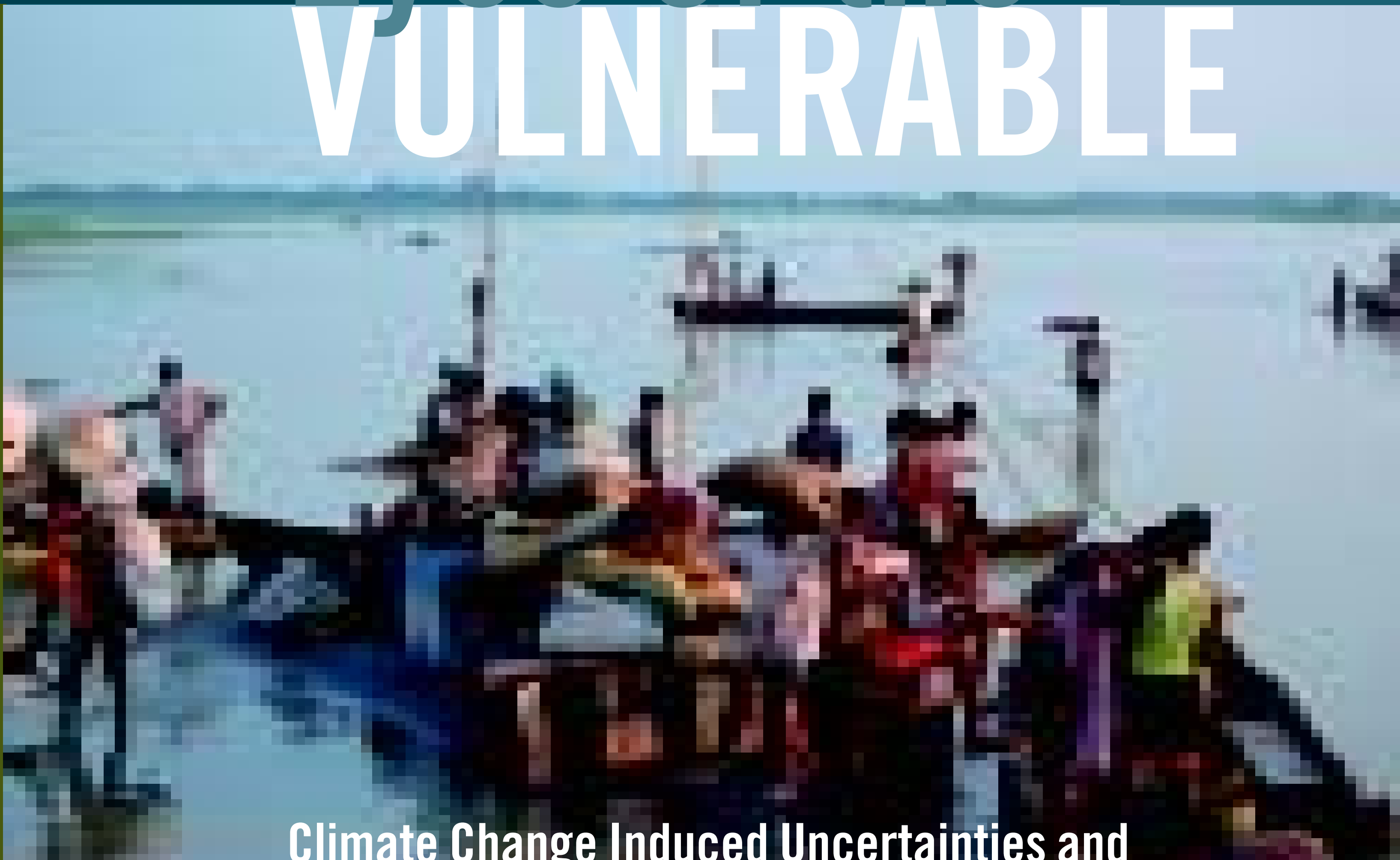
VULNERABILITY Through the Eyes of the VULNERABLE



Climate Change Induced Uncertainties and Nepal's Development Predicaments

Nepal Climate Vulnerability Study Team (NCVST)
October 2009

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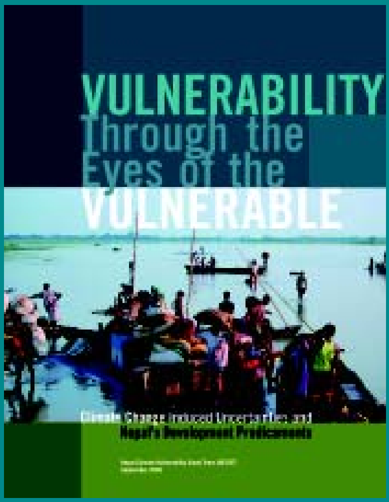

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2nd reprint with some improvements and corrections.

Disclaimer
This report was prepared for the *Kathmandu to Copenhagen 2009: The Way Forward for Nepal* conference in Kathmandu on 2nd September 2009. Its primary purpose is to bring the voices from the grassroots to the fore, to assemble together the knowns and the unknowns on climate change in the Nepal Himalaya, and to explore potential directions for future research as well as adaptive development activities. As an ongoing research initiative, its information range is far from exhaustive, and its conclusions only exploratory and tentative. To improve and refine future research and development initiatives, Nepal Climate Vulnerability Study Team (NCVST) actively solicits comments on this report, which should be sent to: iset@wlink.com.np; nwcf@wlink.com.np

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ACRONYMS

BPC	:	Butwal Power Company
CDM	:	Clean Development Mechanism
DHM	:	Department of Hydrology and Meteorology
DSCWM	:	Department of Soil Conservation and Watershed Management
DST	:	Desakota Study Team
GCM	:	General Circulation Model/Global Climate Model
GDP	:	Gross Domestic Product
GLOF	:	Glacial Lake Outburst Flood
HDI	:	Human Development Index
ICIMOD	:	International Center for Integrated Mountain Development
IDDWSS	:	International Decade for Drinking Water Supply and Sanitation
INPS	:	Integrated Nepal Power System
IPCC	:	Intergovernmental Panel on Climate Change
ISET	:	Institute for Social and Environmental Transition
ISET-N	:	Institute for Social and Environmental Transition-Nepal
ISM	:	Information System Management
NEA	:	Nepal Electricity Authority
NEWAH	:	Nepal Water for Health
NRCS	:	Nepal Red Cross Society
NSET	:	National Society for Earthquake Technology-Nepal
NTFP	:	Non -Timber Forest Product
NWCF	:	Nepal Water Conservation Foundation
PAN	:	Practical Action Nepal
RCM	:	Regional Circulation Model/Regional Climate Model
REDD	:	Reducing Emission from Deforestation and Degradation
SAM	:	South Asian Monsoon System
UNFCCC	:	United Nation Forum for Climate Change Convention
VDC	:	Village Development Committee
WARM-P	:	Water Resource Management Programme
WUMP	:	Water Users Master Plan

ACKNOWLEDGEMENTS

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CHAPTER 1

CLIMATE CONUNDRUM

In its fourth assessment report, the Intergovernmental Panel on Climate Change (IPCC) depicts the Hindukush-Himalaya, including Nepal, as a "white spot," a region about which scientific information on climate change is limited or lacking altogether. Given that the rise of this mountain range, the world's highest, has had a considerable influence on global wind circulation and climate dynamics, this knowledge gap does not speak well of our ability to understand climate change or its potential impact. Indeed, research by Hodges (2006) and his team on the Himalayan-Tibetan orogenic system now indicate that there is a positive feedback between heavy monsoon and geological deformational processes.[1] Plate tectonics pushed up the Himalaya, which block the summer monsoon forcing it to dump enormous amount of rain, which in turn washes away millions of tons of sediment from the southern range front between the Main Central Thrust and the South Tibetan Fault behind the Himalayan Crestline. Studies have placed sediment yield from the Ganges basin alone at 430 to 729 million tons per year at Farakka (Mallik and Bandyopadhyay, 2004). To counterbalance this mass loss, the weight of the Tibetan plateau forces the fluid lower crust of Tibet to extrude south to the range front causing the on-going uplift of the Himalaya. This erosion-extrusion process has been going on since Early Miocene epoch some 20 million years ago, with a force incomparably greater than any that human activity could undertake.

Besides its significance for influencing global climate and in the formation of the fertile Indo-Ganga plains, the Hindukush-Himalayan region is the headwaters of many major rivers in Asia, rivers which support the lives and livelihoods of almost a billion people as well as its unique reservoir of biodiversity. If climate change alters snow and ice cover in the Himalaya, leads to more frequent floods and droughts, or catalyses the spread of disease vectors, the regional and even global implications are enormous for fundamental human endeavours ranging from poverty alleviation to environmental sustainability and even to human security. For this reason, improving our understanding of the impacts of climate change on the Himalaya and identifying potential adaptive response is essential not just for Central, South and South-East Asians but for the entire world.

Exploring these multi-faceted implications with new knowledge is particularly crucial to Nepal since it forms the southern face of the central Himalaya and since its very low development indicators render its population particularly vulnerable to climate change. This report is a first attempt to synthesise existing scientific and socio-economic information on the likely impacts of climate change in the Nepal Himalaya and to assess the complex patterns of vulnerability such changes will expose its citizens to. It has three goals:

1. To pinpoint key areas where improvements in basic climate-related data and the capacity to analyse it can strengthen Nepal's capacity to understand the ongoing processes of change;
2. To identify likely impacts of climate change in the region and their economic consequences; and
3. To outline potential strategies for responding or adapting to the impacts of climate change that address the needs of vulnerable populations and/or protect critical national forests, biodiversity, energy and other resources.

Existing information on climate change in the Nepal Himalaya suggests that the key impacts are likely to include the following.

1. Significant warming, particularly at higher elevations, leading to reductions in snow and ice coverage;
2. Increases in climatic variability and the frequency of extreme events, including floods and droughts; and
3. An overall increase in regional precipitation during the wet season but decrease in precipitation in the middle hills.

These trends suggest that recent extreme events may form the staple of future blueprint of climate change on the region. For this reason, in its assessment of the complex pattern of vulnerabilities in Nepal which could be exacerbated by climate change, this study begins by reflecting on the impact of recent "signature events" - extreme floods, droughts and diseases that have caused grievous harm to local populations. Without more scientific investigation, it is impossible to assert that climate change was the direct cause of these disasters; but their consequences do suggest what may happen if indeed the impact of climate change, as is widely predicted, includes an increase in the frequency and intensity of floods and droughts as wells as shortages of petroleum products, spikes in the price of food and disease epidemics.

The eight signature events selected for analysis are mostly water-related disasters since climate change is anticipated to have a particular impact on the hydrologic systems of the region. In analysing them, our analysis pays particular attention to the manner in which climate change is expected to exacerbate the vulnerabilities of all groups, including the already marginalised populations. The following events are considered in detail:

1. The 1998 Rohini River and other Tarai floods;
2. The 2008 Koshi embankment breach;
3. The 2008 floods in Far-West Nepal;
4. The 1993 mid-mountain cloudbursts and floods
5. Recent glacial lake outburst floods;
6. The 2008/2009 winter drought;
7. The 2009 forest fires across the Himalayan region; and
8. The 2009 cholera epidemic in the mid-western hills.

All of these events caused major harm to local populations consistent with the predicted impacts associated with existing climate change scenarios for the region. While many of the impacts are localised, the winter drought and the famine it fosters almost draws attention to the fact that far-off climate-related events such as hikes in the price of oil and a surge in the demand for bio-fuel can become unforeseen disasters even for communities deep in the rural hinterlands of the Himalaya. Though Nepal and Nepalis contribute very little to global climate change through the emission of greenhouse gases, they and their development endeavours are victims of unbridled emissions elsewhere. The impact of the Himalayan forest fires that occurred in the winter and spring of 2009 may have major global implications of another type: it will threaten the use of forests for carbon sequestration. Reforestation, such as is seen in Nepal's globally-renowned community forestry programme, is currently being promoted as a major global strategy for reducing greenhouse gas, but if climate variability and the increased frequency of drought conditions in the middle hills lead to increases in the frequency of forest fires, this carbon-banking strategy could quite literally backfire.

This report is based on a relatively rapidly implemented but carefully structured set of activities that include:

1. A review of the existing data and information on the climate system in the Himalaya and the impacts of climate change in the region;
2. An analysis of key signature events that, although they cannot, at this early stage of scientific investigation, be directly attributed to climate change, are consistent with existing projections of future effects;
3. Detailed consultations with rural and urban communities in eastern, central and western areas of Nepal across ecosystems ranging from the lower Tarai (plains) to the high Himalaya about their experiences with, and observations and perceptions of climate change;
4. An analysis of the economic consequences of the above eight signature events; and
5. The production of new downscaled climate scenarios for the region using regional climate models.

This report attempts to capture the risk an increasingly capricious climate poses for Nepal and Nepalis. It links its unique ground-level "toad's-eye" perspective with the results emerging from high-level scientific analyses and suggests the need for intensifying scientific research in order to bridge the gap between the two. High-end global climate science and local-level civic science with their traditional knowledge base must be brought together. The report also recognises the need to foster institutional pluralism in the planning and implementation of development programmes if sustainability is to be ensured and unpleasant surprises minimised. Nepal is currently engaged in the herculean task of dealing with the dual stresses of rapid socio-economic transition and the institutionalisation of the peace process through a restructuring of national governance. To these immensely challenging goals, it must add the charting of new development strategies to adapt to the partially known or even unknown multiple stresses induced by climate change.

The path that Nepal has followed since the 1950s, that of fossil fuel-dependent development, is susceptible to extreme climate change-induced stresses; and Nepal's rural communities are finding themselves more vulnerable than most to its effects. These vulnerabilities arise precisely because the causes behind them are far removed from the geographical horizons of most villagers; and neither they nor their elected representatives have much say or control over them. The increase in the demand for bio-fuel and hikes in the price of oil are distant climate change-related events, but their impact has been no less painful for being distant; and the villagers find this reality frightening. The globalisation of national and local economies has brought new products and amenities, sometimes unimagined wealth, but has also been accompanied by invisible threats to sustainable wellbeing.

Since the mid-1990s, rural Nepal has witnessed the wide-scale migration of able-bodied workers to labour markets in the Gulf, Malaysia and South Korea in addition to traditional destinations in Indian cities. The attraction of jobs was the main pull factor; the decade-long Maoist insurgency, the main push factor. The result of this mass exodus was a shortage of agricultural labour. According to villagers, depopulation, in combination with vagaries in the weather, including delayed monsoon rainfall, flood damage from intense cloudbursts, and rising temperatures resulting in the migration of weeds and plant disease vectors to higher altitudes, has made their lives difficult. Both agricultural production and livestock rearing plummeted as remittance inflows allowed villagers to buy their food from cities instead of growing it in vulnerable rural hamlets (DST, 2008).

For years, Nepali hill people have coped with food shortages through seasonal migration, but recently the rates of out-migration have soared. In addition, from 2005 to 2007, the demand for bio-fuel accounted for an estimated 60 per cent surge in the global consumption of cereals and vegetable oils, and thus for a dramatic rise in food prices (Tangermann, 2008). To make matters worse for Nepalis, world crude oil prices reached their highest levels, USD147, in June 2008, just when the Nepal Oil Corporation was no longer able to provide a regular supply of diesel and petrol to its consumers (improper pricing practices left it unable to pay its long overdue bill to India Oil Corporation, which cut of supplies in response). It was during this very period, before the Maoist conflict had scarcely cooled, that a new cast of political agitators in the Nepali Tarai began to call for transport shut-downs. Because hill villagers no longer grow food for subsistence and are instead dependent on imported food, the food shortage of 2008 promised to turn into a calamity. Mercifully, the global financial crisis brought the price of oil crashing down, the demand for bio-fuels subsided and the near continuous political agitations in the Tarai settled down to sporadic outbursts.

The question that must now be considered is how long will this breathing space last. The international price of non-renewable petroleum products is bound to increase, either because of speculation or simply because of the growing scarcity of fossil fuel; and the rise will increase the demand for bio-fuels in industrial economies. The emigration of able-bodied labourers from the Nepali hills and the continued inflow of remittances will prevent local agriculture production from flourishing. It is expected to decline except in places such as the Tarai and hill valleys, where groundwater-dependent agriculture will grow, but only if the fuel supply for pumping is not disrupted. It is in this environment, where the existing structural weaknesses in socio-economic arrangements are amplified by the stresses induced by the second-order impacts of climate change that the vulnerability of the rural population of Nepal will play out. Addressing the energy poverty nexus will have to be a key part of our strategy to reduce that vulnerability (PAN, 2009).

Today's climate change problems have emerged from unbridled growth in fossil fuel consumption globally. For the resolution, Nepal needs to cap the use of these fuels and shift to locally feasible renewable energy sources. This will require a statesman-like decision such as that made by Iceland. In the 1950s Iceland, like Nepal, was on a typical, fossil-fuel based path of growth; and electricity generation as well as space heating relied on imported oil. However, a radical decision was made soon thereafter to shift to renewable hydro and geothermal power, both sources that Iceland had in abundance. In the 2009 meeting the president of Iceland, Olafur Ragnar Grimsson[2] stated that had this decision not been made a generation ago, the collapse of Iceland's banking system in October 2008 would have been much more devastating. As it turned out, the energy security bestowed by obviating the need to import fossil fuel (except for limited transportation) has provided Iceland with the space to address its banking problems while keeping the rest of the economy intact.

Such a transition to non-fossil fuel dependent pathway makes economic and strategic sense for Nepal, and also would show a historical commitment of one of the least developed nations re-crafting its political future as it attempts to overcome tumultuous political upheavals. Such a transition notwithstanding, as one of the least significant emitters of green house gases, Nepal and Nepali people already face and would continue to face the problems that they had little role in creating, viz. climate change. The impact is higher cost to its social and economic development. This study is an attempt to highlight these costs.

Key insights and recommendations generated by the study include the following:

- The increase in the number and intensity of natural disasters will prevent many Nepali households from rising above the poverty line. Under median climate change projections, the flood impact on each household will double and the number of households affected directly will increase by 40%. As temperatures increase and the climate becomes more erratic, the incidence of forest fires may increase, thereby reducing the amount of mean residual energy available in forests for use by local communities.
- Responding to local as well as global socio-economic, political, institutional and climate-induced pressures, Nepal's population, most of whom work in the informal sector, has, autonomously and without government support, made a significant transition away from the primary agriculture sector and its reliance on natural resources. It is now leaning towards the service sector (as opposed to the manufacturing sector), which is less resource intensive and polluting than fossil fuel-based industrial production.
- The existing energy policy does not serve the nation well as it ignores the current mix of energy sources and over-emphasises making production more efficient through achieving economies of scale. The result is that Nepal is burdened by a slow-growing, supply-driven energy monopoly. This monopoly subsidises electricity for a few (5% of rural and 20% of urban dwellers) as well as of imported petroleum product. This factor indirectly taxes the most vulnerable, those Nepalis who are most dependent

on dwindling natural resources, while at the same time draining state coffers and reducing the nation's capacity to switch strategies to respond to future challenges.

- Provisioning reliable supply of electricity can function as an essential gateway service to help build people's adaptive capacities through income diversification. Empowering local institutions to implement decentralised renewable energy systems already found in Nepal, including solar, small and medium hydroelectricity, wind and biogas systems will halt the widespread burning of biomass as well as create many "green jobs". Realising this shift in Nepal's energy profile would also reduce emissions and reverse the ongoing loss in the sequestering potential of Nepal's national and community forests.
- The additional cost of using such alternatives should be borne by developed nations, which should pay Nepal "energy compensation" for exposing it to the climate stresses associated with using fossil fuel. This payment would provide financial incentives to Nepal to switch away from fossil fuel toward an adaptive and non-polluting development pathway. The cost of making this switch would be about 44 million U.S. dollars per year for next 20 years.
- Nepal too must begin its own indigenous efforts in mobilising its resources to engender that shift. The government must introduce well-designed incentives and policies that help channel remittance inflows from Nepalis who work abroad (a source of income which dwarfs both government revenues and foreign direct investments) away from non-productive land speculation and jewellery purchases towards climate-resilient investments. No more than ten per cent of Nepal's total remittances, if so directed, could fund the entire investment needed to shift towards a renewable energy pathway. Similar incentives need to be provided for making local infrastructure such as irrigation systems, roads, and bridges as well as public buildings like schools, health posts and government offices climate resilient.

