

Climate Change: Challenges Facing India's Poor

E SOMANATHAN, ROHINI SOMANATHAN

Briefly summarising the existing literature on the causes and the characteristics of expected climate changes in India over the coming years, this paper discusses the ways in which these changes might affect the lives of the poor. Rising temperatures, changes in rainfall patterns, and an increased frequency of floods and droughts are likely to have serious effects on rural populations in the absence of policies that actively help these households adjust to their changing geography. Survey data from villages affected by the Kosi flood of 2008 is used to speculate on how households and governments are likely to respond to unexpected weather events. The flood in Bihar rendered much of the land in the area uncultivable and resulted in large-scale unemployment. The state, while effective in providing immediate relief to flood victims, has done little to help the rural population adapt to their changed geography.

Sanjay Pandey and the district administrators of the affected areas provided us with valuable information on the Kosi flood and on state relief efforts. The Mass Oriented Research and Social Elevation Lab administered our survey, Bhupendra Mehta generated digitised maps of the surveyed area, and participants of the New Delhi conference gave us helpful comments. We are grateful to them all.

E Somanathan (som@isid.ac.in) is at the Indian Statistical Institute, New Delhi and Rohini Somanathan (rohini@econ.dse.org) is at the Delhi School of Economics.

1 Introduction

The major human contributors to climate change in India can be classified into two groups. The first consists of greenhouse gases such as carbon dioxide, methane, nitrous oxide, and halocarbons. Greenhouse gases are globally mixed pollutants with long residence times in the atmosphere. Their impact on the world is not therefore determined by the source from which they are emitted. Particulate emissions constitute the second group; they do not disperse as quickly and their impacts on the climate are mainly felt in their region of origin. Thus, the climatic impacts of south Asian particulate emissions are felt mainly in south Asia. This distinction is crucial in framing appropriate policies to combat climate change because it means that particulate emissions and their effects are, to a considerable degree, under India's control. In contrast, we emit only a small percentage of world emissions of greenhouse gases, so our direct influence on their concentrations is small, and international negotiations and agreements have an important role to play in reducing their levels.

We begin, in the next section, by outlining some of the mechanisms through which both these types of emissions affect climate and discuss how these changes are likely to affect the lives of the poor. Although there is considerable uncertainty about the extent to which climate will change, even the most conservative projections lead us to expect substantial reductions in crop yields, rises in the sea level and an increased occurrence of flood and drought conditions. India's poor remain highly dependent on agriculture and, in the absence of creative policies that insure rural incomes and provide alternative livelihoods, increased poverty may well accompany changes in physical geography.

In Section 3, we present results of a survey of 10 villages affected by the Kosi flood of August 2008 in northern Bihar. Although the flood itself was attributed to negligence in the maintenance of the Kosi dam and its embankments, it provides a useful case study of the impact of an unexpected event on a rural and largely poor population. Using household survey data we find that with the help of transfers from local communities and the state, flood-affected households showed remarkable resilience in the immediate aftermath of the flood. Their long-term prospects however remain grim. Very little of the land in these villages is under cultivation, unemployment is pervasive and even mandated state programmes such as the National Rural Employment Guarantee Scheme (NREGS) have remained largely inactive. Although these effects are clearly not limited to the poor, the poor are particularly vulnerable to these changes because of their limited access to insurance and credit.

We conclude with some suggested directions for policies to combat climate change and its effects on the Indian population.

Given that some amount of global warming seems inevitable, these policies should combine mitigation with adaptation. A comprehensive policy agenda will include rethinking embankments, enacting and enforcing laws that limit the burning of rubbish, biofuels and plant residues, developing new crop varieties that can be used profitably in areas which undergo physical changes, controlling urban air pollution, and introducing social insurance programmes that can help local populations deal with shocks induced by climate change. Many of these programmes will provide benefits that go far beyond their effects on climate change. They require, however, a state committed to constructive change.

2 Projected Climate Changes and Their Effects

The average global temperature has risen by about 0.8 degrees Celsius from the pre-industrial level. The projected hazards of continuing anthropogenic climate change include decreased crop yields, the disappearance of mountain glaciers and snowpacks, more extreme weather events such as floods, droughts and storms, increased coastal flooding, and species extinctions. We discuss each of these and their likely impact on the poor.

Crop Yields

Climate change is projected to reduce net cereal production in south Asian countries by 4% to 10% by 2100 under the most conservative scenario of the Intergovernmental Panel on Climate Change (IPCC) (Cruz, Harasawa et al 2007). Several studies have found a negative correlation between crop yields and poverty rates. Time series data from India for the period 1958-94 indicate that increased yields lowered poverty almost one for one (Datt and Ravallion 1998). Household data in the 1983-99 period suggested that agricultural productivity growth was responsible for at least four-fifths of the 75% growth in real agricultural wages in that period (Eswaran, Kotwal et al 2008). A recent survey of the literature on Indian economic growth concludes that "agricultural productivity would have to continue to increase for improving the living standards of the rural poor" (Kotwal, Ramaswami et al 2009).

We now have some evidence linking particle emissions to yields. These emissions result in reduced solar radiation reaching the ground, especially in winter (Chameides, Yu et al 1999), and the deposit of smoke particles on leaves obstructs photosynthesis (Bergin, Greenwald et al 2001). It is estimated that the brown cloud formed as a result of these emissions reduced the mean annual rice harvest in India by nearly 4% in the period 1966-84 and by nearly 10% in 1985-98 (Auffhammer, Ramanathan et al 2006).

