 2000; Deardorff and Stern, 2000; O’Brien and Leichenko, 2003). Vulnerability to globalization may also be understood through the typology of adaptive capacity, sensitivity, and exposure. The same biophysical, socioeconomic, and technological indicators that represent adaptive capacity for climate change also serve to characterize adaptive capacity for agricultural trade liberalization: soil conditions and groundwater availability influence the types of crops that can be cultivated, while literacy levels, gender discrimination, infrastructure, and the availability of irrigation provide indicators of social and economic means of adapting to changing conditions of production. The percentage of farmers and agricultural wage laborers not only represents the importance of agriculture to the district, but also captures the presence or lack of alternative economic activities.

In mapping district-level globalization sensitivity under exposure, we focus on exposure to import competition. While growing dependence on crops for export may also leave farmers vulnerable to economic disruption as the result of world price fluctuations, we limit our attention to import-sensitive crops because import competition represents a greater immediate threat to Indian agriculture. Our import sensitivity map takes into account cropping patterns and productivity of a representative basket of crops that may be subject to competition from imports, and the distance of the district to the nearest international port. Import-competing crops that are less productive or produced closer to international ports face greater competition than crops that are more productive or produced in more remote inland areas. Fig. 4 displays our map of import sensitivity. Exposure to import competition was assumed to be uniform across the representative crops so that all crops are weighted equally (i.e., assumed to be equally sensitivity to import competition). Regions with high or very high import sensitivity are found

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12 Mapping of regional export sensitivity requires a different set of crops and different assumptions about factors driving vulnerability.
13 Crops were selected for inclusion in the indices based on importance of the crop nationally, whether or not the crop was internationally traded, geographical representativeness (i.e., we chose crops that are grown throughout the country), and availability of district-level production area and yield data. Based on these criteria, the following import-sensitive crops that have been imported since 1991 and/or are expected to face competition from international imports were selected for inclusion in the index: rice, wheat, groundnuts, rape/mustard seed, gram, and maize.
14 Capturing differential exposure to liberalization would require application of a range of future trade liberalization scenarios and differential weightings of crops used in the trade sensitivity index.
throughout the country, but are most concentrated in the southern and central states of Karnataka, Maharashtra, Madhya Pradesh, and in the eastern state of Assam.

The globalization vulnerability profile was constructed by combining for each district the values of the adaptive capacity (Fig. 1) and import sensitivity indices (Fig. 4). The resulting map (Fig. 5) shows high vulnerability in most of Rajasthan and Karnataka, as well as in substantial portions of Bihar, Madhya Pradesh, Maharashtra, Gujarat, and Assam. Notable areas of low vulnerability occur along the Indo-Gangetic plains, a highly productive region that is commonly referred to as the breadbasket of India.

4. Vulnerability to climate change and globalization: mapping double exposure

The third step of our approach combines information from the climate and globalization vulnerability maps to identify areas that are vulnerable to both stressors. Fig. 6 illustrates the districts that exhibited high or very high vulnerability to globalization in addition to high or very high vulnerability to climate change. This map was created using the climate change vulnerability map (Fig. 3) as the “base” and then identifying via diagonal cross-hatching those districts that are in the high or very high category in both the climate change vulnerability (Fig. 3) and globalization vulnerability (Fig. 5) maps. These districts, which are most concentrated in Rajasthan, Gujarat, Madhya Pradesh, as well as in southern Bihar and western Maharashtra, may be interpreted as areas of “double exposure,” where globalization and climate change are likely to pose simultaneous challenges to the agricultural sector (O’Brien and Leichenko, 2000).

Why are these “double exposed” districts a concern? They are likely to be areas where farmers are adapting to a variable and changing climate under conditions of economic stress. Reacting to two processes of change simultaneously will, of course, present challenges throughout India, but these districts are likely to feel disproportionately more stress, particularly if there is a mismatch between climate-compatible crops and market-driven demand for those crops. It is in these areas of double exposure where policy changes and other interventions may be most needed in order to help farmers to negotiate changing contexts for agricultural production.