NOTES

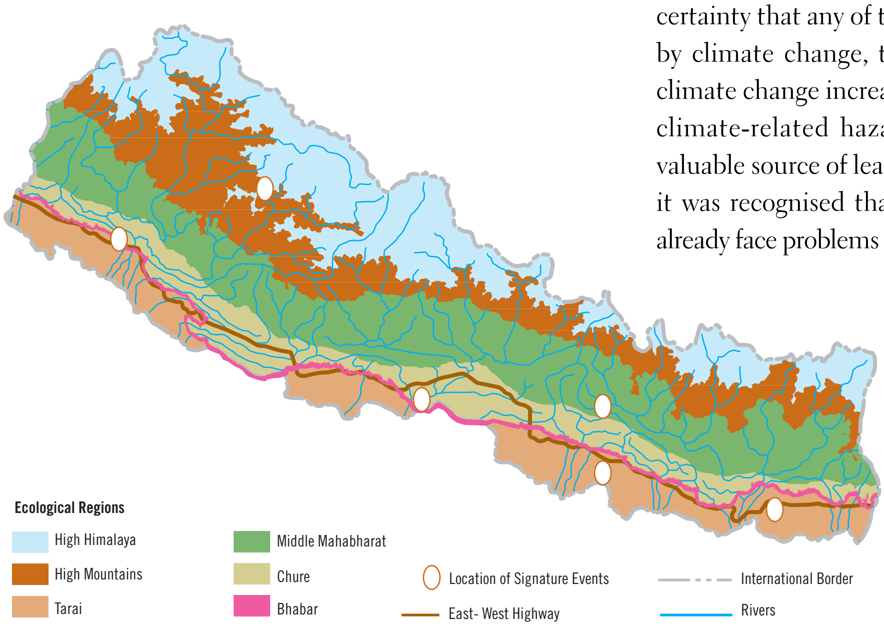
[1] Hodges' work quoted above and the implications for mountain-man relationship in the context of uncertainties in the Himalaya are discussed in Thompson and Gyawali (2007).

[2] Said at the International Hydropower 2009 World Congress held on 23 June, 2009, in Reykjavik.

MINING CLIMATE CHANGE LESSONS FROM SIGNATURE EVENTS

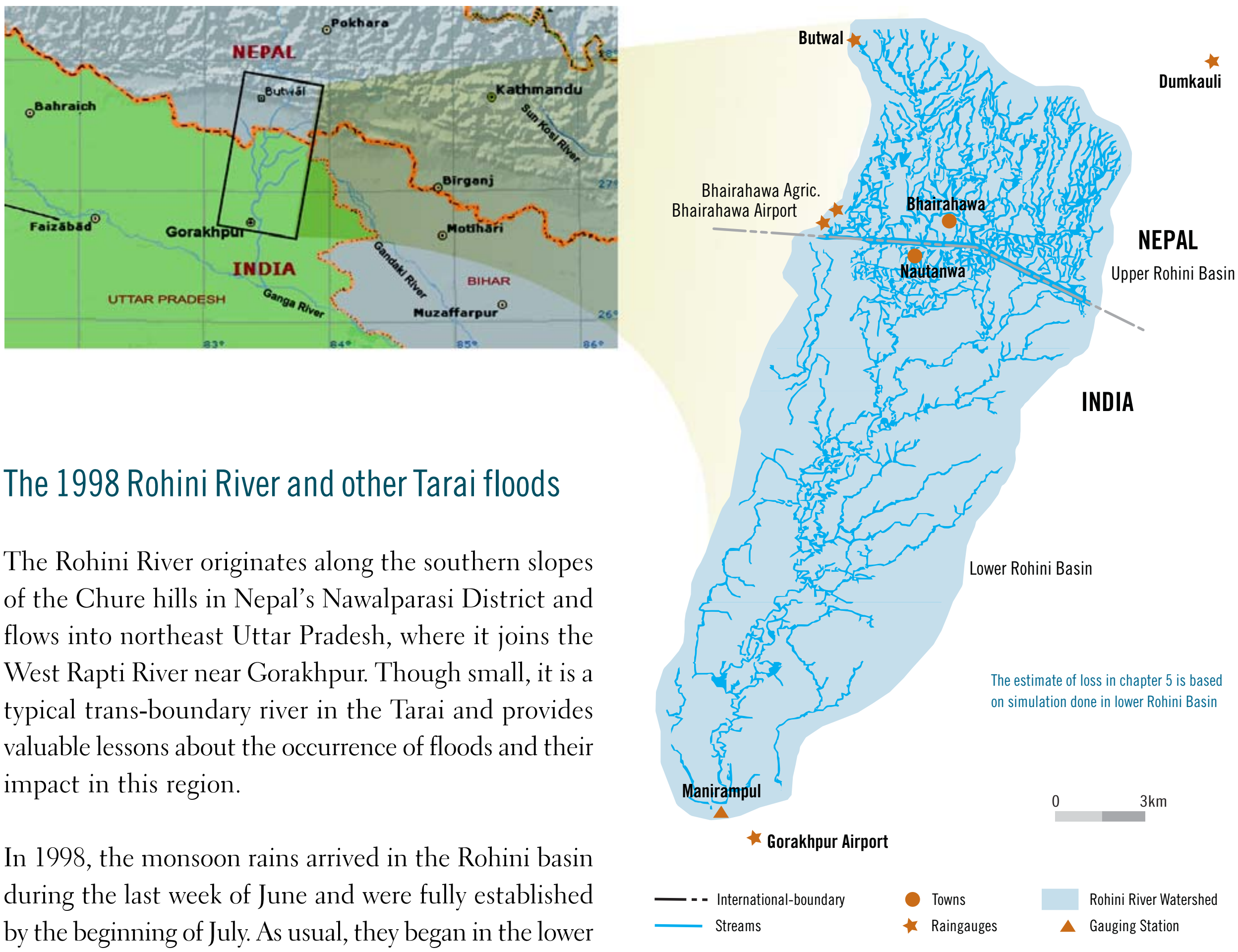
CHAPTER 2

Figure 2.1: **Location of signature events**



This chapter presents eight signature events of the recent past that have had impacts consistent with those projected to occur as a consequence of climate change. Though it cannot be asserted with scientific certainty that any of these disasters were directly caused by climate change, they do show what can happen if climate change increases the frequency and intensity of climate-related hazards and are, in consequence, a valuable source of learning. In the study of these events, it was recognised that many rural regions and villages already face problems that are similar to the likely impacts of climate change projected by most scenario models, problems they had no hand in creating. These signature events include: the 1998 Rohini River and other Tarai floods, the 2008 Koshi embankment breach, the 2008 floods in Far-West Nepal, the 1993 mid-mountain cloudbursts and floods, recent glacial lake outburst floods, the 2008/2009 winter drought, the 2009 forest fires across the country, and the 2009 diarrhoea epidemic in the Mid-Western hills.

Figure 2.2: **Rohini River system**



The 1998 Rohini River and other Tarai floods

The Rohini River originates along the southern slopes of the Chure hills in Nepal's Nawalparasi District and flows into northeast Uttar Pradesh, where it joins the West Rapti River near Gorakhpur. Though small, it is a typical trans-boundary river in the Tarai and provides valuable lessons about the occurrence of floods and their impact in this region.

In 1998, the monsoon rains arrived in the Rohini basin during the last week of June and were fully established by the beginning of July. As usual, they began in the lower catchment and spread northward to the foothills that constitute the upper catchment. The months of July and August were exceptionally wet, with both the upper and lower catchments receiving high volumes of rainfall, three times more than usual, in fact. In addition, several cloudbursts occurred, particularly in the upper catchment, where there were more cloudburst and wet days than in the lower catchment. According to the Indian Meteorological Department, Gorakhpur had received a record-breaking 1,232 millimetres of rainfall as of August 20. On August 24, another record was broken in the Nepal Tarai (in Ramgram municipality, Nawalparasi) when 460 millimetres fell in just 24 hours.

This August precipitation was part of a larger weather system that spread from the Bay of Bengal northwest to Central Nepal and Eastern Uttar Pradesh and had a huge impact on local populations. From the first week of July till the end of August, newspapers and humanitarian agencies on site reported myriad deaths, inundation, collapsed houses, eroded riverbanks, breached embankments, sand deposition, disease, and damage to infrastructure, including roads, bridges and power lines, occurring daily right across the region.

In Nepal, the floods associated with this rainfall affected 279 families in Nawalparasi District, washing away about 24 hectares of land and damaging property worth over NPR 680,000. India lost 1.393 million hectares of crops—1.224 million hectares in Bihar and 0.131 million hectares in West Bengal.[1] The damage in Bangladesh was still more devastating: almost two-thirds of the country (an area of 100,000 square kilometres) was inundated for 65 days and 33 million people were displaced, 18 million of whom needed emergency food and health services (Ahmed, 1999). Dhaka experienced serious health, housing, food, security, employment, and communications problems, and the livelihoods of the urban population were adversely affected by inundation (Nishat *et al.*, 2000).

Nine years later, in 2007, the region faced a similar situation as flood waters caused by the monsoon rains swept over the South Asian landscape. In parts of the Tarai and the larger Ganga basin in Nepal, India and Bangladesh, flooding inundated large areas, killed hundreds and displaced millions. Agricultural and other losses were high and disease spread across much of the flood-affected region, affecting both rural and urban populations.

The monsoon flooding that occurred in 1998 and 2007, although it exceeded long-term averages, was far from unprecedented. Floods are a regular feature of life in the region, important for soil fertility, aquifer recharge, and a healthy regional ecology. But flooding also brings misery to many inhabitants of the basin. The fact that they are so wretched despite decades of investment in flood control demonstrates that current approaches to flood management are unable to mitigate the impacts of recurrent monsoon flooding on human lives and livelihoods.

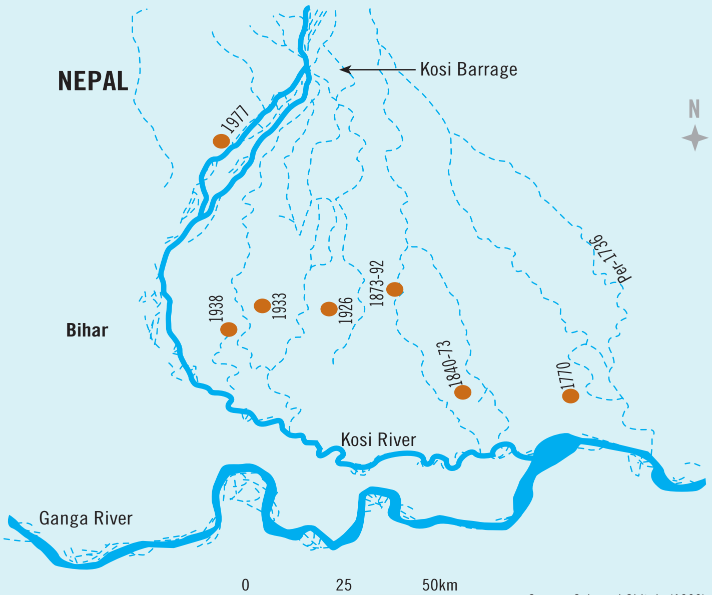
Although the scientific data does not allow attribution of weather hazards of 1998 and 2007 to global climate change, such events are in line with the projections scientists have made of the changes that are likely to occur as a result of climate change. Many of these projections suggest that both overall precipitation and the intensity of individual weather events will increase. If that is the case, both the regional monsoon precipitation pattern and the types of individual cloudbursts that contributed to the flooding in 1998 and 2007 could well become more frequent. Since such rainfall events have not been monitored on a long-term basis, however, it is difficult to draw conclusions regarding trends and changes. More studies are required before any cause-effect relationship can be established.

Overall, this analysis of the event indicates that if climate change projections prove accurate and floods and cloudbursts do become more frequent or extreme, current approaches to flood management will grow increasingly inadequate. Even at present, such strategies must be recognised as partial at best. They consist of (1) a broad array of actions taken by individuals, households and communities to reduce the flood risk they face; (2) a fragmented system of large-scale flood control infrastructure (primarily embankments) constructed by the government; and (3) weather tracking and early warning systems. Research undertaken in the Rohini basin suggests that strengthening community-based risk management strategies and improved early warning systems (which also have a large community-based component) could play a significant role in addressing disasters of the type that occurred in 1998 and 2007. Traditional approaches to flood management often emphasise technical infrastructures such as embankments over distributed solutions. There are, however, many questions concerning the technical effectiveness and trade-offs associated with such infrastructure. Similar lessons were also obtained in lower Bagmati basin in Nepal (The Risk to Resilience Study Team, 2009).

2008 Koshi embankment breach

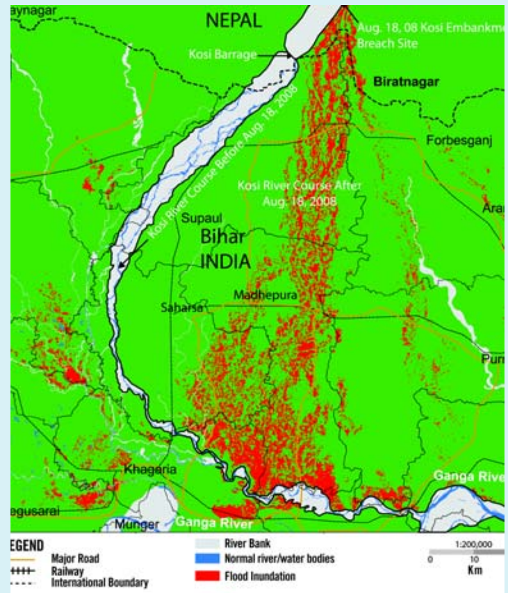
On 18 August 2008, an embankment along the Koshi River in the Nepal Tarai breached unexpectedly, at a time

Figure 2.3: **Koshi embankment breach**



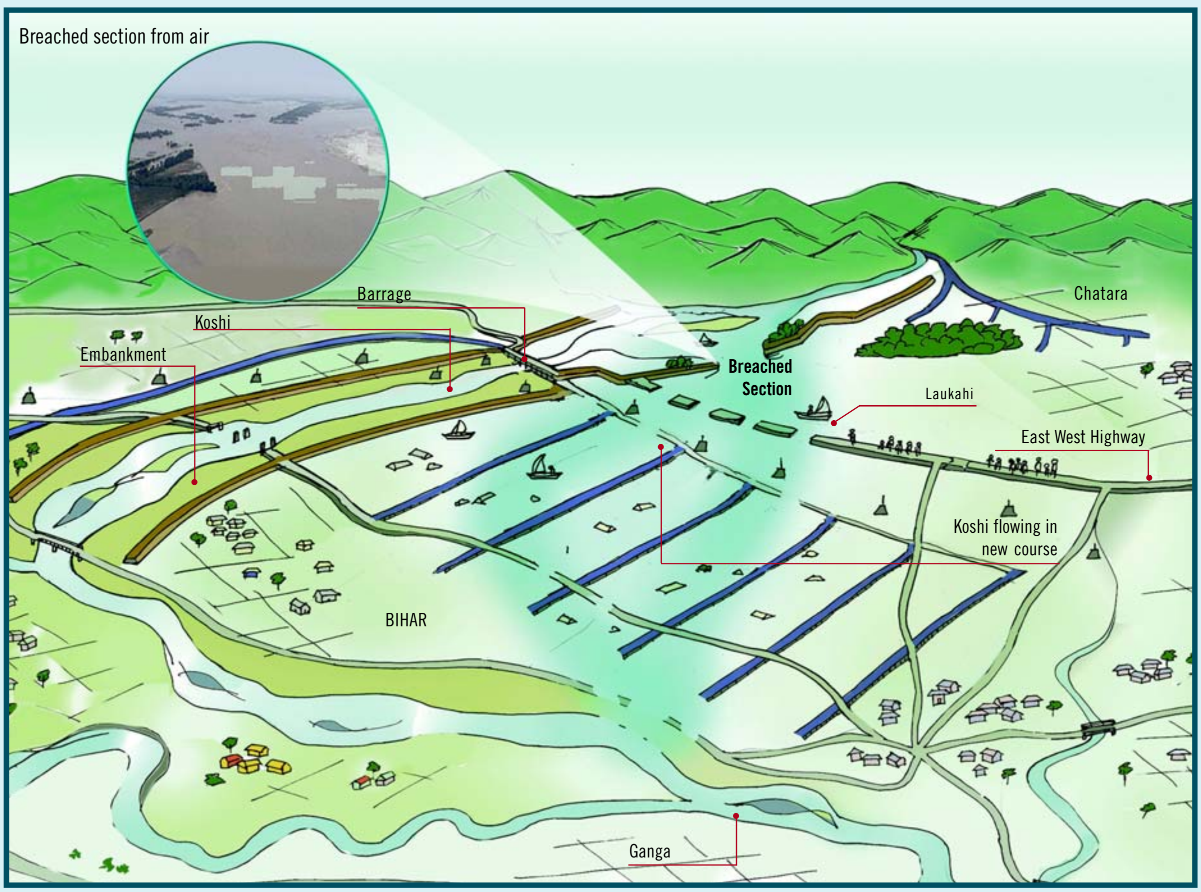
Source: Gole and Chitale (1966)

Flooded Koshi



Based on the analysis of radar sat-2 Data of September 3, 2008.
Adapted from: NRSA, Department of Space GoI

Schematic of the breached embankment and lower Koshi delta



Schematic of embankment breach at Kusaha 2008

Schematic concept by Ajay Dixit, 2008

Refuge on embankment

Living with sand deposition

Kosi flood refuge on cannal embankment, Bihar

when the river flow was almost a third below the long-term average flow for that month. Over the following weeks, a disaster slowly unfolded as the Koshi River began flowing along one of its old courses considerably east of the one defined by the embankments. Some 65,000 people in Nepal and about three million in India's Bihar were displaced. In Nepal, according to newspaper articles three were reported killed with 12 missing while in Bihar people 6,190 died.[2]

The Koshi drains an area of 60,000 square kilometres in Tibet, Nepal and North Bihar. In a single average year, the Koshi transfers an estimated 95 million cubic metres of sediment derived from landslides and mass wasting to the Ganga River. Much of the sediment is deposited at Chatara, where the river exits from the mountains onto the plains and its slope levels off. This phenomenon has created a large inland alluvial sediment fan, across which the Koshi regularly shifts as sediments precipitate and the riverbed aggrades. In fact, over the last 220 years, the course of the Koshi River has shifted 115 kilometres west in a natural process of river dynamics. In 1959, this natural process was interrupted when, as was stipulated in an agreement the governments of Nepal and India signed in 1954, the river was jacketed between two embankments.

The completion of the Koshi barrage in 1964 decreased the river's gradient and sediment deposition within the jacketed section of the river upstream of the barrage. Topographic maps indicate that the section of the riverbed within the embankments is now two to four metres higher than the adjoining land: in other words, the elevation of the bed has increased approximately one meter per decade since the embankments were constructed. Following the 2008 breach, the main river began flowing along a course that the construction of the eastern embankment had blocked. The breach demonstrated that instead of permanently protecting the surrounding area from floods, the embankments had changed the morphology of the river. As the bed gradually aggraded, the river became a time bomb running several metres above the surrounding lands and waiting to spill over. Poor maintenance of those embankments and institutional inefficiencies simply helped to light the fuse. The resulting flood caused widespread inundation and adversely affected those social and economic systems which depend on the river.

In the four decades after 1959, when the Eastern embankment was completed and the area east of the river was largely protected from major flooding, the region saw a surge in infrastructural development. Unfortunately, the newly constructed roads, irrigation channels, railways and other features blocked the natural drainage system even more and divided the region into a series of enclosed basins, low-lying lands and pond, all of which were inundated after the breach, as the river spread out in a fan across 30-40 kilometres, seeking the path of least resistance. In that vast flooded area, low points were scoured and sand was deposited on fields, in irrigation channels and drainage ditches in a hydro-morphological process that has transformed the landscape. While the two-kilometer breach has been plugged, there is no guarantee that the river, still flowing perched high above the surrounding land, will not breach again in the future.