Glacier and Snowpack Decline

Glaciers the world over are thinning and shrinking as the planet warms, and glaciers in the Himalayas are receding faster than anywhere else. If the earth keeps warming at the current rate, Himalayan glaciers are likely to disappear altogether in 25 years (Cruz, Harasawa et al 2007). In the absence of glaciers, rivers in the Indo-Gangetic plain will become much more seasonal, threatening the rabi crop as well as domestic and industrial water supplies in the non-monsoon months. In addition, more precipitation will fall as rain rather than snow and the greater water run-offs will increase flooding.

Up to half of the glacier decline is thought to have occurred as a result of upper atmospheric heating from the black carbon particles in the south Asian brown cloud (Ramanathan and Carmichael 2008). In addition, deposits of these soot particles in snow and ice accelerates melting. This implies that India has the ability to slow the melting of glaciers and snow by reducing particulate emissions. We return to this point below.

Extreme Weather Events

A warmer climate is predicted to bring more extreme weather. The period 1951-2000 has witnessed an increase in the magnitude and frequency of high intensity rain in India and a decrease in the frequency of moderate rain (Goswami, Venugopal et al 2006). The record rainfall and consequent flooding in Mumbai in July 2005 was an example of this. The concentration of rainfall in a few events will tend to reduce groundwater recharge and accentuate droughts in water-stressed regions. India is predicted to reach a state of water stress by 2025 in which per capita water availability falls below 1,000 cubic metres per capita. An increase in cyclone intensity of 10-20% for 2-4 degrees Celsius of warming is predicted for south Asia and adjoining regions (Cruz, Harasawa et al 2007). These cyclonic storms will particularly affect the poor in coastal areas like Orissa and Bengal.

Sea Level Rise

Global warming has been raising the sea level because warm water has greater volume. In addition, there is the melting of Greenland and West Antarctic ice packs. A recent study that takes into account both thermal expansion of the ocean and ice-pack melt suggests that the likely range of the rise by 2100 is 0.8 to 2 metres (Pfeffer, Harper et al 2008). This will lead to the permanent displacement of millions of people in coastal areas in India, about 3 million for a 1-metre rise and more than double that number for a 2-metre rise (Dasgupta, Laplante et al 2007).

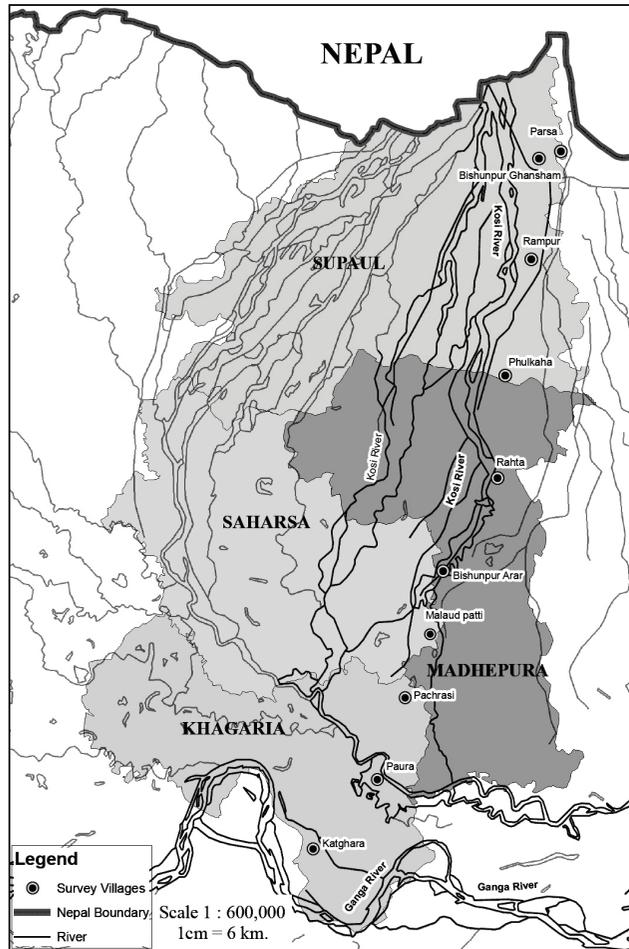
Species Extinctions

The IPCC report predicts that 30 to 40% of all species could go extinct if the temperature were to rise by another 2 to 3 degrees Celsius. Apart from its intrinsic value, biodiversity provides pollinators and species that prey on pests. Species extinctions may result in a fundamental rearrangement of ecosystems and the effects of this on agriculture are unpredictable.