Although policies, local institutions, and other types of interventions and initiatives may have a notable influence on vulnerability, it is important to recognize that these factors are not captured in the indicators of vulnerability used to develop the macro-level profiles. To better understand the role that these factors play, it is necessary to shift to a more qualitative research approach, which will allow us to identify how policies and initiatives originating at different scales interact to shape vulnerability.

5. Case studies: double exposure at the local level

The final step entails local-level case studies in villages located in highly vulnerable and less vulnerable districts. The case studies not only serve to “ground truth” the macro-level analysis, but they also enable us to identify state and local-level institutions and policies that influence coping and adaptation strategies used by farmers in the post-1991 period. Fig. 6 was used to...
identify districts with high to very high vulnerability for the selection of case study sites.

The case studies, carried out in 2002–2003, employed a variety of participatory rural appraisal techniques that allowed us to cross-check responses to key research questions across multiple sources of data. First, we interviewed government officials in the district administration to determine which agriculturally relevant state policy reforms had been implemented since the liberalization process began in 1991. We then selected villages for local-level studies on the basis of secondary statistics of socio-economic and climatic conditions in various parts of the district, as well as on discussions with local experts from governmental and non-governmental organizations. Finally, household surveys were carried out to assess how agricultural reforms have influenced farmers’ and agricultural laborers’ livelihoods and ability to cope with calamities such as drought. The findings from three of the completed case studies—Jhalawar district in Rajasthan, Anantapur district in Andhra Pradesh, Chitradurga district in Karnataka—are summarized below. The results of these case studies support the macro-profiles, which indicated that climate vulnerability will overlap with vulnerability to economic changes. The case study results further suggested that state-level agricultural policies, which vary across India, may play a critical role in increasing local adaptability to climate variability and change in the context of trade liberalization.

Jhalawar district in Rajasthan is located in a semi-arid area that receives an average of 943 mm of rainfall annually (see Fig. 6). In addition to high degrees of climate sensitivity, it also ranks among the lowest of the state’s districts in terms of its adaptive capacity. Over the past 10 years, many farmers in Jhalawar have shifted from traditional crops, such as sorghum and pearl millet, to production of soybeans, which receive higher market prices. However, because soybean prices also fluctuate according to world market prices, the shift toward soybean production has left farmers in Jhalawar vulnerable to external market price shocks. Farmers in Jhalawar are also found to be highly vulnerable to climatic variability. At present, Jhalawar is experiencing its fourth consecutive year of drought, and crop yields have been substantially reduced, particularly for the

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In India, agricultural policies are set by state governments rather than by the national government.

**Fig. 6.** Districts that rank in the highest two categories of climate change vulnerability and globalization vulnerability are considered to be double exposed (depicted with hatching). Doubly exposed areas are superimposed on the climate change vulnerability map to emphasize that districts with high climate change vulnerability may not necessarily be highly vulnerable to globalization. Case study districts are identified.
majority of farmers who lack access to irrigation. To cope with successive years of drought, many small farmers report family members migrating to the neighboring state of Gujarat in search of wage labor. Institutional credit for agriculture in Rajasthan has become less available after structural adjustment, and more farmers now obtain loans from private money-lenders at interest rates of about 36%. Paying back these loans has become difficult when both yields and market prices have been low.

Anantapur district in Andhra Pradesh is another drought-prone area that can be considered “double exposed” to climate change and globalization (see Fig. 6). Groundnut is the principal crop grown in Anantapur, but farmers are now facing a crisis due to growing import competition and stagnating market prices which have coincided with a multi-year drought. Although free market economics would predict that farmers in Anantapur should respond to price stagnation by shifting to production of more profitable crops, our case study results indicate that alternative, drought-tolerant, and economically viable crops are lacking because institutional barriers have made them unprofitable. Rainfed crops which could be economically viable, such as different fruit varieties, either require too much capital, or do not have a long enough shelf life to be marketable under current circumstances. Without irrigation, water harvesting systems, or alternatives to groundnuts, dryland farmers in Anantapur are highly vulnerable to both climate change and trade liberalization.