Every flood-control embankment can breach—this risk is in their very nature—but the risk is particularly great in a river such as the Koshi, where the riverbed aggrades rapidly because of the high sediment load. The 2008 breach was the eighth major one in their 50-year history, and there will no doubt be another. No matter how well

Table 2.1: **Damage caused by the 2008 flooding in Far-West Nepal**

DISTRICT	DAMAGE
Kailali	11 males and 15 females died 2 males and 6 females were reported missing 2,152 houses were completely damaged 12,962 houses were partially damaged 5,647 households lost their entire stock of stored grains 12,552 households lost some of their stock of stored grains
Kanchanpur	18 VDCs and Dhangadhi municipality affected 30,733 people in 5961 households Dekhatbhuli and Shankarpur VDCs and Mahendranagar Municipality worst hit

Source: NRCS (2008). Detailed Assessment-Kailali District

embankments are maintained, breaches are inevitable. An embankment provides relatively high levels of flood protection immediately following its construction but its ability to protect declines at rates that depend primarily on sedimentation and, to a lesser extent, on how well the embankment is constructed and maintained.

If projections of more frequent and more intense extreme rainfall events due to climate change prove accurate, erosion will also increase, as will sediment loads and deposition on the Tarai and Ganga plains. Since the rate at which riverbeds aggraded will increase, the likelihood of embankment breaches will also increase. The increased flood flows predicted will have similar impacts. As the climate changes, flood control infrastructure of the type found in the Ganga basin is likely to be particularly at risk even if core maintenance and design issues are addressed.

A systematic analysis of the potential for future disasters of the scale of the August 2008 flood might assist in identifying strategies for flood control which have less inherent risk than structural solutions like embankments do. "Outside-the-water-box" thinking in addressing this problem may require searching for solutions in architecture ("houses on stilts"), domestic sociology ("one member of the family earning non-farming income in cities") or in rapid communications ("FM stations and information deployment").

2008 Flooding in Far-West Nepal

Between the 19th and 21st of September, 2008, heavy monsoon rains lashed Far-West Nepal, soaking the Tarai districts of Banke, Bardiya, Kailali and Kanchanpur and the hill districts of Dang, Dadeldhura, Doti and Salyan. In just three days, almost all of the Tarai of Kailali and Kanchanpur districts had been flooded. According to an estimate by the Nepal Red Cross Society (NRCS), 158,663 people in 23,660 households in Kailali District and 30,733 people in 5,961 households in Kanchanpur District were affected. When people returned home after the flood waters had receded, they found that most of their cattle were dead and that 35 per cent of their paddy had been destroyed (see Table 2.1).

Data collected by Nepal's Department of Hydrology and Meteorology (DHM) showed that rainfall stations at Tikapur in Kailali District and Shantipur in Kanchanpur District recorded 282.7 and 249.9 millimetres of rainfall respectively on 20 September. The next day, Tikapur recorded only 16 millimetres of rainfall while Shantipur recorded 124.9. While such large amounts of precipitation are not unexceptional in this region, as more roads and irrigation canals have been built in an east-west orientation perpendicular to the north- south flow of rivers, drainage has been impeded. In 2008, this obstruction became a particular problem, one which prolonged inundation.

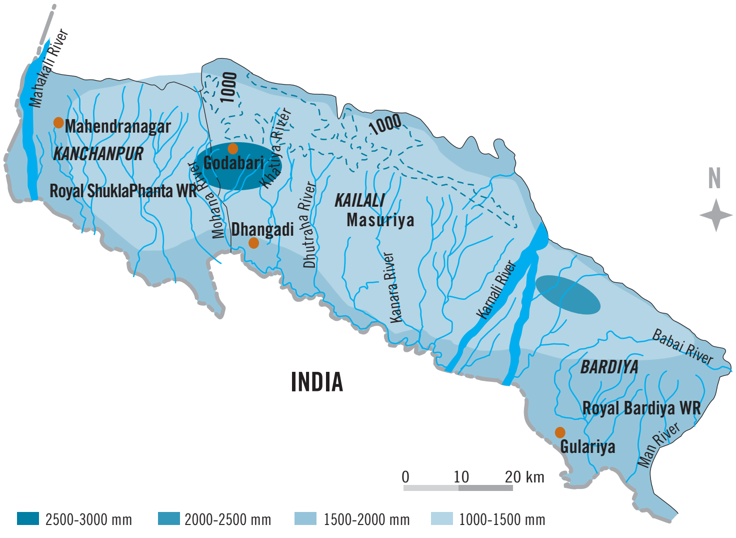


Figure 2.4: **2008 Flood affected region of the Far-West Nepal**

If rainfall variability and the intensity of storms increases, as climate change projections suggest they will, man-made structures that impede drainage could make populations increasingly vulnerable. This signature event clearly illustrates that patterns of development will interact with potential climate changes to increase people's vulnerabilities. Focusing on unimpeded drainage during the flood season rather than diversion control for dry season irrigation might have to be the primary focus of hydro-technical designs; and constructing drainage systems that are able to handle more water will become the priority as the climate changes.

1993 Mid-mountain cloudbursts and floods

Incessant rainfall from the 19th to the 21st of July, 1993, triggered an unprecedented number of landslides and floods in South-Central Nepal. The event was caused by a low monsoon weather system, or, more precisely, a "break monsoon phenomenon". The catchments of the Agra, Belkhu, Malekhu, and Mahesh rivers in the Gandaki River system, and the catchments of the Jurikhet, Mandu, Manahari, Lothar and Rapti rivers in the Mahabharat range were deluged. The Kulekhani catchment was also affected. The storm then moved eastward and settled over Ghantemadi in the catchments of the Marin and Kokajhar rivers of Sindhuli District in the Bagmati basin (MoWR, 1993). A station in Tistung in the Kulekhani catchment recorded 540 millimetres of rainfall in 24 hours on July 19th of 1993, the maximum 24-hour rainfall ever recorded in the history of Nepal (see Figure 2.5). The same station also recorded Nepal's maximum rainfall intensity ever—65 millimetres in an hour.

The rainfall caused both the Bagmati River and its tributaries and the Narayani River and its tributaries to swell, causing major flooding in the mid-hills as well as in the lower Bagmati basin. Altogether 1,460 people died or were reported missing, 73,606 families were seriously affected, 39,043 houses were completely or partially destroyed, and about 43,330 hectares of cultivated land was washed away or covered with debris. The floods damaged 367 kilometres of roads and 213 large and small bridges. After flood waters destroyed six concrete bridges on the national highways, the supply corridor to the capital was disrupted for more than a month. In just three days, landslides and floods destroyed 38 small and large irrigation schemes and 452 school buildings, hospitals and government offices (see Table 2.2).

The cloudburst severely damaged two major water projects; the Kulekhani hydropower plant and the Bagmati barrage. At the barrage, equipment, the gate control system, sections of the main canal, and the housing colony for staff were damaged. The barrage was designed for a peak flood of 8000 cubic metres per second after evidence that a peak flood of 12,000 cubic metres per second had occurred was rejected as a

Table 2.2: **Human and livestock damage casued by the 1993 mid-hill flooding**

DISTRICT	FAMILY AFFECTED	PEOPLE AFFECTED	NO. OF DEATHS	HOUSE COLLAPSED	LAND WASHED AWAY	LAND AFFECTED (HA)	NO. OF LIVESTOCK LOST	INFRASTRUCTURE DAMAGE OR COLLAPSED
Makwanpur	14,748	84,196	247	3,010	4,112	NA	1,872	Kulekhani hydropower plant, roads, schools
Sarlahi	16,812	91,110	687	16,708	379	16,681	11,310	Bagmati barrage, roads, schools
Rautahat	14,644	89,146	111	6,411	1,366	6,748	3,211	Schools, roads
Sindhuli	16,163	83,441	532	718	5,918	1,418	2,045	Schools, roads, bridges
Kavrepalanchok	3,318	18,915	24	885	1,244	NA	114	Same as above
Dhading	1,113	6,358	24	827	1,066	NA	353	Same as above
Chitwan	5,293	34,943	24	2,206	741	2,321	5,880	Same as above
Total	**72,091**	**408,109**	**1,649**	**32,765**	**14,826**	**27,168**	**24,785**	

Source: Annual Disaster review, 1993, DPTC.

statistical outlier; the July flood brought about a peak flood of 15,000 cubic metres per second.

The Kulekhani hydropower system, Nepal's only storage plant, consists of two power plants, the 60-MW Kulekhani I and the 32-MW Kulekhani II. When a flash flood in Jurikhet Khola cause by the downpour severed the penstock of Kulekhani I, the country lost almost half of its total installed electricity capacity from the Integrated Nepal Power System (INPS), and a three-month load shedding regime was imposed. As a result, the 1993 disaster not only affected the lives of ordinary people but also adversely affected the national economy (UNDP, 1997)

The flood also caused long-term damage because of the unprecedented volumes of sediment deposited in the Indra Sarovar, the reservoir of the Kulekhani plant. When impoundment began in 1981, the reservoir had a total storage capacity of 83 million cubic metres. Based on their estimate that the reservoir would receive 700 cubic metres of sediment annually from each square kilometre of catchment, the designers assumed that the economic life of the reservoir would be 100 years. The actual rate of sedimentation was two times

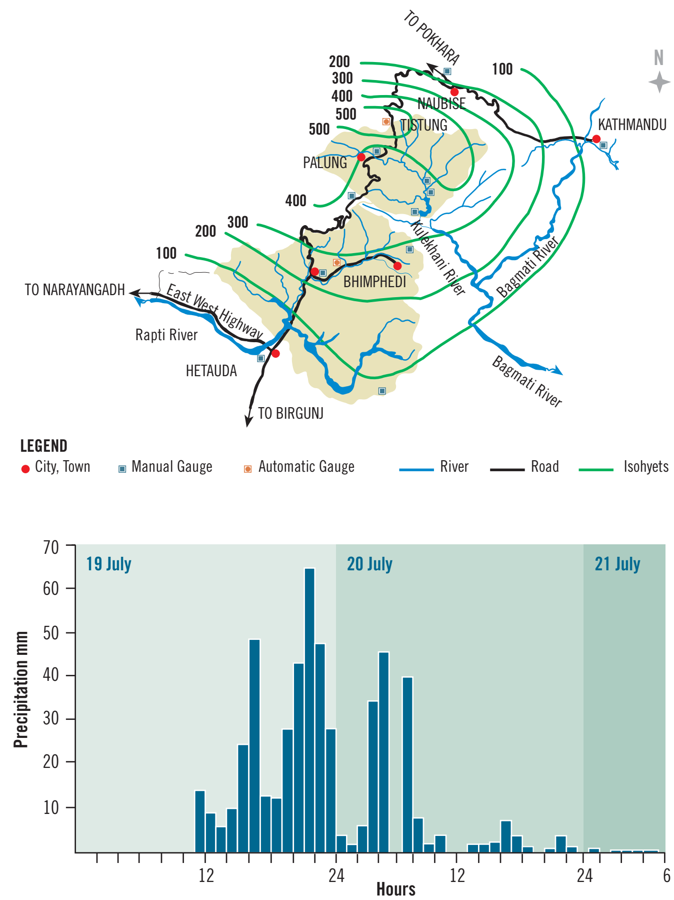
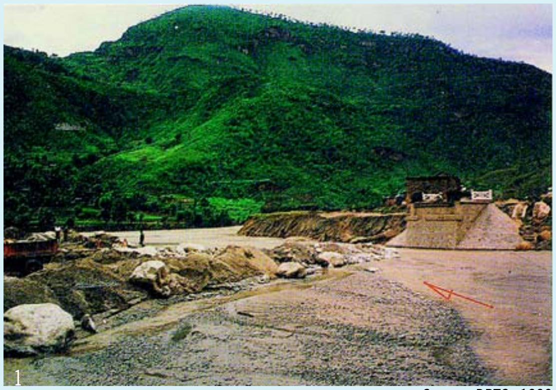


Figure 2.5: **1993 Cloudburst and 24 hour rainfall recorded at Markhu**

Figure 2.6: **Impact of 1993 cloudburst**

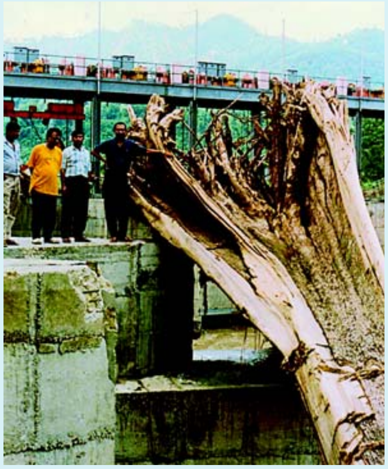


Source: DPTC, 1993

Source: DPTC, 1993

1. Belkhu Khola Bridge
2. Agra Khola Bridge
3. Malekhu Khola Bridge

Damaged Bagmati Barrage



A. Dixit

Khulekhani-I Penstock of Jhurikhet Khola: before and after cloudburst

Source: DPTC, 1993

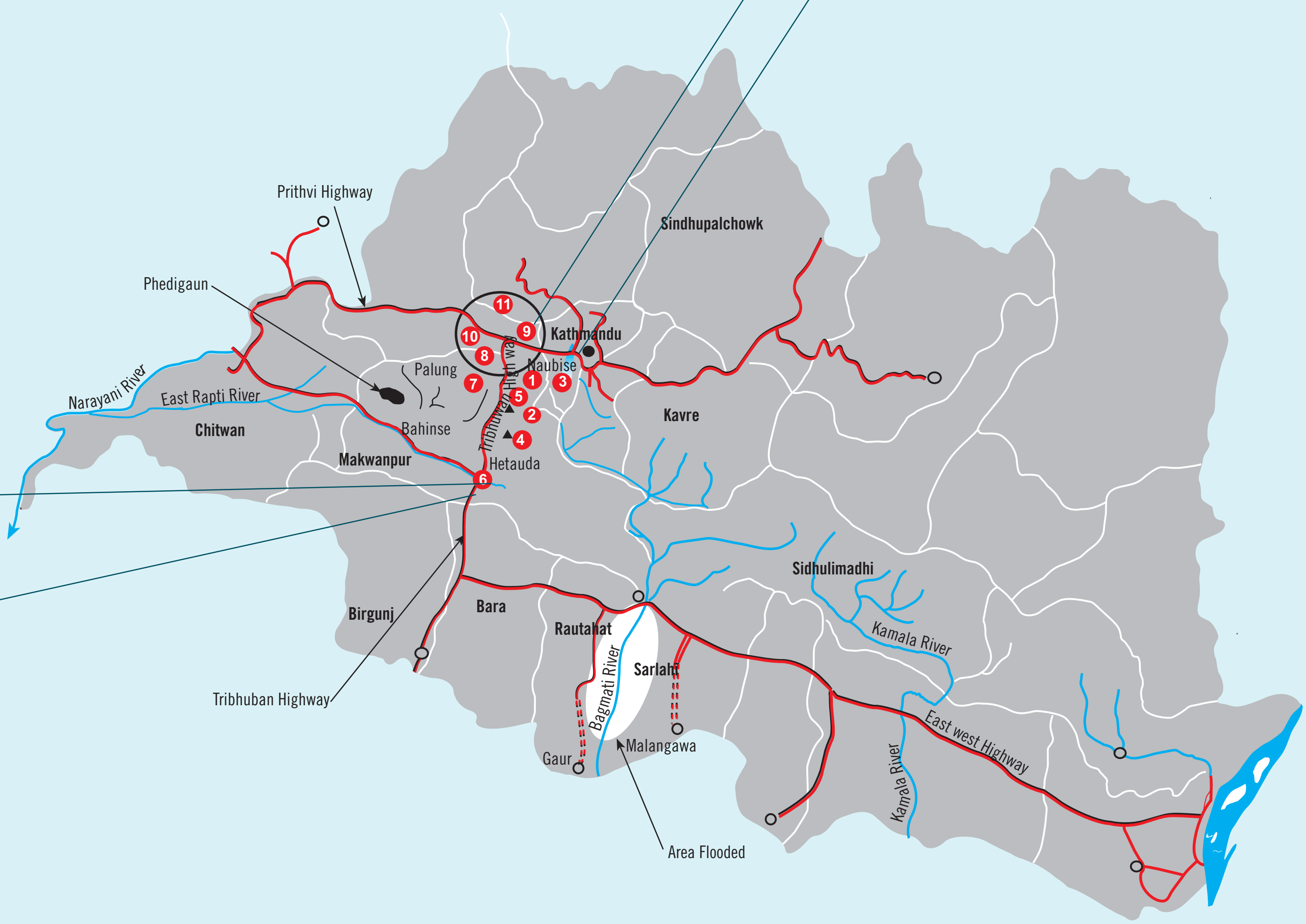
Source: DPTC, 1993

Source: DPTC, 1993

Source: DPTC, 1993

Source: DPTC, 1993

Damage highway



LEGEND

1. Khulekhani reservoir

2. Kulekhani No. 1 power house

7. Flood affected regions Rautahat and Sarlahi districts

Table 2.3: **Reduction in storage capacity (in hundreds of thousands of cubic metres)**

PARTICULARS	1981	MARCH 1993	DECEMBER 1993	SEPTEMBER 1994	NOVEMBER 1995
Gross storage	85.3	83.1	78.3	67.8	63.5
Effective storage	73.3	72.3	70.7	61.3	58.9
Loss in total storage	0.0	2.2	7.0	17.5	21.8
Incremental loss	0.0	2.2	4.8	10.5	4.3

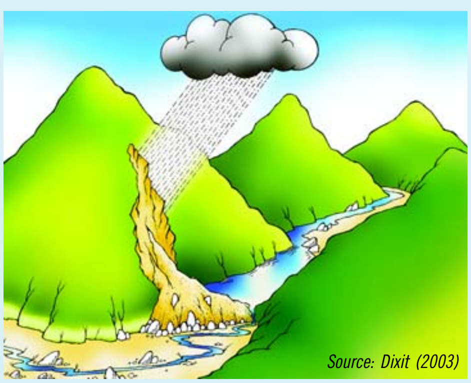
Sources: DSCWM, 1993; Nippon Koei, 1994 and NEA, 1995

the design rate. Surveys by the Department of Soil Conservation and Watershed Management (DSCWM) and the Nepal Electricity Authority (NEA) showed that from 1981 to 1995, a total of 21.8 million cubic metres of sediment, which is equivalent to an average of 1.56 million cubic metres annually, were deposited in the reservoir. In fact, the bulk of this mass came in pulses like that brought down by the 1993 events.

Sedimentation also caused long-term economic losses. The landslides and debris flow triggered by the 1993 cloudburst deposited about 4.8 million cubic metres of sediment in the reservoir, and in 1994 alone, another 10.5 million cubic metres of sediment was deposited. The figure doubled because the unwashed soil loosened by the cloudburst flowed into the reservoir. Sediment inflow was unusually high until 1995 (see Table 2.3). Because the sediment began encroaching on the tunnel intake, a new sloping intake was constructed. Experts from the World Bank, which financed the project, estimated that the economic life of the project was reduced by more than two-thirds, from 100 to just 30 years. The possibility that such an extreme event would occur had not been anticipated.

The 1993 cloudburst brings to the fore the problems posed by extreme rainfall events. They can result in *bishyari*, the temporary damming of rivers by landslides and the flash

Figure 2.7: **Temporary landslide dam on a river (*Bishyari*)**



Source: Dixit (2003)

In the mid-mountains a landslide triggered by a cloudburst often falls into a river, damming it temporarily and creating a reservoir in the upstream reach. When the dam breaks after it is over-topped or when it fails because of its inability to withstand the water pressure, a sudden flood is created. This event, which occurs randomly and cannot be predicted precisely, is called a *bishyari*. Such a flood gouges out beds and banks, thereby increasing the sediment load of a river substantially. It also brings devastation to lives and properties.

Source: WECS (1987)

floods that follow their eventual bursting. Like glacial lake outburst floods (GLOFs), such events increase the already high regional rates of sedimentation and make people more vulnerable. However, GLOFs occur in the sparsely populated high mountains while *bishyaris* plague the densely populated mid-mountains, where the social, economic and humanitarian impacts are far higher.

The 1993 cloudburst and its consequences illustrate several key impacts that climate change will probably bring. Since climatic variability and extreme events are likely to increase, so are cloudbursts of the type that occurred in 1993. But more rain is not the only projection for the mid-mountains; climate change is also supposed to result in a drier climate, particularly during the non-monsoon months. If conditions do become more drought-like, vegetative cover is likely to decline and hillsides will become more prone to erosion and large-scale mass wasting. Like extreme rainfall, then, the increase in overall aridity will probably increase sediment loads. The implications for hydropower projects, as illustrated by the Kulekhani event, are both technically and economically dire. Any increase in landslides will also have direct, large and adverse social impacts in the densely populated regions of the mid-mountains.