Positive Feedbacks and Loss of Control

In discussing the effects of rising temperatures above, we have ignored the role of various positive feedbacks that may come into play and amplify global warming (Lenton, Held et al 2008). The terrestrial biosphere which is now a net sink for carbon dioxide (absorbs CO₂) may become a net source as temperatures rise. Methane frozen in permafrost in the Arctic may be released as the permafrost thaws, leading to still higher temperatures, more methane releases, and a process of runaway global warming that we can no longer influence by addressing our own emissions. There are other such dangers that have been identified but about which too little is known to say just how great a temperature increase is required to take the system past a point of no return. It is

Figure 1: The Flooded Areas and Surveyed Villages



important to note in this connection that these feedbacks are not captured in the predictions of the climate models. This is why it is falsely reassuring to assume, as do many commentators, that if the concentration of CO_2 -equivalent can be held below some target level such as 450 parts per million, then warming will be held to 2 degrees Celsius above pre-industrial temperatures. If some of these positive feedbacks come into play at lower concentrations, it may be impossible to prevent much larger temperature increases.

3 A Case Study of the Impact of a Disaster

This section discusses the Kosi flood of 2008 in Bihar, how it affected the poor and how the government provided relief.

Background to the Survey

We have discussed how frequency of floods and other natural disasters is on the increase as a consequence of climate change. In this section we summarise survey data on household and state responses to a major flood in northern Bihar in 2008. The flood affected communities that are largely agricultural and extremely poor by national standards. Unlike many coastal areas and settlements near rivers, most of this population had not experienced a flood of this magnitude for several decades. To the extent that climate change will result in unexpected changes in local

geography, the impact of the flood on these households may be indicative of the future impact of climate change on the poor.

The Kosi flood of 2008-09 began with the breach of an embankment just north of the border in Nepal on the morning of 18 August 2008. The embankment had been in place for nearly half a century and silt trapped within it had raised the river bed until it was 4 metres higher than the surrounding land. When the breach occurred, the westward loop previously taken by the river was cut off, flooding the area between the breach and the river Ganga, 150 km to the south. The post-breach direction was in fact the course of the river before the embankment was built in the 1960s.

The map in Figure 1 shows both the old course to the west and the north-south course followed by the river waters after the breach.

In February 2009, we surveyed 28 households in each of 10 villages along the new course of the river. The map in Figure 1 shows the surveyed villages along with both the old course to the west and (in darker lines) the north-south course followed by the river waters after the breach. Almost all the villages affected by the flood are in four districts: Supaul, Madhepura, Saharsa and Khagaria. Supaul, the northernmost district in this region was flooded within hours of the breach. The villages along the new path of the Kosi were devastated, but the corridor within which these villages lie is fairly narrow because the waters were flowing rapidly at this point. Most of the lasting damage to land here was through the dumping of alluvial sand carried by the water. In contrast, when the waters reached villages in the districts of Madhepura and Saharsa they had slowed and spread over much larger areas and many of these continue to remain waterlogged. In Khagaria, there were two sources of flooding; the Kosi waters flooded the northern part of the district and the Ganga overflowed into the fields in the south about a week before the Kosi breach.

Given the small number of villages that we were able to study, we decided not to pick them randomly from the affected area. Instead, to examine the role of geography on household behaviour and flood damage, we chose roughly equidistant villages starting from the north-eastern corner of Supaul district. Our northernmost village is 22.5 kilometres from the point of the breach in Nepal. We will refer to these villages by numbers 1-10, with smaller numbers closer to the point of the breach.¹

There is variation across the surveyed villages in both the source and the timing of the flood. Village 1 was flooded on the night of 18 August 2008 and villages 2-4 the following day. Villages 5-8 were affected at varying times between 21 and 25 August 2008. These villagers could have had some information about the flood although it appeared that there was considerable uncertainty about the course of the flood. Our last two villages provide an interesting comparison with the rest. Village 9 is located next to the embankment of the Kosi and was flooded by 13 July, over a month before the breach occurred. Katghara, our southernmost village, is on the banks of the river Ganga and was flooded by 15 August, three days before the Kosi breach. Both these villages are frequently flooded and their inclusion allows us to study how households with some experience of floods

behave differently from others. These areas were also excluded from the area formally defined as the Kosi disaster region, and, as seen in the data presented below, the state responded to the needs of these two villages very differently from the rest.

Characteristics of Surveyed Villages

Table 1 presents data from the 2001 Census of India on mean characteristics of the surveyed villages and other villages in the four districts. The data on population are from the village-level Primary Census Abstract and those on amenities are from village directories. The characteristics of our sample seem fairly representative of the region as a whole, although a sample of 10 villages is too small to make statistical comparisons.

Table 1: A Comparison of Surveyed and Other Villages Using Village Data from the 2001 Census

	Surveyed Villages	Other Villages
Supaul	4	523
Madhepura	2	379
Saharsa	1	441
Khagaria	3	241
Primary schools in village (number)	1.3	1.7
High schools in village (number)	0	.11
Paved approach road	1.4	1.6
Power supply	0	.05
Primary health centre in village	.2	.05
Scheduled castes (%)	13	16
Male literacy (%)	34	37
Female literacy (%)	13	16
Cultivators (%)	26	26
Agricultural labourers (%)	34	37
Household occupations (%)	1	1
Other occupations (%)	7	7

We conducted both a village and a household survey in each of the 10 villages in our sample. The purpose of the village survey was to record the occupational and caste structure of the village, the total number of migrants and fatalities, and changes in the pattern of land-use caused by the flood. It also enabled us to check that we had a reasonably representative sample of households. Village information was obtained from a group of households gathered in a public space in the village, often next to the primary school. They helped us map the village and estimate the number of households in each hamlet. We then divided the total number of hamlets by 28 (the predetermined number of households we had decided to survey in the village) to arrive at the appropriate interval between houses for systematic sampling. This procedure provided us with a random sample of households within each village.