By contrast, groundnut farmers in the neighboring district of Chitradurga, located in the state of Karnataka (see Fig. 6), are not considered to be “double exposed.” They exhibit relatively lower levels of vulnerability to climate change because of lower climate sensitivity and slightly higher adaptive capacity, tied in part to greater irrigation access. However, according to the 1991 data, Chitradurga can be considered highly vulnerable to economic globalization. Yet because institutional barriers have made them unprofitable, many farmers in this district have been encouraged through state government and private initiatives to cultivate alternative crops, such as areca-nut, pomegranate, and banana. Over the last 5 years, export companies have increasingly entered into buyback contracts with farmers for gherkin production aimed at European markets, with plans to expand to other vegetables. While a wider range of adaptation strategies are available to farmers in Chitradurga, as compared with Jhalawar or Anantapur, it is the larger farmers who tend to benefit from government subsidies (for drip irrigation, sericulture rearing houses, and other production technologies), formal bank credit, crop insurance, and access to larger markets. Smaller farmers are disadvantaged due to lack of information and dependence on local merchants for credit. Furthermore, irrigation, which contributes to higher adaptive capacity within the three districts, may not be sustainable in the long run, particularly if water-intensive horticultural crops are produced for international markets while water availability is reduced due to climate change.

What the case studies show, which was not visible through the national profiles, is the effect that institutional barriers or support systems have on local-level vulnerability. In the cases of Jhalawar and Anantapur, institutional barriers leave farmers who are “double exposed” poorly equipped to adapt to either of the stressors, let alone both simultaneously. In Chitradurga, on the other hand, institutional support appears to facilitate adaptation to both climatic change and globalization. However, these supports tend to disproportionately benefit the district’s larger farmers.

6. Conclusion

The results presented above demonstrate a method for mapping vulnerability that can be used to assess climate impacts in the context of a range of societal changes. In developing a new approach for climate vulnerability mapping, we contribute to a growing body of literature on vulnerability science, which is seeking to increase the rigor and enhance the utility of vulnerability assessments for both researchers and policymakers (Kasperson and Kasperson, 2001; Jones and Thornton, 2003; Polsky et al., 2003). As such, it is important to recognize both the limitations and strengths of the method.

Concerning the limitations of the method, one limitation of the macro-profiles is that mapping vulnerability at the district level may lead to a false sense of precision. Abrupt differences in vulnerability across district boundaries might be more realistically represented as fuzzy transitions (Ramachandran and Eastman, 1997). Similarly, differences between farmers and between villages within districts are not captured in the vulnerability maps, although these differences are addressed in the case studies. A second limitation of the approach is that uncertainties associated with regionally downscaled climate scenarios (or scenarios of trade liberalization) are not explicitly represented in the maps. Incorporation of the uncertainties associated with different climate scenarios might be addressed through application of a range of different regionally downscaled models. A third limitation of the approach concerns the time scale of the analysis, and especially the fact that our assessment does not capture changes in adaptive capacity over time, but instead holds adaptive capacity constant to levels in 1991. To capture potential changes over time, the adaptive capacity indicators might be calculated using alternative scenarios of future social and economic conditions which take into account...
the effects of globalization. A final limitation of the approach is that it did not entail detailed investigation of factors that constrain or enable adaptive capacity at the local level. While our case studies suggested that institutions play a critical role in both constraining and enabling farmer adaptation, further study of the role of institutions in influencing vulnerability is needed.

These limitations notwithstanding, the method also has a number of important strengths. One of the key strengths of our approach is that it provides a means for evaluating the relative distribution of vulnerability to multiple stressors at a sub-national level. We accomplish this by applying the IPCC framework to map regional vulnerability as a function of adaptive capacity, sensitivity, and exposure to climate change and another global stressor. Another strength lies in the use of both top-down and bottom-up approaches to understanding vulnerability. By combining regional vulnerability mapping with local-level case studies, we are able to capture factors and processes operating and interacting at different scales, and to understand how local-level decisions are shaped by factors at the national and international level. Finally, the method helps identify those locations where policy intervention is most critical—both geographically (e.g., double exposed districts) and thematically (e.g., access to irrigation, credit, alternative crops).

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References