Recent glacial lake outburst floods

A warming climate results in the melting of glaciers and a decrease in the amount of water stored in the glacier mass, changes that could alter the regional hydrological system and pose a major risk to the population living downstream. The contribution of glacial melt to the flow of Nepali rivers is yet to be accurately estimated. Sharma (1977) has estimated that glacial melt accounts for about 10 per cent of the average flow of Nepali rivers. More recent estimate suggest that snowmelt from the Himalaya provides about 9% of Ganga's River flow (Jianchu *et al.*, 2007; Barnett *et al.*, 2005).

The melting of glaciers also increases the volume of water in glacial lakes (*tsho*) formed between a moraine and a glacier snout, thereby increasing the threat of a GLOF, which occurs when a moraine dam breaches because it is over-topped or disturbed by an earthquake.

According to ICIMOD (2007), Nepal has 2,323 glacial lakes with areas larger than 0.003 square kilometres situated above the altitude of 3,500 metres. ICIMOD identified 1,062 in the Koshi River basin, 338 in the Gandaki River basin, 907 in the Karnali River basin and 16 in the Mahakali River. The Dudh Koshi sub-basin in the Koshi River basin has the largest numbers of glacial lakes (Bajracharya *et al.*, 2007). Twelve pose the threat of a breach.

Nepal has already experienced 15 GLOFs. The most recent was in 1985, when Dig Tsho in the headwaters of the Dudh Koshi River breached after a large avalanche slid into it, over-topping the dam. Two hours later, the peak flood at Phakding registered 1,500 cubic metres per second. The event transferred four million cubic metres of sediment and destroyed a hydro-electricity project, 14 bridges, 30 houses and farmlands worth four million U.S. dollars. In 1981, when Zhangzangbo Lake breached, four people were killed, and the China-Nepal Friendship Bridge and seven other trail bridges, a hydropower plant, a section of the Arniko Highway and 51 houses were damaged. The breach of Tam Pokhari in 1998 killed two people, destroyed more than six trail bridges and washed away arable land. The loss was estimated at 150 million rupees.[3]

Figure 2.8: **Glacial lake outburst flood**

Source: Dixit (2003)

Source: Dixit (2003)

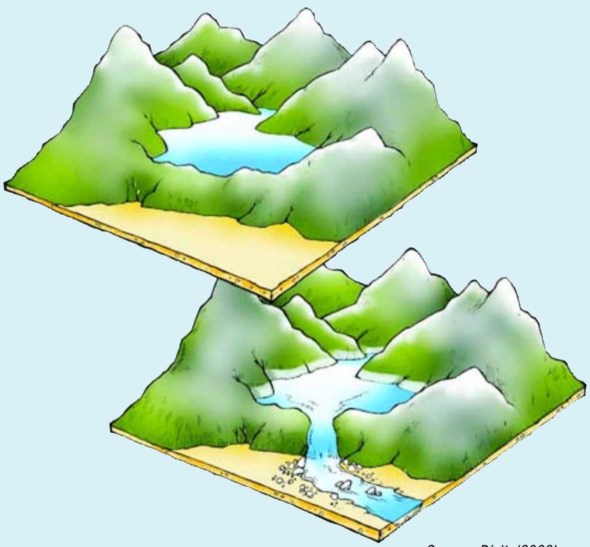
In the Himalayan region, glacial lakes are formed between a glacier end and its moraine. Glaciers have retreated rapidly in the second half of the 20th century, forming, in many cases, ice-core moraine-flanked lakes of melted water. Occasionally, there is a breach in a moraine dam and a lake empties in a very short time. This gives rise to glacial lake outburst flood (GLOF), which are major hazards and a source of sediment. The occurrence of GLOF is frequent and many glacial lakes have breached in the past. GLOF damages trails, suspension bridges, land homes and gouges the bed at banks of the river. GLOF is a huge pulse adding to the rivers' sediment load.

One lake which could very well breach is Tsho Rolpa in Dolkha District. Situated at an altitude of 4,580 metres and fed by the Tradkarding glacier, this glacial lake grew from an area of 0.23 square kilometres in the late 1950s to 1.65 square kilometres in 1997, when it stored 90-100 million cubic metres of water. In 1997, the Tsho Rolpa reached a critical stage. Butwal Power Company (BPC) in the year 1996 was commissioned to study Tsho Rolpa Galcier by the Government of Nepal due to its feared impact on Khimti hydropower plant if it had breached (Gyawali and Dixit, 1997). BPC made various assumptions and depicted the worst breach could cause peak flood of 7,402 cubic meter per second in the steep narrow sections of the Rolwaling Valley with water level reaching 20 metres above the normal level. Budhathoki *et al.* (1996) estimated the resulting flood from breaching of Tsho Rolpa Glacier could have directly affected more than six thousand people in 1996.

As a temporary measure, Nepal's DHM, with support from the Dutch government, built a trapezoidal spillway with a 6.4-metre bottom and a 14-35 cubic metre per second capacity to lower the water level by three metres in two years. At the same time, an early warning system was implemented in 19 downstream villages; this system, as with most 'dedicated' flood warning systems (as opposed to systems integrated into village life such as local FM stations and schools), no longer functions.

While GLOFs pose a direct threat to the high mountains and those who live there, they also threaten lowland regions by increasing regional sedimentation. The exact nature of that threat needs further investigation. The recent inventory of GLOF hazards is a start in improving our understanding of the threats, but we now need to map out the social, economic and hydrological risks of GLOFs and seek measures to mitigate them, including the draining of glacial lakes and the establishment of early warning systems.

Climate change projections suggest that the potential for GLOFs will grow. In fact, increases in temperature, particularly in high regions, are among the most robust projections from climate change scenarios for Nepal



Source: Dixit (2003)

Source: WECS (1987)

(see Chapter 4). This warming will cause increased rate of glacial melt, and the faster filling of glacial lakes, thus increasing the likelihood of breaches. There are other factors that contribute to glacial melt but the level of understanding about these is very low. The presence of dust and black carbon from forest fires, for example, can reduce albedo and increase the rate of snow melt, and as discussed below forest fires in the Himalaya may well increase because of rising temperatures and changes in hydrological system.

2008/2009 Winter drought

The 2008/2009 winter drought exacerbated the food security concerns brought about by the sharp spikes in food prices registered in 2008. Much of the country received very little or no rainfall between November and March 2008, when Westerlies are supposed to bring rain, or at high elevations, snowfall. In normal circumstances, 80 per cent of Nepal's total rainfall occurs during its four summer monsoon months, and the three months from December to February bring three to five per cent of the national annual precipitation. Average winter rainfall is higher in the West (140 millimetres) than in the East (40 millimetres) and accounts for a greater percentage of the total amount.

Figure 2.9: **Comparison of average winter (November to February) rainfall at eight selected weather stations**

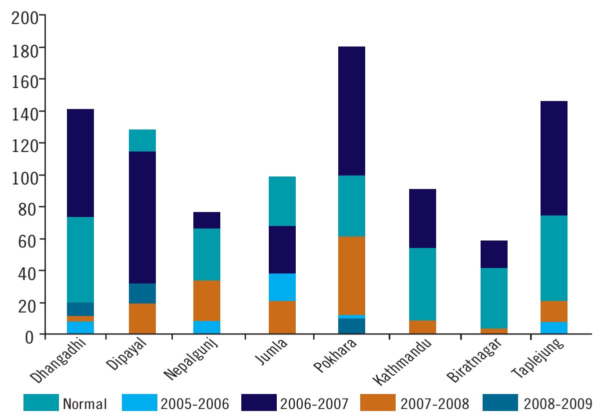
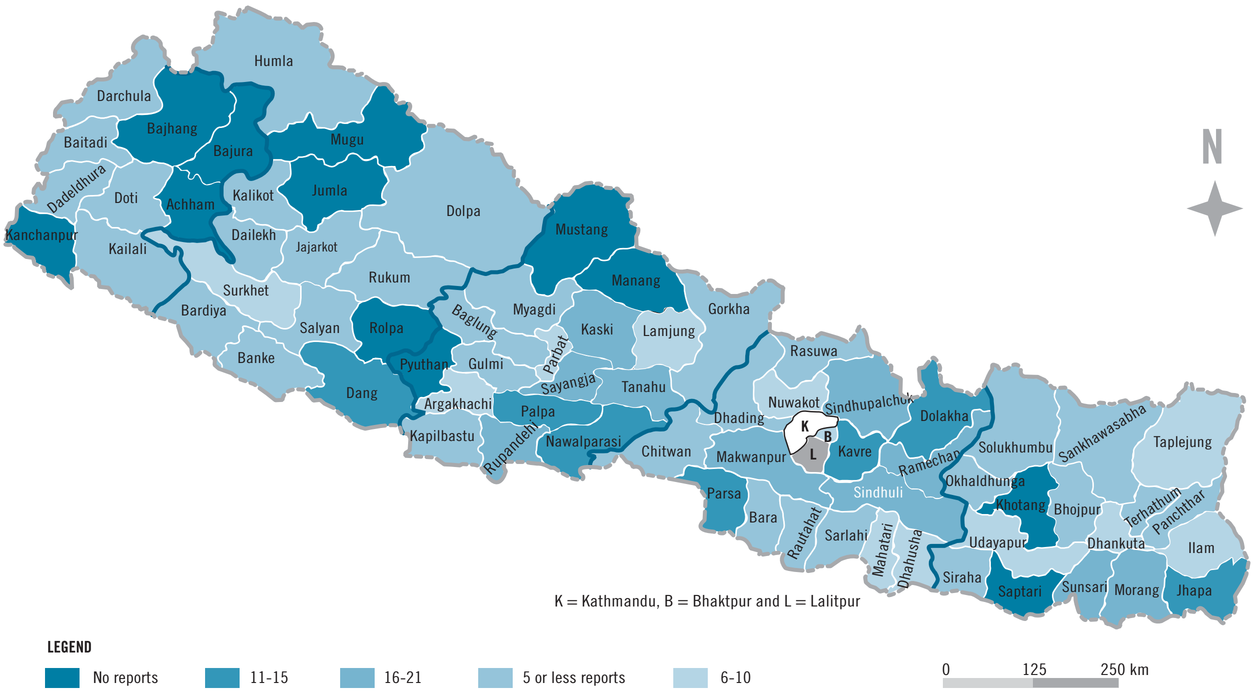


Figure 2.10 a: **Nepal's food deficit districts**



According to the DHM, the period from November 2008 to February 2009 saw less than half the average precipitation in almost all of Nepal's 35 rain monitoring stations. In fact, 15 stations recorded monthly rain levels which either matched, or were lower than the lowest rain levels on record, and almost one-third recorded no rain at all. The resultant winter drought was one of the worst on record, measured in terms of both the significantly reduced levels of rainfall and the vast area affected. The winters of 2007/08 and 2006/2007 were also unusually dry. In the period of 36 years, from 1971 to 2007, more than 150 droughts events were reported in Nepal affecting more than 330,000 ha of agriculture land mainly in the Tarai and western Hills/Mountains (NSET, 2009).

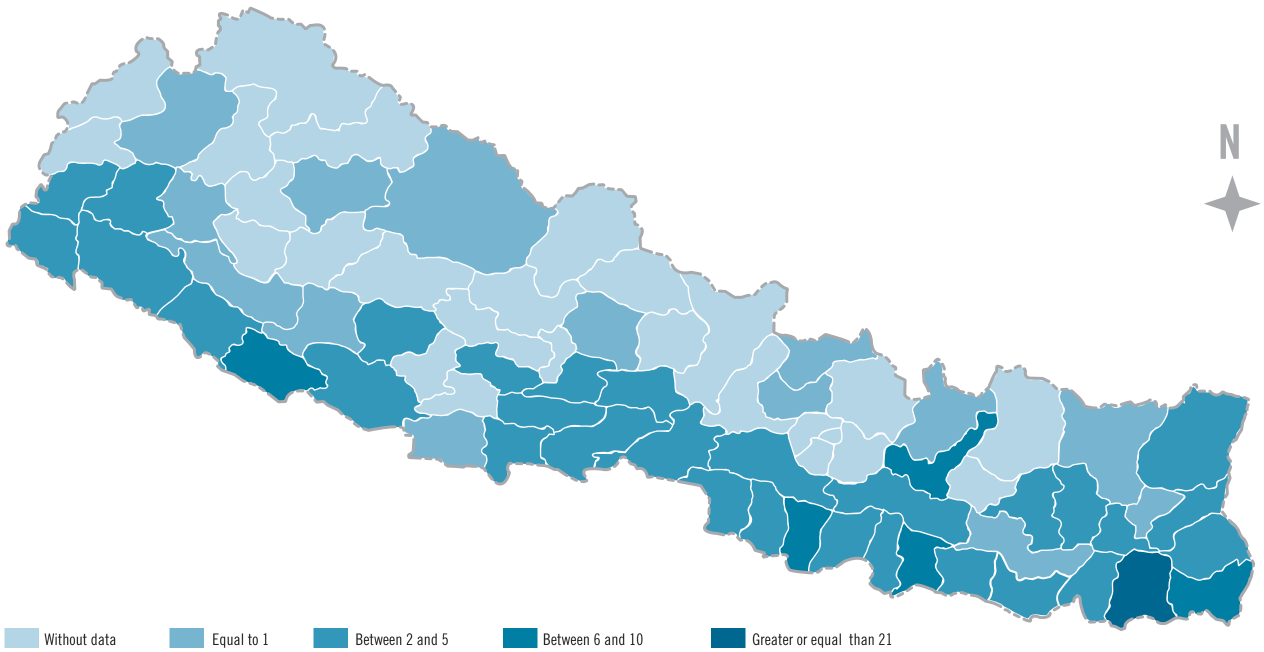
Although the 2008 summer harvest was generally good, many of those areas worst impacted by the winter drought, including the Far and Mid-Western hill and mountain regions, experienced significant summer crop losses due to excessive rainfall and diseases. It remains to be seen what the 2009 summer harvest will bring.

Projections of wide range of precipitation changes, greater climatic variability and increase in temperature over the country (0.5-2 degree Celsius with a multi-model mean of 1.4 degree Celsius by the 2030s for example) suggest that the frequency of winter droughts will increase. Even without climate change, however, the increasing prevalence of droughts in Nepal is a matter of great concern as they illustrate the vulnerability of the country's agricultural sector. Incidentally, Nepal's agriculture has registered food production deficits since the 1990s. If Nepal is to achieve and maintain basic levels of food security, investments in handling both the immediate food shortages caused by drought as well as in implementing long-term improvements in agriculture must be forthcoming.

2009 Forest fires

During the spring of 2009, forest fires blanketed much of Nepal (see Figure 2.11), raging in 634 places and damaging 105,350 hectares of forestland. According to

Figure 2.10 b: **Extent of drought in Nepal (1971-2007)**



Source: NSET, 2009.

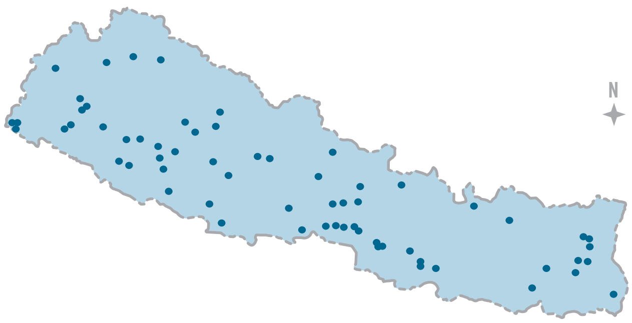
Acharya and Sharma (2009), the 2009 forest fires caused 43 deaths, injured 12, affected about 516 families, killed 375 livestock while also damaging 74 houses and 22 cattle sheds, causing an estimated loss of NPR 14 crore. Fire also leads to death of a significant number of livestock due to burning every year. This risk is particulalry widespread in the Tarai, mountains and some Himalayan districts. In the two years of 2004-2005 more than 100,000 cattle were burned to death. In addition to their local impact, fires can have major implications for the rates of glacial and snow melt. As an April 2009 satellite picture shows, smoke from the fires blanketed the Himalaya from Kashmir to Kanchanjunga.

It has been suggested (DfID, 2009), despite the success of community forestry and other local measures (Thompson and Gyawali, 2007), that Nepal has the eighth highest per capita rate of CO_2 emissions among least developing countries, primarily because of deforestation. Recent research suggests that if forest fires continue as a severe issue into the future could significantly increase glacial melt rates in the Himalaya, both by increasing the deposition of soot on glacial surfaces (thereby reducing albedo) and by releasing aerosols into the middle troposphere (thereby warming the atmosphere). While the link between decreased albedo and increased melt rates is well established, the links between aerosols, middle troposphere warming, and glacial melt rates, is more tenuous though isotope data do reveal that there was a 2.5°C per decade warming of the Muztagata glacier over the 1990s and aerosols have been isolated as a likely contributor (Tian *et al*., 2006, Ramanathan, 2007).

The 2009 forest fires may well be indicative of the future Nepal will face as a result of climate change, particularly if recent climate projections of the growing aridity in the mid-mountains prove accurate. Forest fires were reported in just 100 locations in March 2008 but in 1500 locations in March 2009. Most were thought to have been caused by the drought though some were reported to have been started by poachers in their

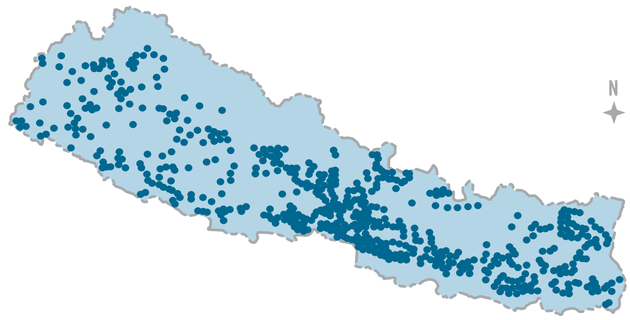
Figure 2.11: **Forest fire across Nepal, March 2009**

(a) 2008



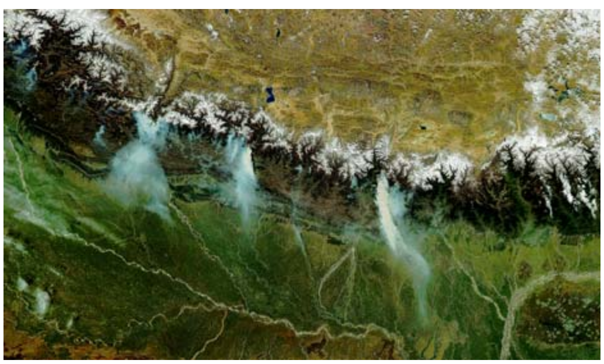
Source: ICIMOD, 2009

(b) 2009

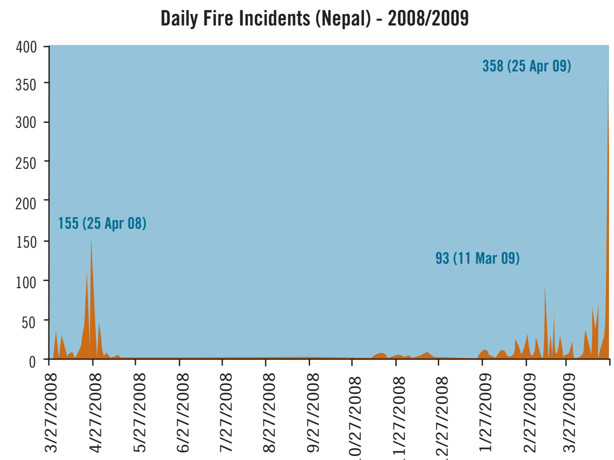


Source: ICIMOD, 2009

(c) Fire incidents (Nepal)-2008/2009



Based on Nepal_AMO_2009071_lrg: acquired March 12, 2009
http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=37518
NASA image by Jeff Schmaltz, MODIS Rapid Response Team



Adapted from ICIMOD, 2009

attempt to flush out game. According to dataset of the Disventar data base (1971-2007) maintained by NSET, a total of 3,880 fire events led to 1,108 deaths, 186 missing persons, and the fires affected a total of 218,278 people (NSET, 2009). An increase in the frequency and intensity of drought conditions and heat waves would greatly increase the risk of forest fires. Emphasis on objectives like increasing bio-mass energy, forests as carbon sink and conservation of biodiversity (see Box 2.1 on Biodiversity) would expand the size of forests but under a changing climate, would increase the likelihood of forest fires.