Table 2 presents some summary statistics based on data from our village questionnaires. The 10 villages contain a total of 4,614 households and several indicators confirm their overall poverty. Many villages have more than half their households reporting no education, and agricultural labour as their primary occupation. A high

percentage of families were reported to be beneficiaries of various state-sponsored poverty programmes, although many of these classifications have been shown to exhibit considerable error. We see that our second village, which has the highest proportion of uneducated families and agricultural labourers, has lower coverage of these programmes than other areas.

We were surprised to observe very little permanent migration following the flood, in spite of high rates of unemployment in these villages. Four of the 10 villages had no land under cultivation at the time of our survey, yet most households who had left at the time of the flood were back in the village. There were a total of 33 deaths reported as being caused by the flood and about half of these occurred in a single village.² Only two people in these villages were reported to be missing.

Figures 2a-2c (p 55) examine changes in land use as a function of the distance of the village from the breach in Nepal. The figures are based on hamlet-level information and each hamlet is labelled by number of the village in which it lies.

Most of the land in the four northernmost villages is uncultivable because of large deposits of alluvial sand from the river bed. As we look further from the breach, we see some variation across hamlets within the same village in the proportion of land that is not in use. As we move from southwards, the problem of sand deposits is replaced by that of waterlogging. The fraction of waterlogged farm land peaks at village 7 and then drops off rapidly. The very different landscapes that have resulted from the flood imply different types of adaptation strategies will be required in making the land productive again. There was, up until the time of our survey, no active state intervention along these lines.

We now turn to an analysis of our 280 household surveys which allow for a much more detailed study of how households were affected by the flood.

Household Responses

We have information on a total of 1,655 members of the 280 households we surveyed. We asked for information on all members that were part of the household either before or after the flood. In terms of religion and caste composition, 17% of the total households are Muslim and most of the others are Hindu castes classified as Other Backward Castes by the state and national

Table 2: Some Characteristics of Surveyed Villages

	Village Number									
	1	2	3	4	5	6	7	8	9	10
Total households	905	140	412	475	1,300	128	300	145	444	365
Uneducated (%)	42	57	30	8	10	4	12	17	5	4
Agricultural labour (%)	70	100	67	56	34	0	38	59	6	68
Indira Aawas Yojana (%)	29	2	33	7	13	5	13	35	12	1
Below Poverty Line (%)	64	51	68	55	57	11	25	39	72	19
Antodaya Anna Yojana (%)	21	5	14	11	17	8	7	37	9	2
Land cultivated (% landowned)	0	0	9	0	0	57	17	52	24	1
Male unskilled wages, 2008 (Rs/day)	80	50	60	70	70	70	80	100	100	70
Male unskilled wages, 2009 (Rs/day)	70	50	50	65	70	50	80	75	80	80
Male skilled wages, 2008 (Rs/day)	200	150	150	100	100	150	150	130	120	110
Male skilled wages, 2009 (Rs/day)	175	150	150	80	100	150	150	130	120	110
Households not returned after Aug 2008	11	0	15	0	10	0	0	0	0	0
Missing after flood (number of persons)	1	0	0	0	0	0	1	0	0	0
Deaths (number of persons)	1	0	8	5	17	0	1	0	0	1

Figure 2a: Fraction of Owned Land Cultivated

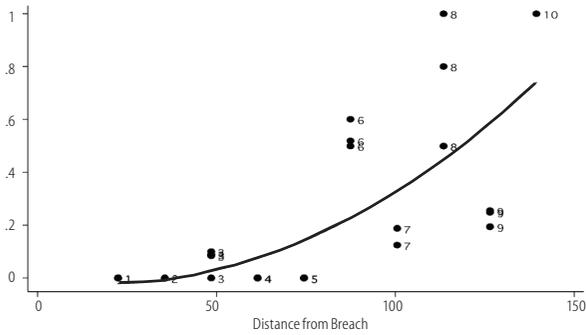


Figure 2b: Fraction of Owned Land Covered with Alluvial Sand

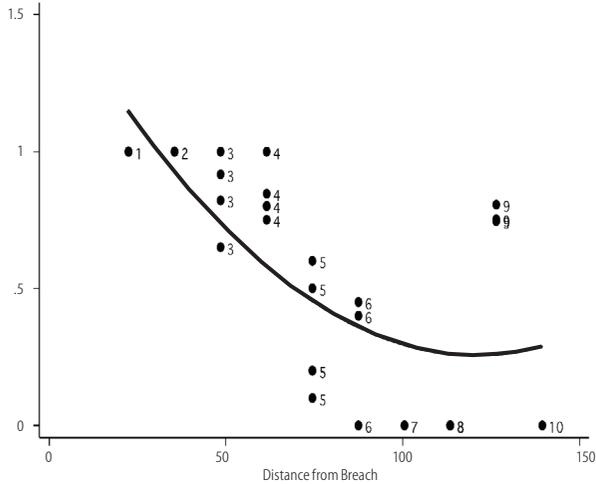


Figure 2c: Fraction of Owned Land Waterlogged



government. Muslim families are concentrated in the northern villages, and enter our sample only in villages 1, 2 and 4. Among the Hindu castes, Yadav families are the most numerous and constitute over a quarter of the total households. Other numerically large castes are the Shah and Kurmi, each constituting about 10% of our sample. There is very little mixing within villages of these three groups. The Kurmis are all in village 10, the Shahs in village 2 and the Yadavs are in several villages other than these two. Other groups that constitute more than 5% of our sample are Rajputs (7%) and Mallahs (6%). Poorer groups are located in the northern villages in our sample and this pattern of residential segregation implies a correlation between social groups and the impact of the flood. Our sample is however too small to explore this more carefully.