If there are more fires, the implications for reforestation and carbon banking are dire. In recent decades, Nepal's success in increasing forest cover through its community forestry programme has achieved global recognition. Increasing forest cover is perceived as a cost-effective mechanism for carbon banking as it mitigates the impact of greenhouse gas emissions while at the same time providing an array of products that help local populations meet their needs and adapt to the impacts of climate change. However, more forest fires and their attendant ills may be the unintended consequence of rising global temperature on a genuine and successful development initiative. To understand the emerging vulnerabilities will require deeper investigations into this previously unforeseen risk in present-day policies.

In addition to their direct impact, fires will also increase rates of sedimentation. Intense precipitation on areas

BOX 2.1: **Threat to Bio Diversity**

Forest fires destroy grasses, shrubs and trees, threatening Nepal's rich biodiversity. This is especially unfortunate because it is already under stress from anthropogenic and climatic factors. In some areas exhibiting high endemism hotspot, species are found here and nowhere else in the world. Their importance lies in regional, national and global interests for their conservation. Local people report declines and in the prevalence and coverage of some alien plant species. In the Far West, over-harvesting has considerably thinned species like *Acacia catechu* (*khayar), Dalbergia sissoo (sisoo), Madhuca butyracea* (*kalo* chyuri), *Embilica officinalis* (*amala*), *Terminalia chebula* (*harro*), *Terminalia bellerica* (*barro*), and *Acorus calamus (bojho)* and endangered other flora such as *Pterocarpus marsupium* (bijayasal). Some grass species like *kukhure suli*, a weed which used to grow on mustard farms in the Tarai, have disappeared altogether. And some of those species that still have healthy populations are under another threat: the shortening of the flowering and fruiting time of other plants has lowered their productivity. Locals also report declines in the populations of wild animals. The number of certain birds such as parrot and cranes, for example, has disappeared from the middle hills in Western Nepal, and insect pests have proliferated.

Another threat to Nepal's biodiversity is invasion and colonisation by exotic species, which often displace local species. For example, *Eupatorium adenophorum* (banmara) now covers pasture and grazing lands in the hills, the *Eichhornia crossipes* (water hyacinth) has taken over water bodies in the Tarai and *Lantena camera* (phul kanda) has inhibited the growth of other species such as *Cynodon dactylon* (dubo) in the Bhabar region. Forest degradation in the Tarai has left behind an Imperata cylindrical (siru)-dominated tall grass ecosystem with a profusion of other tall grass species such as *Eupatorium* (banmara) and *Mikania micrantha* (Chinese creeper), and grasses like *Thysanolaena maxima* (broom grass) and *Saccharum species* (*kans*), all of which are susceptible to fire.

Though the decline in biodiversity is not a concern of the majority of the population, the shortage of forest products such as firewood is. The interest of local people in conserving biodiversity has been weakened as their dependency on farming and animal husbandry has decreased with increased opportunities to earn cash elsewhere. This shift in interdependence has changed the linkages between ecosystem services and farm based livelihood security (DST, 2008). Another complication is that because Nepal's conservation policy does not differentiate between conserving forests and conserving biodiversity, most conservation interventions aim to address general degradation problems but not the endemism of hotspots. Furthermore, although protecting forests is a key step in conserving biodiversity, the protection of a succession forest developed in a degraded area does not preserve biodiversity. For instance, over the last four decades the degraded native *Shoerea robusta* (sal) forests in the Bhabar region of Far-West Nepal have been replaced by emergence of low-grade timber species; however, while the later do produce firewood, they do not allow other *understorey* species to grow.

The examples above are indications of the existing and emerging stresses on Nepal's rich biodiversity. Unfortunately, neither the anthropogenic nor the climatic causes or full implications of threats to plant and animal species are well understood. Much more study is needed. Current efforts to preserve biodiversity will also need considerable reflection. Restoring degraded biodiversity using the agronomic approach by planting limited number of preferred species pursued by most conventional reforestation programmes raises questions because such programmes not only rely on high subsidies for management but also focus on achieving a narrow ecological equilibrium with low biodiversity, an equillirium whose sustainability will be jeopardised by climate change. An ecological approach to restoring degraded biodiversity, in contrast, seeks to create communities and landscapes that can persist not just in static but in changing conditions, without continued human intervention or subsidies. Rather than promote a particular vegetative cover, the ecological approach initiates changes that underpin ecological systems and processes. By shifting from the existing agronomic-dominated paradigm to one that considers ecological as its cornerstone, we can sustain biodiversity in the long run, even as climatic conditions change.

Biodiversity losses also extend to agriculture and have thus directly impacted the livelihoods of local communities. Though the cultivation of imported species, the use of hybrid seeds and the uncontrolled application of agrochemicals have helped improve agriculture production in the last four decades, these practices have also replaced hundreds of low-producing but locally-adapted varieties, thereby reducing agricultural biodiversity. The choice to go non-indigenous, in part the outcome of changing food habits and prevailing mono-cropping culture, has limited the scope for using locally-adapted seeds as part of a shifting strategy of adaptation and for developing crop varieties that can thrive in changing climatic conditions. How the changing water and temperature regime will affect improved seed varieties and hybrids has to be determined. Thus far, the only impact noted by farmers is that there are more insects and diseases. Exactly how these blights affect crops, both imported and local, has not yet been fully examined. It will be important to preserve agricultural biodiversity and to develop suitable local varieties as soon as possible if Nepal is to be able to meet its food production requirements in a changing environment.

deforested by fire and drought tend to generate higher sediment loads and exhibit more "flashy" runoff patterns than do areas with extensive vegetative cover. This is because fires destroy vegetation, exposing more land surface, and thereby increasing erosion-transportation processes. If policies designed to increase forest cover have such negative outcomes, they could greatly increase the impact of climate change both at local and regional hydrologic levels.

Building our understanding of the interaction between forest and water management on the one hand, and of climate projections on the other will help us develop significant but as of now still poorly understood.

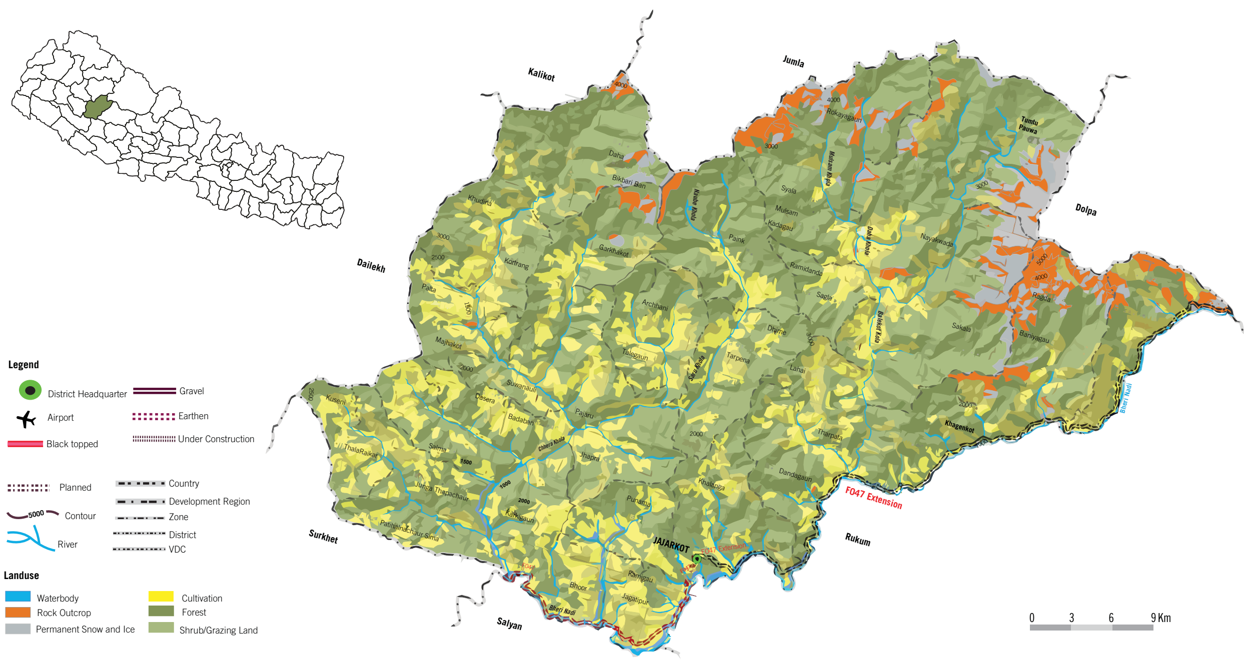
Nepal's own community forest management programme are often highlighted as success stories and efforts are ongoing to include it in the global initiatives effective strategies for adapting to and mitigating the impacts of climate change in the mid-hills and mountains of Nepal. As the above discussion illustrates, the impacts of both climate change and human responses to it may involve complex systemic interactions that cross scales and sectors and reach unexpected tipping points. Agriculture, for example, depends on irrigation, which in turn depends on flows and sediment loads that are themselves affected by local vegetative cover, snow/ice melt rates and erosion-transportation processes. These impacts are further affected by factors such as fires and regional climate dynamics. The implications of these complex systemic interactions for policy are such as reducing emissions caused by deforestation and forest degradation (REDD). But unless fire risks can be minimised, changing climate conditions could make relying on forestry for carbon banking and local adaptation counterproductive both at the local level and at the basin level scale. If this is the case, attempts to support local livelihoods based non-timber forest products for example, would not succeed. Should that happen, local populations will increasingly resort to migration or seek direct support from international institutions to meet their basic needs. The policy implications of such cross-scale systemic dynamics must be explored.

2009 diarrhoea epidemic in the mid-western hills

The Mid-Western Development Region has been experiencing a diarrheal epidemic since April 2009. The epidemic was initially limited to Jajarkot District, but as monsoon rains began to fall in the third week of June, the adjoining districts of Rukum and Rolpa, areas that saw much destruction of basic infrastructure during the Maoist insurgency, were also affected. By the second week of July, deaths were being reported in Dailekh, Doti, Surkhet, Dadeldhura, Kanchanpur, Dolpa, Dang, Bajura, Bajhang, Rolpa and Salyan districts as well. In Jajarkot, the death toll had reached 143 by 21 July and more than 2,000 people were reported to be seriously ill. Rukum was also hit hard: 42 had died by the end of July. Reports by the NRCS in 2009 showed that altogether more than 20,000 families had been affected and that 240 had died by August.

Thirteen of Nepal's poorest and most remote districts were affected. Some affected areas are a five-day walk from the nearest road-head. Jajarkot, home to a population of 151,551 in 30 Village Development Committees (VDCs) covering 1,502 km^2, is one of the nine backward districts of Nepal's 75 districts with the lowest HDI (UNDP, 2009). The other eight districts are Achham, Kalikot, Jumla, Dolpa, Bajhang, Bajura, Mugu and Humla.

Figure 2.12: **Jajarkot and adjoining districts and the locations of health and sub-health posts**



According to government sources, only 50 per cent of Jajarkot's residents have access to clean drinking water and only 19 per cent use toilets. Open defecation is widespread and often takes place close to local water sources. Warm summer temperatures (averages range from the mid 20-30 degrees Celsius) may have exacerbated the spread of diarrhoea.

Local heath workers attribute the epidemic to inadequate access to safe drinking water and poor sanitation. While officially half of the population has access to water supply systems, this figure obscures the fact that in reality many systems are dysfunctional because of poor maintenance, age or damage by hazards. Poor sanitation complicates matters, as does the fact that the density of health services is very low and access very limited (Table 2.4).

Table 2.4: **Numbers and their coverage of health-related institutions in Jajarkot District**

VDCs	30
Government hospitals	1
Primary health care centres	1
Health posts	8
Sub-health posts	25
health institutions	35
Primary health care outreach clinics	117
Female community health volunteers	270

Water-borne diseases continue to take lives in Nepal. In fact, over 80 per cent of all illness is attributed to inadequate access to clean water supplies, poor sanitation and poor hygiene practices. According to the Ministry of Health, diarrhoeal diseases account for a morbidity rate of 3.35 per cent, which is second to morbidity caused by skin diseases (5.51 per cent), another category of illness associated with dirty water, and poor hygiene and sanitation. About 28,000

BOX 2.2: **Drinking Water Services**

When assessing the coverage on drinking water supply, one must consider quantity, quality, time required for water collection, reliability, continuity and access (see Table 2.5). To ascertain the true level of service in Nepal, it is important to disaggregate the macro-level national data. In fact, even regional- and district-level data distort the true picture in local communities. Within any given community, disparities between household-level services are significant. Tables 2.6 classifies service levels and Table 2.7 gives a sense of regional differences in drinking water and sanitation services.

Table 2.5: **Water supply service levels**

SERVICE LEVEL (SL)	AVERAGE FETCHING TIME (MINUTES)*	QUANTITY (LPCD)	QUALITY OF WATER	RELIABILITY (MONTHS/YEAR)	CONTINUITY (HR/DAY)	AVERAGE ACCESS TO SOURCE
Good (SL-1)	≤15	≥45	Good (No risk of Contamination)	12	≥6	Easy
Moderate (SL-2)	>15 but <30	<45 but >25	Moderate (Risk of Contamination)	≥11	≤5	Moderately Difficult
Poor (SL-3)	>30 but <45	<25 but >15	Poor (High Risk of Contamination)	≥10	≤4	Difficult
Very Poor (SL-4)	>45	<15	Very Poor (Contaminated)	< 10	<4	Difficult and Dangerous

**Fetching Time means total time incurred to go to source, collect water and return back.*

Table 2.6: **Drinking water and sanitation coverage by region**

REGION	PERCENTAGE OF NEPAL'S POPULATION	PERCENTAGE WITH ACCESS TO DRINKING WATER	SANITATION
Rural	85	70	20
Hills and Mountains	55	65	20
Tarai	40	85	20
Bhabar	5	83	78
Kathmandu	44	87	95
Small Towns	56	80	65

Table 2.7: **Drinking water and sanitation coverage by development region**

POLITICAL REGION	ECOLOGICAL REGION	PERCENTAGE OF NEPAL'S POPULATION	PERCENTAGE WITH ACCESS TO DRINKING WATER	SANITATION
Eastern	Mountain	2	66	53
	Hill	7	60	52
	Tarai	14	54	41
Central	Mountain	2	82	47
	Hill	15	72	58
	Tarai	17	73	32
Western	Mountain	1	78	38
	Hill	12	77	61
	Tarai	8	83	36
Midwestern	Mountain	1	75	28
	Hill	6	73	24
	Tarai	5	63	39
Farwestern	Mountain	2	84	15
	Hill	3	81	27
	Tarai	4	75	38

Source: Calculated from CBA (2001) NEWAH (2008) and Water Aid (2004)

This regional data still conceals the true VDC-level picture. In 2002 the Asian Development Bank (ADB, 2002), found that in 19 districts of East Nepal, 76 per cent of the completed 5,135 drinking water supply schemes needed major repairs and rehabilitation implying that access to safe drinking water services is much lower than the macro level data. In Gajuri VDC, which border Prithvi Highway in the Central Development Region, coverage of drinking water and sanitation is only 27 and 34 per cent (NEWAH, 2008), a fraction of the aggregate figure of 72 per cent coverage among the central hill population.

Instruments such as the VDC-Level Water Users Master Plan (WUMP) also reveal similar disparities. The Water Resource Management Programme (WARM-P) of the Swiss NGO Helvetas used WUMP to assess the conditions of water and sanitation of 12 selected VDCs in the Far-West and Mid-West. The results (see Table 2.8), prepared in October 2001 and December 2003, show that just 12 per cent the population of these VDCs use toilets and only 11.5 per cent have good (SL-1) drinking water services. In contrast, 30 per cent had poor (SL-3) to very poor (SL-4) services. Incongruously, macro-scale data show high coverage in the regions (see Table 2.7).

The conditions of the VDCs in the districts affected by the 2009 cholera epidemic are also characterised by a poor level of drinking water services and low level of toilet use. Gaps in access to drinking water and sanitation, and poor hygiene conditions contributed to the incidence of the epidemic.

Epidemics are likely to become more serious in the wake of climate change-induced stresses such as increased temperature, extreme rainfall, and droughts if the social political system continues to remain the way it is. Since access to safe drinking water is one of the core elements for adapting to climate change impacts (Moench and Dixit, 2004), achieving and maintaining a good level of service must continue to be a policy priority. What the above numbers also indicate is that development planning, as well as the instruments of that planning including data collection and analysis, must be decentralised to the lowest level of governance complemented by an equally engaged national-level monitoring and evaluation.

Table 2.8: **Condition of coverage according to WUMP**

								COVERAGE				
				POPULATION		DALIT	TOTAL	WATER AND SANITATION COVERAGE				
PREPARED	VDC	DISTRICT	REGION	MALE	FEMALE	HHS	HHS	SL1	SL2	SL3	SL4	TOILETS
Dec-03	Gajari	Doti	FWDR	1,154	1,139	111	351	4	272	73	2	16
Nov-02	Khirsain	Doti	FWDR	1,519	1,565	970	557	0	152	204	201	45
Nov-02	Chhatiwan	Doti	FWDR	1,834	1,698	163	552	0	188	291	73	47
Nov-02	Chhatiwan	Doti	FWDR	1,834	1,698	163	552	0	188	291	73	47
Dec-03	Kaphallekei	Doti	FWDR	2,586	2,501	112	858	303	231	128	196	135
Oct-01	Laxminagar	Doti	FWDR	2,571	2,475	601	850	176	400	189	85	51
Dec-03	Goganpani	Dailekh	MWRO	1,948	1,798	181	627	39	340	222	26	97
Oct-01	Duni	Achham	MWDR	1,013	957	825	402	41	213	89	59	16
Dec-03	Dipayal-Silgadhi	Doti	FWDR	11,369	10,797	986	4,001	257	1,396	1,592	756	775
Dec-03	Ghanteshwar	Doti	FWDR	1,300	1,259	449	541	0	208	306	27	21
Dec-03	Ghanteshwar	Doti	FWDR	1,300	1,259	449	541	0	208	306	27	21
Oct-01	Sanagaon	Doti	FWDR	1,275	1,264	780	473	27	140	34	272	13
						Total	**9,750**	**1,122**	**3,683**	**3,229**	**1,716**	**1,227**
						hhs	**% hhs**	**11.5**	**37.8**	**33.1**	**17.6**	**12.6**

Source: WARM-P (2001) and (2003)

children die each year from diarrhoeal diseases in the country. According to official estimates, 89 per cent of the nation's population had access to clean drinking water in 2008, substantially up from the 34 per cent reported when the International Decade for Drinking Water Supply and Sanitation (IDDWSS) programme ended in 1990. This macro-level figure does not, however, provide a real picture of service at the VDC level. In addition, the data which was used to estimate national coverage does not differentiate the level of service (see Box 2.2).

The data are also deficient in the sense that they do not consider the time taken to collect water, a factor which may serve as a disincentive to using clean water sources. According to WaterAid (2004), only 42 per cent of communities have access to improved water supplies within a return journey time of less than 15 minutes. Other research demonstrates that the time taken to collect water has a strong bearing on water uses and on a family's health. The official figure also does not indicate the nature of the water source—whether it is a piped system, a tubewell, or an improved spring source—a fact which has bearing on the level of service. National coverage of sanitation is just 40 per cent. Populations which lack access to sanitation, particularly old, women and children, are more at risk of ill health. In rural Nepal, the nutritional status of children under five years of age negatively correlates with poor sanitation. This correlation suggests that the health impacts of poor sanitation are longer term issue than immediate sickness.

Because of limited mobility, the provisioning of health services in Nepal's mid-mountains is generally poor. During the ten-year insurgency, these already poorly developed regions also saw most of their infrastructure (train bridges, VDC buildings etc.) destroyed and their social workers displaced from the villages. In 2008, after the monsoon withdrew, most of Nepal received no rainfall for almost eight months. In addition, the onset of the monsoon in 2009 was delayed by 15 days and was often less than average. The dry winter and low monsoon rainfall resulted in the drying up of non-polluted spring and other water sources forcing the people to rely on polluted streams. The available health institutional faculties in the district is too thinly spread out to offer effective support (Table 2.4). That fact, combined with the prevailing social vulnerabilities associated with class, gender and caste, contributed significantly to the deadly epidemic.