Location and Food Supply

We asked respondents for a list of all individuals who were either part of each household before the flood, or had joined the household after the flood. For each of these individuals in our list, we asked about their current whereabouts and obtained both current and retrospective information on their employment and earnings. We also asked households whether they moved out of the village on the day the flood waters reached their village and their location and source of food on each of the 20 subsequent days. Consistent with the findings from our village survey, we find stability in household composition. Of all 1,655 household members, 96% were present in the village both before and after the flood, 3% were there before but not after and under 1% moved into households after the flood. This was in spite of large-scale evacuation from the northern villages following the flood.

Table 3 provides information on household locations and food sources. We present summary statistics separately for the four northernmost villages, then the next four, and finally the last two, which were not officially part of the Kosi disaster. We find that within 20 days of the flood, half of the families in the worst-hit areas were living and eating in relief camps and about 10% of families from the first eight villages who were residing in other locations received food from households and small organisations in nearby areas.

Table 3: Household Locations Following the Flood (Percentage of total households)

	Village Numbers		
	1-4	4-8	9-10
Immediate responses			
Moved to raised ground outside the village	75	34	9
Moved to a safe place in the village	16	18	45
Moved to a relative's house	4	26	0
Stayed home	5	22	46
20 days later: locations			
In a relief camp	49	10	0
In the village	10	33	66
20 days later: source of food			
Families in the local area	9	13	2
Cooked meals in a relief camp	49	10	0
Rations from home	27	59	93

Employment and Earnings

Figures 3a and 3b (p 56) plot smoothed densities of days worked and average daily earnings for the month preceding our survey in February 2009 and for February 2008. These figures only include those with positive earnings in both time periods. We find that in spite of large employment effects, wages appear to be relatively inflexible. Median wages for those with positive earnings in both years are Rs 70. The big change is in median days worked which go from 22 days to eight days and one-third of those working in February 2008 were unemployed at the time of our survey.

Patterns in employment and earnings across villages are shown in Table 4 (p 56). Not surprisingly, the largest employment effects are in the four northern villages, where most land remains uncultivated.

To examine whether savings were used to smooth consumption, we asked households for the value of their bank and cash savings on 1 August 2008 and on the date of the survey. Only a small fraction of households had any bank savings – 12% in 2008

Figure 3a: Average Days Worked (2008 and 2009)

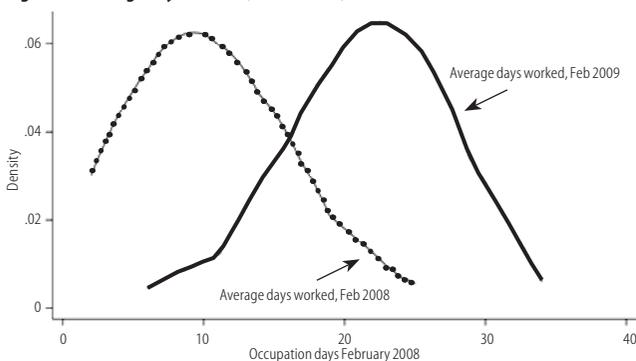
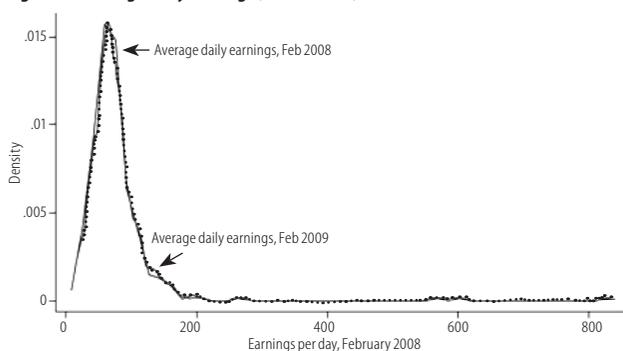


Figure 3b: Average Daily Earnings (2008 and 2009)



and 10% in 2009. Most saving was in the form of cash at home which appears to have been used to cope with the large income shock. Of all households, 51% reported non-zero cash savings in 2008 and 24% in 2009.

Table 5 describes changes in selected assets between 2008 and 2009 by village categories. In the first four villages, the fraction of households with cash savings fell from 54% before the flood, to 8% six months after the flood. These families also began with lower total savings than those in other villages. For all villages taken together, mean bank savings between the two dates (for those with positive savings) went from Rs 28,000 to Rs 4,912 and cash savings declined from an average of Rs 4,462 to Rs 743.

Table 4: Employment Patterns Across Villages: February 2008 and 2009

	Village Number		
	1-4	4-8	9-10
Median days worked			
February 2008	22	20	5
February 2009	4	10	13
% of earners in 2008 unemployed in Feb 2009	45	27	0
% of earners in 2009 unemployed in Feb 2008	4	2	1

We finally turn to the role of state-sponsored relief and development schemes in helping households adapt to the fall in their incomes and assets. We examine three different types of government interventions: employment through the NREGS, the distribution of staple grains through the public distribution system (PDS), and food and cash transfers through the emergency relief fund that was set up following the flood.

Table 6 (p 57) summarises our results on government relief and stabilisation programmes. We find that although 77% of households had heard of the NREGS, very few had benefited from it. We asked for total days worked under the programme before

and after August 2008. About 8% of the households in our sample had received benefits under the programme and on average, this group of beneficiaries had engaged in 21 days of work before August 2008. Since August 2008, only four days of work were reported in the entire area, two days each by two households of village number 2. Most likely, these were days before the occurrence of the flood. On the basis of our survey, it therefore appears that the NREGS was completely ineffective as a stabilisation scheme in providing work to the rural poor at a time when they had lost their usual source of employment.

We find that the PDS did provide rice and wheat at lower prices than the market, but only to a few families. During the seven days preceding the survey, 17% of households bought either rice or wheat from the PDS. From the table we see that the outreach of the PDS seems to be most limited in the villages where food scarcity was the greatest. For families that did have access to the PDS, the prices paid were about half of those prevailing in the open market.

Finally, we turn to government transfers in cash and kind. We listed all transfers received by the household over two time periods, July 2007 to June 2008 and July 2008 to the survey date. These transfers include pensions, relief payments and all other allowances. We find that while 20% of families received transfers

Table 5: Changes in Household Savings

	Village Number		
	1-4	4-8	9-10
Bank savings			
Households with savings on 1 August 2008 (%)	10	14	11
Median savings on 1 August 2008 (Rs if >0)	1,600	6,500	5,500
Households with savings on the date of survey	9	9	13
Median savings on the date of survey (Rs if >0)	650	2,500	1,000
Cash savings at home			
Households with savings on 1 August 2008 (%)	54	53	41
Median savings on 1 August 2008 (Rs if >0)	1,100	2,000	1,000
Households with savings on the date of survey (%)	8	13	29
Median savings on the date of survey (Rs if >0)	250	500	350

in the first period, 80% received them after July 2008. In the year before the flood, transfers were most generous in villages 9 and 10, where 45% of families received some transfers. The modal transfer during 2007-08 was Rs 1,200 and this was received by about one-fifth of the families in villages 5-10, but by no family in villages 1-4.³ In the following six months, the largest transfers were received by households in the first four villages and a large fraction of families received exactly the same amount, Rs 5,840. The last two villages, which were not officially part of the Kosi disaster affected area, received no compensation and even previous transfers seem to have been suspended or delayed. Since our survey was completed in February, it is possible that these were subsequently paid out.

We can summarise our results from the Kosi survey as follows. In the immediate aftermath of the flood, households seemed remarkably resilient – there were very few fatalities or missing people and most individuals returned to their villages after most of the relief camps closed in November 2008. The state relief apparatus seemed effective, both in terms of getting large numbers into relief camps and ensuring that cash and grain transfers

reached flood victims. The value of transfers to the worst-hit villages was the largest. Transfers seem to have been targeted at villages rather than households with most households receiving the same transfer in villages 1-8. In spite of flooding in villages 9 and 10, no transfers were received.

It does not appear that existing social programmes such as the NREGS or the PDS did much to insulate households from large income shocks. The long-term prospects for this area appear quite grim. A sizeable fraction of previously cultivated land is likely to remain fallow over the next few years, and there is large-scale unemployment. Moreover, the state apparatus has done very little so far to help with adaptation to this dramatically changed physical environment.

4 Possible Policy Responses

A certain amount of further warming, of about 1 degree Celsius, appears to be inevitable, given the inertia in the climate system, and the fact that even with major breakthroughs, carbon emissions are unlikely to end in less than two or three decades. Therefore, we have to adapt to at least this much warming. At the same

Table 6: Government Transfers and Stabilisation Programmes

	Village Number		
	1-4	4-8	9-10
NREGS			
Households who knew about NREGS (%)	83	71	80
Households receiving benefits before August 2008 (%)	8	4	14
Households receiving benefits since August 2008 (%)	2	0	0
Public distribution system (PDS)			
Households using PDS in the week before the survey (%)	10	18	29
Rice purchased by PDS households (kg/week)	10	11	11
Average payments for PDS rice (Rs/kg)	6.7	6.2	6.9
Average payments for open market rice (Rs/kg)	14	14	13
Value of cash and in-kind transfers from the government July 2007-June 2008			
Households receiving government transfers (%)	2	18	45
Mean value of government transfers (over all households)	177	771	1,307
Modal transfer (Rs)		1,200	1,200
Households receiving modal transfer (% total households)		23	21
After July 2008			
Households receiving government transfers (%)	99	95	2
Mean value of government transfers (if transfers > 0)	7,782	5,632	79
Modal transfer (Rs)	5,840	5,840	
Households receiving modal transfer (% total households)	22	36	

time, it is clear that mitigation is necessary to avert the considerable danger of disaster.