According to Shrestha (2004), temperatures in the region are rising about 0.02ºC per annum and our climate scenario suggests that by 2030 Western Nepal is likely to register temperature increase of 1.4 degree Celsius relative to a mean of 1970-1999 (see Table 4.4, Chapter 4). Scientifically it is not possible to directly attribute the epidemic in the Mid-West to climate change. However, under these changing climatic conditions described above, it is likely that smaller water sources that supply drinking water to local communities will dry out and communities might be forced to use contaminated sources increasing the possibilities of diarrheal outbreaks.

Conclusion

Thus we can see from these eight signature events how climate change can potentially increase the hazards faced by Nepal's population, in both rural and urban areas. The possibility of exacerbation of these events both in intensity and frequency means that development planning must learn to first deal with increased *intensities* of such disasters: increased *frequencies* can then be better handled. But for this to happen, if the disasters caused by increased frequency and intensity of changed weather events are to be minimized, the country's institutions and governance structures must improve substantially.

NOTES

[1] These details were furnished from questions in the Indian *Rajya Sabha see Moench and Dixit (2004)* www.nepalnews.com.np/archive/2008/avg/avg19/news01.php . Accessed on August 25, 2009

[2] According to (IHD, 2009) losses to the affected region (1,000 villages) were far higher than many earlier official estimates. More than 6000 people died, and the valuation of houses damaged stands at around INR 880 crore (USD 195 million). Enormous amounts of goods were lost, including food-grains and domestic items worth INR 400 crore (nearly USD 88 million) and INR 155 crore (USD 34 million) respectively.

[3] www.freewebs.com/climatehimalaya/WWF2005/WWF-1-Regional Overview. pdf

A TOAD'S EYE VIEW: VULNERABILITY THROUGH THE EYES OF THE VULNERABLE

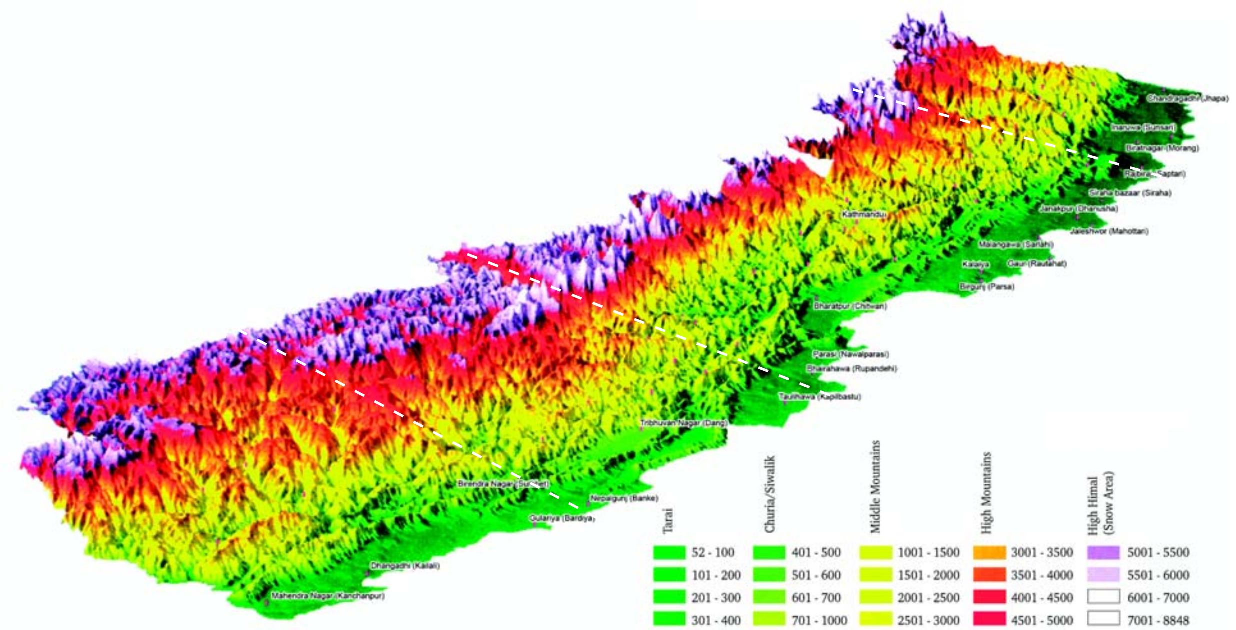
CHAPTER 3

The previous chapter tried to capture, by presenting a number of signature events, a mosaic of Nepal's vulnerabilities. The events described show just how susceptible the people, infrastructure and socio-economic systems of Nepal are to the risks of climatic hazards. The future bodes still worse for Nepal: according to most scientists, such events will grow in both frequency and intensity as the global climate warms. The complexity of Nepal's interconnected physical and social environments presents unique challenges to the country's development goals, and climate change impacts will only make things more difficult.

Variations in altitude and precipitation have blessed the relatively small territory of Nepal with diverse climatic conditions from tropical to alpine, and almost everything in between. This wide spectrum in turn accounts for its having multiple ecosystems and much biodiversity: within its 147,181 square kilometres, Nepal boasts 118 ecosystems, 75 types of vegetation and 35 types of forests as well as 635 species of butterflies, 185 species of freshwater fish, 43 species of amphibians, 100 species of reptile, 860 species of birds and 181 species of mammals (Bhuju *et al.*, 2007). It also supports a highly diverse array of cultures and livelihoods from the mountain-dwelling Sherpa transhumant traders and yak herders, to the culturally diverse peoples of the hills and Tarai, most of whom are farmers. Each socio-economic system is finely tuned to take advantage of the opportunities afforded by specific micro-climates and localised ecosystems and to respond effectively to the constraints on livelihoods they impose.

These human and ecological systems are embedded within three types of river systems classified on the basis of their dry-season discharge and their origin: the Himalayan, the Mahabharat and the Chure. Nepal has four perennial snow and glacier-fed Himalayan rivers: the Sapta Koshi, the Narayani, the Karnali and the Mahakali (Nepal's western border). Mahabharat rivers are also perennial but they are rain-fed and originate in the middle mountains. They include the Mechi (the eastern border) the Kankai, the Trijuga, the Kamala, the Bagmati, the East Rapti, the Tinau, the West Rapti and the Babai. The Chure rivers, as the name implies, originate in the Chure range and have low or, in some cases, no dry season flow. Because monsoon rains are their main source of water, their flows are flashy and highly variable. To develop Nepal's climate change scenario this report has divided the country into three broad regions (see Chapter 4 for an explanation), the

Figure 3.1: **Transects in three regions**



Perspective view of Nepal from 582 km above the Earth: South West: Vertical Exaggeration: 5
Elevation values are in meters. The elevation range assigned to each physiographic zone is approximate.
The prespective shows the diverse ecological subdivisions of Nepal starting from Tarai to Himal.

Source: USAID, Kathmandu

Sapta Koshi, Narayani and Karnali regions. In each region, three north-south transects were selected (the Rajbiraj-Sagarmatha, Bhairahawa-Mustang and Nepalgunj-Jumla transects respectively) so that the dramatic variations in Nepal's three major geophysical regions could be captured-the mountains, the hills and the Tarai plains (Figure 3.1).

The IPCC's 2007 Fourth Assessment Report is characterised by a "Himalayan gap": it includes very few references to scientific studies conducted in this region. This gap is less an oversight than a reflection of the paucity of information available. That said, a few studies do suggest that the impacts of global warming on the Himalaya will be considerable. Shrestha *et al.* (1999), for example, report that in Nepal temperatures are increasing and rainfall is growing more variable. Though the lack of extensive scientific research and data has limited the ability of the global scientific community to evaluate the implications of climate change for the region, there is another source of information—the local people, who, in contrast to the "eagle's eye view" of the high science of satellites, provide a "toad's eye view" rooted in the civic science of traditional knowledge and on-the-ground observation.

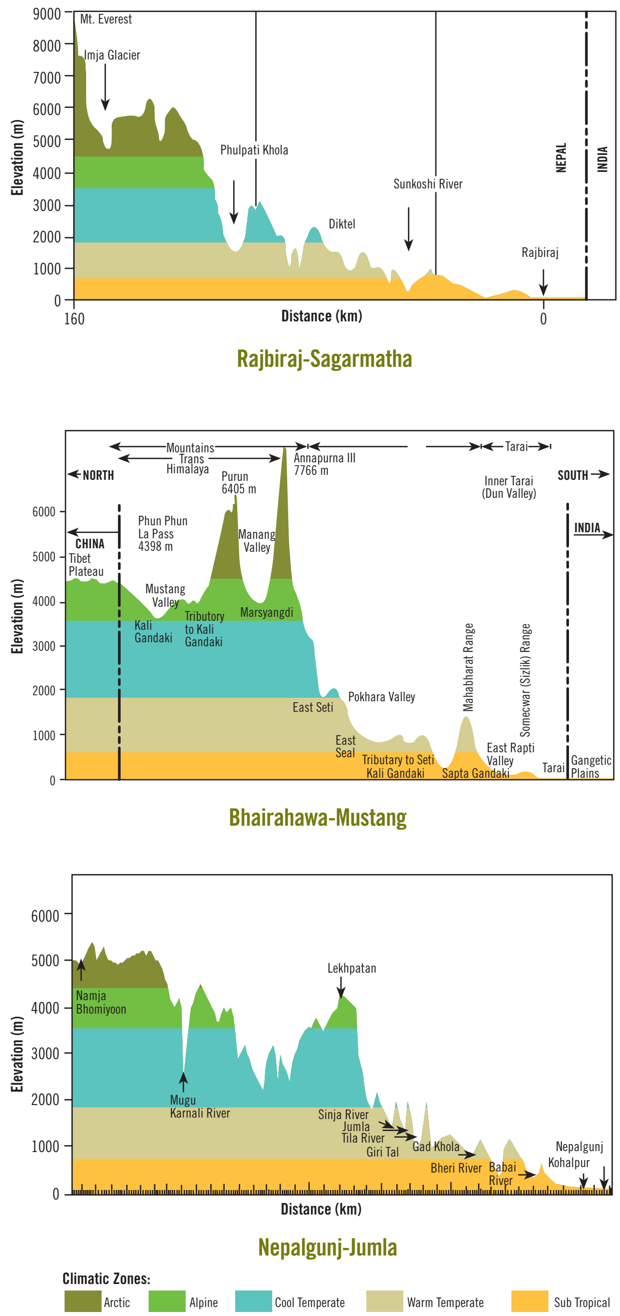
Governments and international agencies need high-end climate science so that they can link emerging global scientific projections of climate change with national-level conditions and use these connections as the foundation for their long-term response and development programme planning. In order to improve climate understanding, high science will need significant investments, but even if such investments are indeed made, and they may not produce robust results useful for development planning or for those most vulnerable to the impacts of climate change. To make up for this discrepancy, it is important to listen to the voices of grassroots civic science. As a source of insight and information, the perspectives and observations of local communities are critical in their own right; indeed, they provide much information which could never even be collected through formal scientific investigation. Observations at the local level also often document critical change patterns long before they can be quantitatively documented through formal scientific research.

Even more importantly, it is upon perceptions founded on these ground-level observations that millions upon millions of households making everyday decisions that not only affect their livelihood but also have implications for societal resilience in the face of climate change uncertainties. Local observations and perceptions drive behaviour. This behaviour, in turn shapes livelihood systems, infrastructure decisions and economic activity in ways that centralised, top-down strategies cannot. As a result, understanding the observations and perceptions emerging at the grassroots level has fundamental importance for developing systems that are adaptive and resilient to climate change.

Local people, though they have no access to or knowledge of scientific data and analysis, are capable of identifying changes which have undermined their ability to earn a livelihood from natural endowments such as air, land, water, vegetation, crops, and livestock. While it is difficult for them to assume a macro perspective on climate change (i.e., a eagle's eye view), they are much better positioned than the global community of scientists to provide real observations (i.e., a toad's eye view) of what climate change means on the ground and how it has affected their lives.

To collect snippets of these toad's eye views, we organised three consultative meetings: one each in Biratnagar, Pokahra and Nepalgunj. Participants came

Figure 3.2: **Rajbiraj-Sagarmatha, Bhairawa-Mustang and Nepalgunj-Jumla transects**



from across nine geophysical and hydrological regions: they spanned the mountains, hills and the Tarai regions of the Sapta Koshi, the Narayani and the Karnali basins. We also organised two consultative meetings in Kathmandu; the first involved national consultation with experts and senior government officials, while the second involved local people from the Tarai, Mid-Mountain and High Himal region of the Central Development Region. The following sections present a first-hand account of the changes these people shared at the meetings.

Drawing upon their experience and observations, the representatives of nine geophysical regions provided anecdotal evidence about signature events as well as about gradual changes in climate and their effects, including their impact on local hydrology and agriculture. Their evidence helps us appreciate the impacts of climate change even though we have left all attempt to correlate it with scientific data to the future, when universities and other research organisations will, we hope, carry out sustained research into climate change.

National consultation among experts

A variety of experts, including government officials, highlighted the following concerns in a half-day-long meeting held at Malla Hotel, Kathmandu on 7th June 2009.

One major issue was the natural variability of climate in Nepal. Participants recognised that Nepal's topography greatly influences its climate and causes considerable macro-, meso- and micro-scale variations. Summer monsoon rainfall is greatest in the east and decreases as one moves west though there are numerous meso- and micro- scale variations within each region. Because climate change will have impacts on almost all sectors, including water, agriculture, food systems, health, and biodiversity, there is an urgent need to carry out a national climate change impacts assessment study, especially as many past studies lack reliable and substantive evidence.

Participants recognised that the reliability of data is an important issue. In order to develop climate change scenarios, we must collect original and reliable data, and allocate sufficient resources to verify, analyse, assemble and propagate it. Without the data needed to feed into the climate change models used to generate future scenarios, governments will find it difficult to formulate effective policies. It is important to ensure the quality and accessibility of data, as well as develop the infrastructure needed to collect and manage it.

Participants felt that climate science must receive more emphasis if Nepal is to adequately confront the threat of climate change. A regional climate model such as PRECIS (a high-resolution climate model in a 25-kilometre grid) could generate climate change scenarios for Nepal but its operation, which must be continuous, would be handicapped by the unreliability of Nepal's power supply. This limitation must be overcome if our local modelling capacity is to be developed. Besides PRECIS, there are other regional climate models whose relative capacity to accurately capture conditions in Nepal must be also assessed.

The next issue touched upon in the expert consultation was knowledge management and capacity-building. It is not easy to generate new knowledge or build capacity though it is very important. We need mechanisms that facilitate interactions within and between local communities as well as with national-level organisations so that knowledge can be generated, disseminated, challenged and refined through constructive engagement at various levels. Since climate change impacts are localised, each experience will be different. It is important to understand all these differences. Enriching the capacity of core ministries such as the Ministry of Environment, the Ministry of Science and Technology and the Ministry of Forest could help us create, manage and consolidate our knowledge of climate change if such information were made available to all stakeholders using accessible and easy-to-use platforms.

Participants also emphasised that coordination and communication among agencies must be improved so that a consensus on solutions can be reached. Effective mechanisms for communicating climate-related information on floods and droughts to farmers must also be developed.

Another major issue that emerged in the consultations is that Nepal's participation in global negotiations must increase. Participants stressed that Nepal should acknowledge the role global debates and discourses play in shaping climate change policies and that agencies in Nepal which work on climate change should develop a single voice in order to increase Nepal's visibility in global processes such as the United Nations Framework Convention on Climate Change negotiations.

Participants emphasised the need to transit, in the long term, to an economy independent of fossil fuel. To do so, Nepal needs to build infrastructures which are suited to the country's geology, resilient to climate impacts and environmentally sustainable. At the same time, it needs to increase local capacity to minimise the impacts of climate-related disasters by augmenting social resilience and creating opportunities to earn non-agricultural livelihoods.

Central region consultation in Kathmandu

There was a general consensus during this consultation that surface temperatures are somewhat higher than they used to be and that the rate of increase in temperature is more evident in the mountains than it is in the Tarai.

Participants reported that weather patterns are more erratic both by season and by geographic area. They feel that common and traditional knowledge can no longer be applied to predict the increasingly variable and erratic patterns of rainfall and other weather phenomena. They also reported that normal variations in climate parametres are frequently exceeded. For example, snow fell in the mountains in April, a historic first, and permafrost thawing can be observed with the naked eye. The rate of melt of snow and ice has also visibly increased.

In addition, there are many reports that the lack of seasonal or timely rainfall has resulted in moisture stress and drought. Agriculture, especially winter crops, is suffering, as is human health because spring water sources are drying up or getting contaminated. This stress was particularly evident in the winter of 2008/2009 when, as rainfall records and local testimony document, the winter rains failed.

Recent outbreaks of forest fires were attributed to prolonged dry seasons and the resultant dryness of vegetation as evapo-transpiration rates increase significantly. The impact of the forest fires was directly evident to most people living in central Nepal during the spring of 2009: smoke and haze blanketed the region. Satellite imagery confirms this anecdotal evidence.

The hydro-geophysical changes observed have greatly affected agriculture, often negatively. The 2008/2009 drought, for example, resulted in low harvest levels of crops in many regions. It also caused mango yields to drop sharply as fruits cannot mature without sufficient water and simply dry up and fall off. Warmer temperatures have caused declines in potato yields in the hills in the summer and in the plains in the winter. The yield of black lentils in the Tarai has also plummeted. Not all effects are negative, however: horticulture in the hills got a boost as farmers can now grow litchis, a tropical fruit and in the Tarai plains paddy is maturing unthinkably early. Other livelihood activities have affected too: for example, warming temperatures have hampered yak-rearing in the mountains.

The overall picture of agricultural harvests has put people's livelihoods at risk. Poor households with small landholdings face the greatest hardship because their crops are not diverse and because they have no other income sources. Thus, if their major crop fails, they have little to fall back on.

People's health deteriorates when drought conditions dry up local surface water sources and they are forced to use unsafe alternatives. It is not just water-borne diseases that are on the rise; as temperatures rise, mosquitoes and mosquito-transmitted diseases have grown more prevalent, even in the mountains.

People in the Mid-Mountain, like residents of Dhading District, which lies at an elevation of about 1400 metres, have begun, inexplicably, to find earthworms in water sources. Whether this is due to a shift in the temperature line bears research. They also report that they no longer see eagles or snakes in the district. In Timure VDC of Rasuwa District, for example, when the warmer temperatures reduced harvests of chillies, their main crop, and consequently inhibited their trade with Kerung, Tibet, farmers were left at a loss. They complained that they have no options to adapt, change livelihood or diversify. They suggested that governments need to help put systems in place that will provide alternative sources of income. Those coming to the meeting also suggested that skills levels of farmers must be enhanced to help them turn to new source of livelihood as agriculture is at risk.

Narayani River region consultation in Pokhara

Our consultation with residents of the Nayarani River Region was held in Pokhara on June 22. Participants agreed with our general finding that average surface temperatures are rising and that rainfall pattern is growing increasingly erratic. In addition, people from Mustang reported unusual and unprecedented weather events, including a hailstorm, snowfall in May and an unusually dry July, the peak monsoon month.

Participants said that these changes in climate had affected hydro-geophysical phenomena as well like lowering the flow regimes of rivers, drying up of streams and increasing drought conditions and moisture stress. In fact, river flow has dropped so much, the unimaginable has happened: bridges have become redundant in, of all districts, Baglung, which pioneered indigenous suspension bridges and has more bridges than any other district in Nepal. Participants reported that the natural recharge of aquifers has also declined and that groundwater tables have been dropping rapidly. They currently stand at 50-70 feet below the surface and water availability has become critical even in areas once known to be rich in water resources.

Table 3.1: **Summary matrix of Narayani River region consultations**

GANDAKI

	MOUNTAINS	HILLS	TARAI
Agriculture	Apple affected by insects (unusual) and hail. Elevation for growing apple moved to higher altitude.	Skills and knowledge adapted to local agriculture and animal husbandry lost due to outmigration Rice planting delayed, production loss and decline, citrus orchards wiped out by fungus.	Delayed monsoon delays rice planting, shortening ripening time, hence rice production declining. Diseases in oil seed crops commonplace
Livestock		Number of cattle decreased due to labour shortage; fodder less as pasture moisture declines; new diseases seen, migrating plants toxic to goats.	
Water sources	Decreasing winter snowfall resulted in less moisture and fodder growth in pastures. Unusual hailstorm in Mustang	Water source drying, discharge reduced by 90 % during winter compared to past. Water supply systems failed. Decreased soil water lowers soil fertility. Absence of winter snow Bridges in Baglung (district with most suspension and suspended bridges in Nepal) useless after rivers dried up last winter. Snowfall in the month of May in Ghandrung (2000 meters elevation). July was dry.	Groundwater level declined from 50 to 70 feet, erratic rain and flood damaged planted rice.
Forests/pasture		Grass palatable to livestock rapidly declining. Banmara weed chokes pasture lands. Grazing lands have turned into livestock unfriendly jungle. Forest fires increasing in size; even holy Pipal trees being cut down.	
Floods/ landslides		Lanslides in unexpected areas and with increased frequency, flash floods damaging infrastructures,	Frequency of flash floods increased in Chure area. Lower Tarai inundation and sediment casting increased.
Health		Increase in mosquitoe infestation in upper region; increase in skin diseases and eye infections.	
Crop calender		Ghandurk summers feel warmer Snowfall on Machhapuchre in March instead of December/January	
Energy		Because of drying springs, pumps have been used to pump drinking water from streams.	Energy demand for pumping is increased

The reported water shortages are of great concern since so many people are dependent on rainfall for their livelihoods. Just 42% of cultivated land is irrigated,[1] so any decline or delay in rainfall reduces a farmer's ability to maintain household food security. When rainfall is late, paddy plantation is delayed and unfortunate consequences will ensue because there will be no harvest.

Increasingly, people are realising that indigenous knowledge is not up to the task of providing early warnings against extreme events or of safeguarding traditional agricultural production practices against the vagaries of nature. Just as climate variability is reaching new heights, farmers' ability to cope with it is declining because indigenous knowledge no longer has the answers.

Participants also see their growing trouble with pests as climate related. Mustang's apple harvest has declined due to the upward migration of a devastating pest which has so baffled farmers that they have been unable to implement effective mitigating measures. They have also been unlucky in citrus fruit farming as the rise in average temperature has encouraged a fungal attack which caused widespread morbidity. Farmers have recently planted pomegranate trees in the hope that this fruit will, at long last, provide them with a sustainable livelihood. In addition to pests, other invasive species are emerging as problems. For example, *Ageratum houstonianum (neelgandhey)*, a non-toxic grass species native to the Tarai, has appeared in the hills of Lamjung along the Marshyangdi Valley, where it is reportedly poisonous to goats and cattle (DST, 2008). This grass has probably moved upward from its native location because temperatures at higher elevations are increasing.

The climate-related changes identified by participants in the consultation are perceived as having had a major impact on the traditional livelihoods of the poor. They were considered as a major reason they had responded to corporate enticements to convert their paddy fields into micro-scale tea gardens, a transformation which may serve as an effective adaptation strategy. However, it is not yet clear if tea plantation will be sustainable and the observed decrease in local water resources and ambience moisture is not a positive sign.

Karnali River region consultation in Nepalgunj

The participants here felt that temperatures are rising and that rainfall is growing more erratic in its timing, intensity and duration. Participants did not agree whether total monsoon rainfall is increasing or decreasing. Some say that it has declined considerably, while people from Tarai report that total rainfall has increased slightly in spite of a decrease in the duration of the monsoon season.

In terms of the hydro-geophysical consequences of the changing climate, people report that the region has experienced moisture stress and phonological drought, and attribute this aridity to the delay in the arrival of and the erratic rainfall during the monsoon. Another important observation they made is that the groundwater table is falling, a phenomenon they attribute to reduced winter rainfall, more intense rainfall events (which do not allow for slow percolation), and excessive groundwater extraction.

These drought-like conditions have caused problems for those engaged in agriculture-based livelihoods in the Tarai plains of the Nepalgunj-Jumla transect. People

Table 3.2: **Summary matrix of Karnali region consultation**

	MOUNTAINS	HILLS	TARAI
Agriculture	Drought recurrent, crop failures	Decrease in production of crops, Fast maturity of crops/plant.	Decrease in crops yield, insect in rice and mustard, caterpillar increased, empty grains of pulses.
Livestock	Livestock number reduced due to lack of grazing, *Karnali Truck* (salt/grain carrying sheep) is out of use	New diseases and pests due to declining population of parrot and cranes in Dang, Dog mating year round, livestock decreasing due to shortage of labor, one productive buffalo instead of many unproductive, interest to produce manure in reduced. Local goats replaced by cross breeds	Certain weeds (*kukhure suli)* lost from mustard farms. Tractor replacing drought animals with added energy demand
Water sources		Total rain in tarai slightly increased, Winter rain failed, Monsoon rain erratic, untimely and decreased, shortened monsoon period, hotter days increased Water supply systems have lost water in the sources	Ground water table continues to decline despite rainfall events. Water source emerging in once dry areas.
Forests/pasture	Insects infestation increased. Fodder in pasture less available.	Time of flowering and fruiting of some plants have shortened. Biodiversity affected. Native flora are going extinct.	Deforestation increasing with firewood pressure
Floods/ landslides		Landslide and debris flow events increased	Flood events becoming more destructive, crop land lost to sand casting, flash floods increased
Health	Mosquito appears in Jumla	New diseases are appearing	
Crop calender		Local agriculture calendar changing	
Energy			Shift to tractor requires more imported oil

complained that crops mature far ahead of time and that that the total maturation period has decreased resulting in low yields. Crops are also threatened by previously unseen pest infestations and diseases, and certain indigenous flora species are endangered, some critically so.

Mosquitoes are a new hazard in the hills and some say that certain animal species, such as dogs, now reproduce year round, instead of just during a specific period of the year. It is not known whether such changes are due to the impacts of climate change.

People wonder if it is the past felling of trees in the Tarai that caused the changes, especially the increase in episodes of drought. Farmers want to know how they can get access to scientific information about imminent changes in weather patterns, approaching storms or impending droughts, early enough to enhance their ability to avoid loss. In a bid to enhance their resilience, they are looking for access to relevant information. They would also like the opportunity to increase their capacity to face new hazards.

In the Tarai region of the Nepalgunj-Jumla transect, floods are gradually causing noticeable problems, which was not the case in the past. People favour having an early warning system and increasing the flow of information to them so that they can devise local-level plans to safeguard their agricultural and other livelihoods.

Sapta Koshi River region consultation in Biratnagar

The July 13 consultation in Biratnagar revealed a number of local-level observations that testify to the impact of climate change. In terms of climate variability and change, people's reports are no different from those in every other consultation: they see a general warming trend and more erratic rainfall patterns. The temperature increase is captured by scientific data but the extreme rainfall variability appears to be a new phenomenon requiring further analysis. Local experience needs to be validated with scientific observations.

In terms of observed hydro-geophysical changes, local people identified a paradoxical increase in the occurrence of both-floods and waterlogging as well as droughts and moisture deficit. Drought appeared to be increasing in magnitude and becoming more erratic: when once July/August, the peak of the monsoon season, was a month people struggled with excess water, today they face extended droughts and moisture stress.

In addition to climate-driven hazards, climate-induced hazards were also prevalent. The incidence of forest fires has increased considerably, probably as a result of the prolonged dry season coupled with the associated high evapo-transpiration rates.

The signs of drastic changes are ominous. Because of erratic rainfall and temperature rises, neither the traditional crop calendar nor long-standing crop rotation rules are applicable any longer. While it is true that legumes in general suffer when topsoil moisture is lacking, beans are now failing even during peak monsoon season. Moisture stress has been taking a toll on tea and sunflower production as well. Tea leaves have dried up and turned black, an early sign of decline in production, and sunflower seeds did not even germinate in the field because of insufficient moisture. Mustard yields declined as much as 80% because of the lack of rainfall. Intriguingly, cucumber farmers found that male flowers predominated and that the relative scarcity of female flowers adversely affected cucumber production.

Not all changes are bad, though they are unsettling: wild berries can now be harvested six to eight weeks earlier than normal due to the early thawing of frost, while the flowering of peach trees has advanced considerably.

Scientific findings confirm local people's reports of increased infestation of pests, weeds and fungi. An unknown disease reduced the cardamom yield by 60%. Participants suggested that *Alnus nepalensis* (*utis*) trees have been severely infected by a beetle that has

Table 3.3: **Summary matrix of key finding: A Sapta Koshi River region consultation**

	MOUNTAINS	HILLS	TARAI
Agriculture	Shift from rice to tea; blackening of tea leaves.	Tea plantations replacing maize & wheat crops. Maize replaced by cardamom Cardamom becoming yellow due to disease, 60% harvest lost Tea leaves getting blackened New weeds and insects appeared in maize farms Disease in orange farms - roots of trees rot and the plants ultimately die out. Vegetable was good initially, now not good. Business destroyed by indiscriminate use of fungicide and insecticide. Organges and junar replaced by pomegranates due to rising temperature. Paddy fields dry since last five years. Crops seeing increased incidents of insects and diseases.	Beans failed even in July . Sunflower did not germinate, some died at a hight of 2 inches. Lentils (e.g Mung Dal) failed Mustard affected by insects, production decreased by 80 % Paddy production declining. Productivity not even 1 mund in 1 Bigha. More male flowers in cucumber due to higher temperature, hence no cucumber. No rainfall or irrigation in planting time, still no rainfall by end of July. New plantations dried up.
Livestock	Decline in goat and sheep population due to lack of access to grazing	Decreasing livestock, increasing fallow lands, decrease in livestock manure. Farmers attracted to poultry, pig farming in place of cow, buffalo rearing in place of cow , goat rearing in place of cow. Reduction in livestock numbers and shift to fewer hybrids.	
Water sources	Snowline now higher than ten years ago	Drying of spring sources, need to augment supply from other sources. Water for irrigation is insufficient. Rainfall erratic, drought period is increasing.	Rainfall erratic, drought period increasing. Water decreasing in river streams, canals in winter season. No water in Sunsari Morang Irrigation Canal system. Water irrigates fields in Bihar.
Forests	Rhododendron, chanp, and *katus* are flowering/blossoming earlier as compared to the previous years	Fire decreasing forests and pasture areas	Sal timber production declined (problem in regeneration?). Embankments a problem because of water logging problem
Floods/ landslides	Increased events	Increasing landslide and bank cutting	Increasing inundation, bank cutting and sand deposition
Health	Garbage problem (plastics and solid waste) increasing	Poor water quality, dysentery and diarrhea during the rainy seasons. Contagious disease (Scabies etc.) on the rise.	Presence of Arsenic not tested in all of Tarai, some households continue to drink arsenic contaminated water. Maintainign toilet in high water table landscapee is difficult.
Crop calender		Farming cycle is changing, Peach and Prunus flower early, berries ripe in February instead of March/April Changing planting, weeding, harvesting time in agriculture sector due to erratic rain. Hot summer days and cold winter season are causing diseases on flora and fauna Increasing rainfall intensity, shifting of rainfall time, affecting production of vegetables and fruits.	
Energy		Imported expensive oils, LPG inaccessible to many because of village poverty. Difficult to manage with kerosene and firewoods. LPG has been is use in town but fire-woods, maize stalks, cowdung and kerosene are the only energy source in villages for cooking. Positive bio-gas development supported by NGOs. Drinking water is pumped from streams because of springs drying in hills.	Deep tube wells for irrigation have important energy dimension. Growing demand for cold storage increasingdemand for energy.

significantly lowered its wood quality. Studies have also revealed increasing beetle activities with temperature rise. Another unknown disease affected the root zones of orange trees and devastated the harvest. In fact, in a considerable altitude band, citrus fruit no longer seems to be a viable crop. Though large landholders have faced significant economic losses, it is small landholders who suffer most from this loss. Maize fields have been plagued with new weeds and badly affected by insects local farmers did not anticipate. In many areas tea and sunflower leaves have dried up and turned black, an early sign of decline in production, and due to lack of moisture sunflower seeds did not even germinate. Intriguingly, cucumber farmers found that male flowers predominated and that the relative scarcity of female flowers adversely affected its production.

The earning opportunities of farmers have shrunk considerably due to the widespread failure of crops, especially of vegetable cash crops but also of paddy. Because of late flooding and/or waterlogging, the most fertile lands along the floodplains of the Tarai, yield smaller harvests than their potential. In addition, as soil quality has declined, farmers need to apply even greater amounts of fertilisers, pesticides and herbicides to see the same yields. Since increased chemical usage is not viable either environmentally or economically, farming practices in the Tarai are under threat. The drought of 2008-2009 has made a complex situation all the more complex.

Ironically, some of the challenges farmers identified are associated with recent business-as-usual disaster risk reduction activities. For example, in a bid to reduce vulnerability to flooding, embankments were built along flood-prone rivers. However, in the new hydrological reality these embankments no longer contain floodwaters; instead, they cause waterlogging. Since paddy cannot be planted in still water, the household food security of poor farmers has been compromised. Obviously, development plans which do not take climate variability into consideration are a threat to people's livelihoods. It is not clear if new varieties introduced will help

Similarly, irrigation projects conceived and implemented without taking the increasingly erratic climate into consideration do not serve the interests of farmers. In particular, business-as-usual drought risk reduction approaches that focus on irrigation development do not anticipate that a reduction in flow will limit the availability of water and will leave upstream regions dry when they most need water. Such approaches will not guarantee climate-safe livelihoods for local people; they will simply increase their vulnerability.

The recent achievement in improving water supply and sanitation coverage also suffered a heavy blow, as declining recharge rates have meant that springs that once provided water year-round no longer do so at all or provide reduced flows. In consequence, water supply systems and sanitation facilities have been rendered dysfunctional, leaving all people, but especially women, more vulnerable to disease and hardship.

In a bid to bring in more income, many poor households have switched crops. Instead of cultivating paddy they grow high-value monoculture crops such as cardamom or fruit, but such single-crop systems are increasingly threatened with failure as climate grows more erratic. Untimely drought has rendered these strategies ineffective and put food security still more at risk. The promise of a better life has not materialised.

General learning

The participants at all consultations reported that temperatures have increase, precipitation has grown more variable and that it is increasingly hard to predict climate patterns. They also reported that these observed changes had somewhat similar impacts across all regions:

1. Increases in both flood and drought conditions (and increase in their associated impacts on high and low stream flows and groundwater);
2. Changes in seasonality: seasonal weather patterns no longer hold.
3. Invasion of new undesirable plant and pest species, including fungi, insects, and invasive grasses
4. Changes in the behaviour of key crops and other plants (earlier flowering, earlier ripening, yield declines, shifts in viability)
5. Changes in the presence and behaviour of livestock and other animals (the presence of snakes, changes in yaks)
6. Declining reliability of traditional and indigenous knowledge about climate and plants: historical conditions can no longer serve as a guide to the future.

These commonly observed changes have major impacts at the local level. Livelihoods based on subsistence agriculture are suffering because of the adverse effects of climate change. Delays in the onset of the monsoon set back paddy transplantation, which in turn may be responsible for its early maturation and low yields. Since rice is the staple food for most Nepalese, a considerable decline in paddy yields can have a devastating impact on household-level food security. Poor households are at greater risk.

The production of vegetable protein (lentils, chick peas, beans, and the like) has declined due to delayed monsoon rains and/or vertical shifts in temperature regime. This decline exacerbates the food-related vulnerability of poor households and puts human health at risk.

Horticulture and vegetable production have been suffering, too, as water supplies decline when winter rainfall is used up faster than groundwater aquifers can be recharged. There is no longer a guaranteed supply of water from known springs.

The prolonged drought-like conditions which arise with the delay in the monsoon also affect livestock management. People tell stories of selling livestock to cope with the water shortage, and yak rearing in the mountains is reportedly on the decline, perhaps because of a vertical shift in temperature zones and the resultant shrinkage in the habitat boundaries of yaks.

In some areas, the risk of floods has increased due to episodic monsoon rainfall (short and high intensity downpours) during the late monsoon. Untimely snowfall and unprecedented hailstorms are other striking extreme event anomalies in local climate systems.

Of late, people have tried to adopt new forms of livelihoods. Either through the influence of the community or of large farmers and corporate representatives, people have begun to embrace new agricultural technologies and monoculture. Unfortunately, focusing on just one or two crops puts farmers, especially small landholders, at great risk if their crop fails. In the mountain districts of Manang and Mustang, for example, tea, citrus and apple plantations suffered severe blows. Once a small landholder's land is committed to a long-term plantation programme, there are very few alternatives open to him when climate-related stress increases. In fact, monoculture cultivation reduces farmers' capacity to cope and pushes them deep into crisis. The small gains they achieve through such an adaptation strategy do not provide sufficient cushion in times of despair.

Besides experiencing losses in agriculture-based livelihoods, people have become victims of inappropriate development. For example, many rural areas were provided with small-scale water supply systems which were based only on current realities and ignored the implications of climate change. Many of the springs that fed these systems have now dried up and the systems themselves have ceased to function. In the absence of any alternative, people are forced to collect water from unsafe sources and face the risk of water-borne diseases. Participants suggested that the diarrhoea epidemic in Jajarakot is one manifestation of the increasing stress on water supply.

The five bottom-up, toad's-eye-view consultations that were held helped provide local perspectives on weather vagaries that might be related to climate change. It is difficult to assert with certainty without more scientific investigations that it is so; but as has been emphasised previously, these vagaries and the increase in their frequency and intensity are consistent with most climate change predictions. In the next chapter we present the different scenarios that climate models present and identify synergies and gaps.

NOTES

[1] Water Resource Strategy Nepal 2001 reports that the total irrigated area in Nepal is 1,104,000 hectares, which is 42% of the total cultivated area.

CLIMATE CHANGE PROJECTIONS FOR NEPAL

4 CHAPTER

Summary / key points

- Nepalese rainfall patterns (timing and amount) associated with the South Asian Monsoon System (SAM) are inherently complex due to highly varied topography over short distances. Temperature patterns are also strongly controlled by elevation and aspect.
- Topographic complexity over Nepal makes projecting climate changes more difficult than usual.
- There is evidence that all-Nepal rainfall (1959-1988) during the monsoon (JJAS) and post-monsoon (OND) season was strongly correlated with the Southern Oscillation Index (the pressure component of the El Niño Southern Oscillation pattern). If this relationship holds for the future, rainfall projections from climate models will be dependent on the ability of models to simulate ENSO and the links to Nepal rainfall.
- All GCMs currently have difficulty in replicating key large-scale features that influence the entire Asian Summer Monsoon System (ASM), such as the Intertropical Convergence Zone, the Madden Julian Oscillation and ENSO. Nor are any of the models currently in agreement about the evolution of these large-scale features under different SRES greenhouse gas scenarios.
- General circulation models and regional climate models do not, as yet, adequately represent the convection mechanisms or topography that influence local Nepali rainfall systems embedded within the larger SAM.
- The performance of GCMs over South Asia is typically validated against the Indian summer monsoon observations. Yet, all-Nepal summer monsoon rainfall is not well correlated with all-India monsoon (ISM) rainfall. It cannot be assumed that because a particular GCM replicated key features of the ISM that it will be able to do so for Nepal. Thus a GCM and RCM inter-comparison project needs to be done for Nepal to see what models are suitable to Nepal.
- The few climate change projection studies that could be accessed for Nepal indicate that GCM / RCM temperature and precipitation outputs can be strongly biased (too hot/cold and too little/too much rain) for most parts of the country, reducing confidence in climate change projections.
- In short, making climate change projections for Nepal will be difficult and any projections must be interpreted and used cautiously, given the

limitations of GCMs, RCMs and observational datasets for this region of the world. A great deal of uncertainty exists in the projections.