Adaptation strategies need to proceed along many different fronts. There have been cogent criticisms of the strategy of flood control through embankments (Iyer 2008; Dixit 2009). These demand even more attention in light of the expected increase in the severity of floods. Dixit proposes a strategy of living with floods by building infrastructure above the expected floodwater level and investing in drainage. This will be expensive, and a serious cost-benefit analysis needs to be done. As yet, there appears to be little will to do the necessary data collection and research. Preparations also have to be made for a rise in sea level and storm surges. This means the areas that will be affected have to be demarcated and sign-posted to discourage development. Stronger measures like bans on development may need to be

imposed, as well as the creation of endowment funds for the rehabilitation of those now living in danger zones.

Even if better policies are put into place to adapt to floods and other disasters, it will still be the case that disasters will occur. The Kosi case study highlights the importance of the need for social security. For the poor whose major asset is their own labour, the impact of a fall in the demand for labour as a result of the destruction of complementary assets is life-threatening. The only unemployment insurance for the unskilled, the NREGS, needs to be operated far better than it is now, and particular attention has to be paid to ensure that areas hit by disasters are well served by the scheme in the months and years that follow.

Turning to mitigation, it was pointed out in Section 2 that domestic particle emissions have been implicated in drought, in glacier and snowpack melt, and have major health consequences. Reducing these emissions will help with these three problems. It is estimated that only a quarter of the soot or black carbon particles in the brown cloud come from fossil fuels. More than 40% comes from wood, agricultural residue, and dung from cooking fires, and about a third are from the open burning of agricultural residues in fields after harvests and from forest fires (Venkataraman, Habib et al 2005, 2006). Restrictions on the burning of waste and organic matter such as leaves and encouraging composting appear to be a cheap way to reduce these emissions. In cities like Delhi, these regulations are in place but are rarely enforced.

Reducing emissions from cooking fires, the single largest source of smoke, is clearly desirable. About three-quarters of Indian households use wood or other solid biomass fuels (Gangopadhyay, Ramaswami et al 2006). Combustion in traditional stoves is incomplete and produces a number of greenhouse gases and black carbon, so a switch to even fossil fuel based electricity would be approximately neutral in terms of its global warming effect (Smith, Uma et al 2000). If most of these households were to switch to electricity or gas for cooking, they would reduce harvesting pressure on forests that have degraded (Prabhakar, Somanathan et al 2006; Baland, Bardhan et al 2008). As these forests return to their full natural stock level, they would accumulate carbon over several decades. Hence, the net effect of the switch would be to reduce global warming.

Bans on burning agricultural residue by farmers have been tried and failed in Punjab, owing to farmers' political power. A realistic policy would make an economical alternative available in conjunction with education. Public agricultural research has already been directed toward this end in collaborations between Indian and Australian agricultural scientists as part of a programme to promote agriculture that improves soil quality. The approach is to develop sowing machinery that makes removal of the previous crop's residue unnecessary. This programme needs expansion and can be supported by appropriate restructuring of water and fertiliser subsidies. Another possibility is subsidised procurement of residue for use as fuel in power plants where combustion will be much more complete and particle emissions controlled.

Invigorating a decaying agricultural extension system can help with both adaptation and mitigation. This system could address the yield problem directly and provide areas that experience

floods and droughts with new crops that are suited to their changed soil composition and rainfall patterns. It can also bring in new agricultural technologies that provide farmers with incentives to give up practices such as the burning of crop residues which aggravate the brown cloud problem.

In addition to the above approaches, are standard urban air pollution control policies. Emissions from transport and congestion can be reduced through investments in electric railways, public transport, and traffic control. Road pricing to deal with congestion externalities is now technically feasible and has been implemented in Singapore as well as London and Stockholm.

Finally, a word on the link between international and domestic policies. In a nutshell, the problem is that Indians in general and the poor in particular have a strong objective interest in getting the world to sharply reduce greenhouse gas emissions, but little ability to do so since we are responsible for only 3% of world emissions of carbon dioxide. This is made worse by the fact that the true scale of the problem is known to only to a handful of people in this country. As a consequence, Indian government policy on climate change so far has not been motivated by domestic demand, but by external pressure. This is deeply ironic since India is in much greater immediate danger from climate change than are the affluent countries that are pressuring it to act. The government

has shown little interest in operationalising its own National Action Plan on Climate Change that was released a year ago.

5 Conclusions

We began by articulating the mechanisms that link climate change to rural livelihoods. Our study of the Kosi flood highlighted the manner in which natural disasters alter long-term opportunities for the poor. The state was impressive in providing immediate relief but has so far been completely ineffective in facilitating long-term adaptation. This makes us sceptical of the extent to which the state will help poor rural populations deal with the effects of climate change.

The sluggish response of the Indian government to mitigating and adapting to climate change has been accompanied by the rhetoric of helplessness. State officials have often argued that India's share of emissions is too small for anything we do to matter. We surveyed a well-respected body of research that emphasises the need to distinguish between greenhouse gases and particle emissions and shows that the latter are a major source of climate-related problems. Since these emissions are directly affected by Indian policies and there are some low-cost options for particle emission reductions, it is important that these opportunities be seized.

NOTES

- 1 We first chose the village in Supaul that was closest to the breach and yet accessible. We used district maps from the district census handbooks of these areas to select villages 2 through 10 to be 13 kilometres apart (as the crow flies) according to the scale given there. Subsequently, looking at digitised maps such as the one shown in Figure 1, these earlier distances do not appear to be accurate.
- 2 It was unclear why these deaths occurred. There appears to be have been some uncertainty about whether the village would be flooded, and the water reached late at night, making it harder for families to escape.
- 3 The two families receiving transfers in the July 2007-June 2008 period received different amounts. We have left the cells for the modal transfer and the percentage of households receiving this transfer blank.

REFERENCES

- Auffhammer, M, V Ramanathan et al (2006): "Integrated Model Shows That Atmospheric Brown Clouds and Greenhouse Gases Have Reduced Rice Harvests in India", Proceedings of the National Academy of Sciences, 103 (52), 19668-672.
- Baland, J-M, P Bardhan et al (2008): *Forests to the People: Decentralisation and Forest Degradation in the Indian Himalayas* (Delhi: Indian Statistical Institute).
- Bergin, M H, R Greenwald et al (2001): "Influence of Aerosol Dry Deposition on Photosynthetically Active Radiation Available to Plants: A Case Study in the Yangtze Delta Region of China", Geophysical Research Letters, 28 (18), 3605-608.
- Chameides, W L, H Yu et al (1999): "Case Study of the Effects of Atmospheric Aerosols and Regional Haze on Agriculture: An Opportunity to Enhance Crop Yields in China through Emission Controls?", Proceedings of the National Academy of Sciences, 96 (24), 13633-13636.
- Cruz, R V, H Harasawa et al (2007): *Asia. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M L Parry, O F Canziani,

- J P Palutikof, P J van der Linden and C E Hanson (Cambridge: Cambridge University Press), 469-506.
- Dasgupta, S, B Laplante et al (2007): *The Impact of Sea Level Rise on Developing Countries: A Comparative Analysis* (Washington DC: World Bank).
- Datt, G and M Ravallion (1998): "Farm Productivity and Rural Poverty in India", *Journal of Development Studies*, 34 (4), 62-85.
- Dixit, A (2009): "Kosi Embankment Breach in Nepal: Need for a Paradigm Shift in Responding to Floods", *Economic & Political Weekly*, 44 (6), 70-78.
- Eswaran, M, A Kotwal et al (2008): "How Does Poverty Decline? Suggestive Evidence from India, 1983-1999", Bread Policy Papers.
- Gangopadhyay, S, B Ramaswami et al (2006): "Reducing Subsidies on Household Fuels in India: How Will It Affect the Poor?" Energy Policy.
- Goswami, B N, V Venugopal et al (2006): "Increasing Trend of Extreme Rain Events Over India in a Warming Environment", *Science*, 314 (5804), 1442-45.
- Iyer, R R (2008): "Floods, Himalayan Rivers, Nepal: Some Heresies", *Economic & Political Weekly*, 43.
- Keohane, R O and K Raustiala (2008): "Toward a Post-Kyoto Climate Change Architecture: A Political Analysis", The Harvard Project on International Climate Agreements.
- Kotwal, A, B Ramaswami et al (2009): "Economic Liberalisation and Indian Economic Growth: What's the Evidence?" (Delhi: Indian Statistical Institute).
- Lenton, T M, H Held et al (2008): "Tipping Elements in the Earth's Climate System", Proceedings of the National Academy of Sciences, 105 (6), 1786-93.
- Pfeffer, W T, J T Harper et al (2008): "Kinematic Constraints on Glacier Contributions to 21st Century Sea-Level Rise", *Science*, 321 (5894), 1340-43.
- Prabhakar, R, E Somanathan et al (2006): "How Degraded Are Himalayan Forests?" *Current Science*, 91 (1), 61-67.
- Rai, V and D Victor (2009): "Climate Change and the Energy Challenge: A Pragmatic Approach for India", *Economic & Political Weekly*, this issue.

- Ramanathan, V and G Carmichael (2008): "Global and Regional Climate Changes Due to Black Carbon", *Nature Geoscience*, 1 (4), 221-27.
- Smith, K R (2000): "National Burden of Disease in India from Indoor Air Pollution", Proceedings of the National Academy of Sciences, 97 (24), 13286-293.
- Smith, K R, R Uma et al (2000): "Greenhouse Implications of Household Stoves: An Analysis for India", *Annual Review of Energy and the Environment*, 25 (1), 741-63.
- Somanathan, E (2009): "What Do We Expect from an International Climate Agreement? A Perspective from a Low-income Country" in R N Stavins and J E Aldy *Climate Change Policy Beyond Kyoto: Implementing Architectures for Agreement* (Cambridge, UK: Cambridge University Press).
- Venkataraman, C, G Habib et al (2005): "Residential Biofuels in South Asia: Carbonaceous Aerosol Emissions and Climate Impacts", *Science*, 307 (5714), 1454-56.
- (2006): "Emissions from Open Biomass Burning in India: Integrating the Inventory Approach with High-resolution Moderate Resolution Imaging Spectroradiometer (MODIS) Active-fire and Land Cover Data", *Global Biogeochemical Cycles*, 20, GB2013.

Permission for Reproduction of Articles Published in EPW

No article published in EPW or part thereof should be reproduced in any form without prior permission of the author(s).

A soft/hard copy of the author(s)'s approval should be sent to EPW.

In cases where the email address of the author has not been published along with the articles EPW, can be contacted for help.