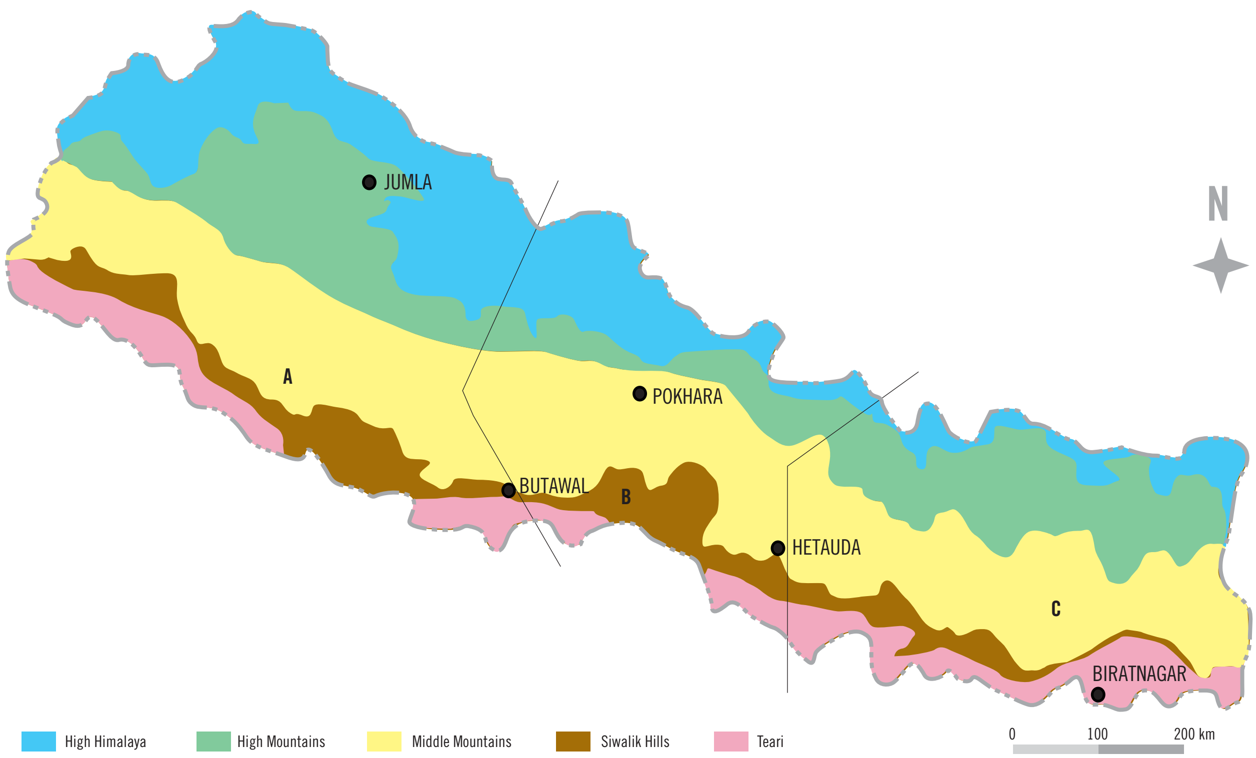
- However, uncertainty in climate projections is not necessarily a barrier to assessing vulnerability and assessing adaptation options.
- GCM projections indicate a potential increase in temperature over Nepal of 0.5-2.0 °C, with a multi-model mean of 1.4 °C by the 2030s, rising to 3.0-6.3 °C, with a multi-model mean of 4.7 °C, by the 2090s. There is very little differentiation in projected multi-model mean temperature changes in different regions (East, Central, West) of Nepal.
- GCM outputs suggest that extremely hot days (the hottest 5% of days in the period 1970-1999) are projected to increase by *up to* 55% by the 2060s and 70% by the 2090s
- GCM outputs suggest that extremely hot nights (the hottest 5% of nights in the period 1970-1999) are projected to increase by *up to* 77% by the 2060s and 93% by the 2090s
- GCMs project a wide range of precipitation changes, especially in the monsoon: -14 to + 40% by the 2030s increasing -52 to + 135% by the 2090s.
- Relative changes in precipitation in other seasons are similarly large.
- A majority of GCMs project increases in heavy precipitation events.
- Only a few Regional Climate Model results are available; large-scale changes are consistent with GCM changes, but show considerable variability in regional response.
- At this stage, there are insufficient RCM outputs to make definitive statements of the range of possible future changes at fine resolution across Nepal.

Climate of Nepal

Nepal's climate is primarily affected by two major natural features, the Himalaya mountain range and the South Asian Monsoon (SAM). The Himalaya results in a strong topographic gradient from SW to NE across the country. Kansakar *et al.* (2004) divide the country into five regions (see Figure 4.1) from south to north with increasing altitude: the Tarai (<900m), the Siwalik Hills (900m to 1200m), the Middle Mountains (1500m to 3000m), the High Mountains (3000m to 5000m) and the High Himalayas (>5000m). The Tarai and Siwalik Hills have tropical to subtropical climates. As elevation increases, temperature generally decreases, with valleys in the Middle Mountains being warmer (subtropical) than ridges. The High Mountain and High Himalaya climates are quite cold, yet also block many Siberian fronts from penetrating deep into Nepal, generally precluding snow in the valleys of the Middle Mountains. Rainfall in Nepal is largely associated with the SAM, and most locations in Nepal receive close to 80% of their annual precipitation as rainfall during the months of June-September. However, such broad statements belie the true spatial and temporal complexity of rainfall distribution throughout Nepal. In particular, topography interacts with the SAM to produce large variations in precipitation.

In general, there are four precipitation seasons: (i) the hot, dry pre-monsoon spanning March – May; (ii) the monsoon season (June – September) in which ~80% of the annual rainfall occurs for much of the country; (iii) the post-monsoon, transitional period of October – November; and (iv) the cool/cold dry winter season (December – February) with occasional snowfall events in the High Mountain and Himalaya regions. Onset of

Figure 4.1 **Regions of Nepal**



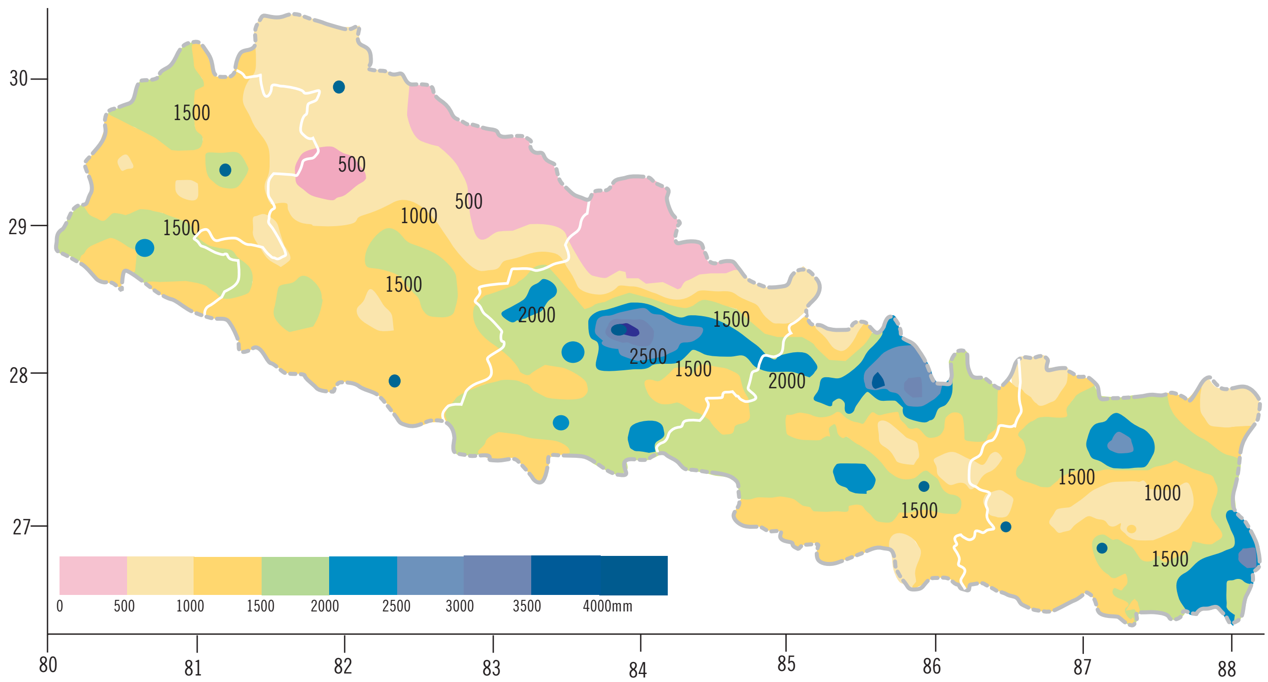
Adapted from Kansakar et al. (2004: 1647). Base map adapted from wikipedia.org. The black lines indicate the crude basin boundaries of A) the Karnali River, B) the Narayani River and C) the Sapta Koshi River. Each was define as Saptakoshi region, Narayani region and Karnali region in chapter 3 (see figure 3.1). In each five broad ecological subdivisions was considered.

the summer monsoon occurs first in eastern Nepal and progresses northwest. Withdrawal of the monsoon typically begins in the west. Consequently, the monsoon season is shortest in the NW parts of the country. Sharp terrain contrasts (a couple thousand meter elevation differences) over short distances (< 10km) strongly influence local convective process embedded within the larger monsoon complex on sub-daily timescales, but are not adequately captured via the weather station network. Rainfall gauges tend to be located in valleys, with ridge top representation sparse. Station density at the highest altitudes of the High Mountains and Himalayas is particularly low. Nonetheless, studies indicate that local variations in rainfall amount and timing can be drastic, with ridges receiving 4-5x the rainfall amounts of the valleys situated nearby (Higuchi *et al.*, 1982; Barros and Lang 2003), demonstrating the importance of orography to convective processes. Above ~3000m, precipitation amounts tend to decrease with elevation (Ichiyanagi *et al.*, 2007). Additionally, south-facing slopes (windward side) tend to receive more precipitation than north-facing (leeward side) slopes, as these are often in rain shadows. Strong diurnal signals have also been observed, with daily rainfall peaks frequently occurring during the night (Barros and Lang, 2003). Spatially, rainfall maximums are located in the area around Pokhara and the Kathmandu valley (see Figure 2). Even relatively high spatial resolution satellite data do not capture the full extent of this spatial variability (Figure 3).

Limitations of climate models

Before describing climate change projections for Nepal, some the limitations of Global Climate Models (GCMs) and Regional Climate Models (RCMs) are clarified.

Figure 4.2: **Coarse resolution annual precipitation distribution based on 67 climate stations from 1971 - 2005 and 337 precipitation stations from 1998 - 2005**

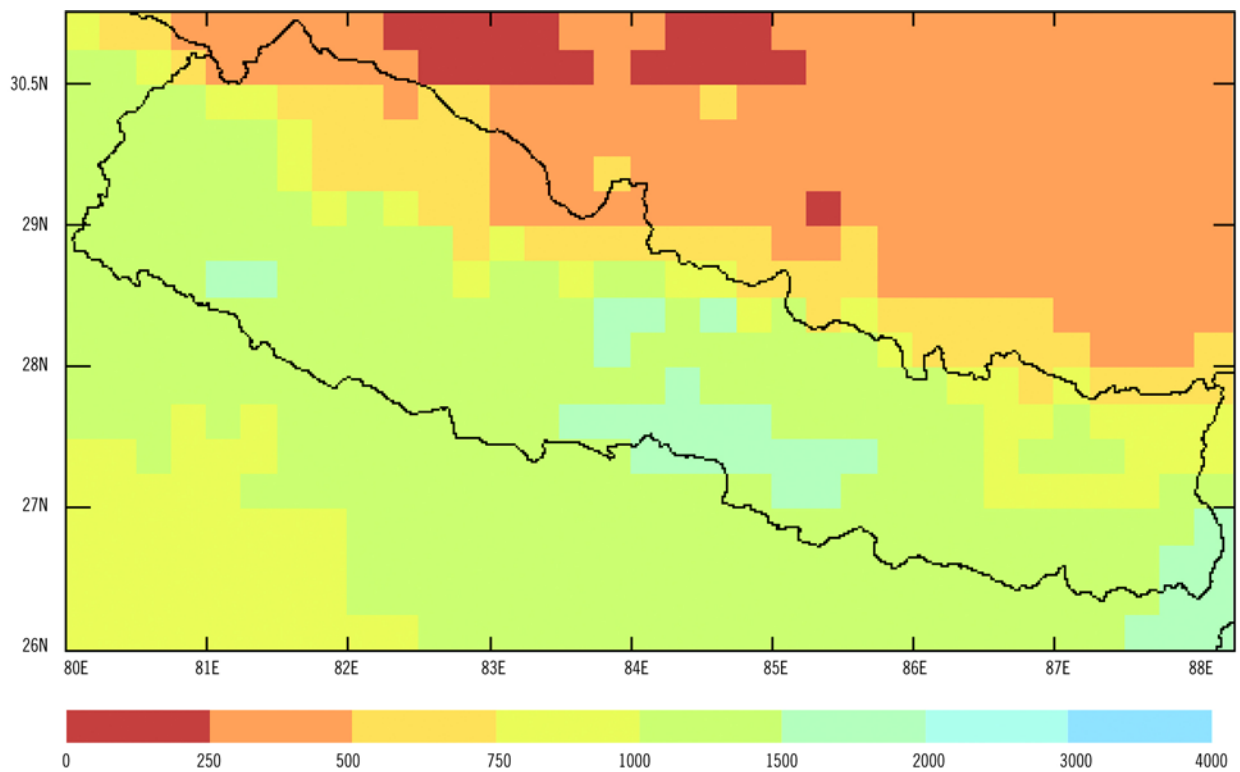


Source: Khan, 2005

GCMs have limited spatial resolution – typically around 2.5 x 2.5 ° latitude/longitude – which means that many of the topographic features important for Nepal's climate are not properly represented. Indeed for most GCMs, Nepal is represented by three grid points, providing some differentiation between east, central and western Nepal, but no real differentiation of the SW-NE topographic gradient or the complex topography within this overall gradient. Therefore, GCM results can *at best* produce projections of large-scale response that would occur in the absence finer scale of land-surface influences.

Additionally, GCMs have biases and errors in their representation of larger scale circulation features, which can degrade the reliability of projected climate changes. Of particular relevance for Nepal are the difficulties that the majority of GCMs have in replicating key large-scale features of the ASM (Wang *et al*., 2004; Lin *et al*., 2006; Lin *et al*., 2008; Zhang and Li, 2008). In particular, they have difficulty matching features such as rainfall distributions (clustering areas of strong convection closer to the equator than actually happens, which implies poor representation of the Inter-Tropical Convergence Zone), onset and withdrawal of the monsoon in many locations, variability on diurnal and subseasonal timescales (inability to capture the Madden-Julian Oscillation that contributes to the active and break cycles of the monsoon), and biasing certain ocean and atmospheric features (temperatures, vorticity and circulation patterns, particularly those associated with ENSO) in the Indo-Pacific oceans regions. Furthermore, each model has different projections about the evolution of ENSO under various climate change scenarios (De Szoeke and Xie, 2008). However, some improvement to GCMs is being seen. Lin *et al*. (2008) and Lee *et al*., (2008) note that certain GCMs capture the interannual and intraseasonal variability better than others.

Figure 4.3: **Coarse resolution (0.25 x 0.25 ° latitude/longitude) annual precipitation distribution from the TRMM satellite for the period 1998 2009.**



With regard to the South Asian region, most studies focus on the ability of GCMs to replicate the Indian summer monsoon component, while ignoring model performance for Bangladesh and Nepal. Two studies have recently assessed the performance of AR4 GCMs over South Asia/India (Kripalani *et al.*, 2007; Lin *et al.*, 2008), and report that some GCMs are able to replicate some mean features (biennial tendency of monsoons, annual precipitation cycle, mean monsoon behavior) of the ISM "relatively" well (Table 4.1). However, as Shrestha *et al.* (2000) noted, the all-Nepal monsoon rainfall does not correlate well with the all-India monsoon rainfall. *Thus, it cannot be assumed that the GCMs listed in Table 4.1 are able to replicate key features associated with the Nepal summer monsoon rainfall.*

In spite of these limitations, a few climate change projection studies exist for Nepal. Two, McSweeney *et al.* (2009) and Khan *et al.* (2005), summarise GCM projections for a variety of SRES scenarios over the Nepal region. The McSweeney study synthesised projections from GCMs utilised in the IPCC AR4, but does not attempt to quantify or correct model biases. Therefore, projections are presented "as is". The APN CAPaBLE project (Khan *et al.*, 2005) also summarised 13 GCM projections, probably from the IPCC AR4 model outputs, although this is not clear from the report. The authors did validate the GCMs' performances against CRU temperature and precipitation datasets spanning Pakistan, Nepal and Bangladesh for the period of 1961-1990, but model biases are not discussed in the report accessed and it is not clear that any bias corrections were made to the climate change projections.

RCMs overcome some of the spatial resolution issues associated with GCMs – typical resolutions are 0.5 to 0.25 ° latitude/longitude (50 to 25km). However, as

Table 4.1 **GCMs used in AR4 that reasonably hindcast features of the Indian summer monsoon**

MODEL	MODEL CENTER	LAND/ATMOSPHERE RESOLUTION	OCEAN RESOLUTION
CGCM 3.1	Canadian Centre for Climate Modelling and Analysis (Canada)	T47 (~2.8°x2.8°)/ L31 (top = 1 hPa)	1.9°x1.9°, L29 rigid lid
MIROC3.2-Medres	Center for Climate Systems Research, Nat'l Inst. for Environ. Studies, & Frontier Research Center for Global Change (Japan)	T47 (~2.8°x2.8°)/ L20 (top = 30 km) (Medres)	0.5°-1.4°x1.4°, L43 free surface
MPI-ECHAM5	Max Plank Institute for Meteorology (Germany)	T63 (~1.9°x1.9°)/ L31 (top = 10 hPa)	1.5°x1.5°, L40 free surface

Source: Kripalani et al, 2007; Lin et al, 2008

noted earlier, rainfall distribution in Nepal is complex and highly dependent topographically forced convection on scales of less than 10 km and over short timeframes. Spatial and temporal (timescales ranging from less than a day to interannual) variability are high for Nepalese precipitation. RCMs run at resolutions typical for climate change projections are insufficient to capture such fine-scale convective or orographic processes. RCMs also inherit the biases of the GCM in which they are nested. Yet, evaluating model biases over Nepal is difficult, due to lack of sufficient (in terms of length, geographic distribution and quality) station data and resultant the gridded observational datasets. Opitz-Stapleton *et al.* (2008) found that for the Nepali side of the Rohini River basin, located in the central Tarai region, station data with 30 years of length did not adequately capture the climatology of that area.

Comparison of various RCMs via the Regional Climate Model Intercomparison Project for Asia (RMIP) actually focused primarily on East Asia (Fu *et al.*, 2005; Feng and Fu, 2006). Publicly available results of the project for the South Asian region are difficult to acquire, and it does not appear that any RCM output was validated over Nepal with station data, only interpolated data. Another smaller RCM comparison project for Nepal, Pakistan and Bangladesh was funded under the aegis of APN-CAPaBLE. This project evaluated the performance of RegCM3 and PRECIS, although, only RegCM3 was evaluated for Nepal. The researchers ran RegCM3 using the MIT-Emanuel convective scheme and driven at the boundaries by the GCM ECHAM5 (Khan *et al.*, 2005). Model performance was validated over the period of 1961-1990 against the CRU gridded dataset (New *et al.*, 1999). Significant model biases were found in both mean temperature and mean precipitation in all seasons. In particular, Shrestha (2008) found that during the winter (December – February) the model had a significant cold bias (-2 to -10°C) over most of the country, except the northern regions where a warm bias ranging from +2 to +6°C prevailed. During the monsoon months, the cold bias persists through much of the country, as does the warm bias in the north. Precipitation is overestimated during the winter months in the central and eastern Tarai/Siwalik areas by 75 to 200%. Precipitation during the winter in western portions of Nepal is overestimated by 25 to 75%, with the overestimation increasing from south to north. During the monsoon season, precipitation estimates are comparatively more reliable, showing overestimations of 10 to 50% for most of the country. The High Himalaya areas, however, are not well represented and portray monsoon precipitation in excess of 100 to 300% of the interpolated CRU data[1]. A small area of the central Tarai, located near the Rohini River basin, displays an underestimation of 15% during the monsoon season.

Table 4.2 **GCMs used to prepare climate projections for Nepal**

MODEL	INSTITUTE
bccr_bcm2_0	Bjerknes Centre for Climate Research, Norway
cccma_cgcm3_1	Canadian Centre for Climate Modelling and Analysis
cnrm_cm3	MeteoFrance/Centre National de Recherches Meteorologiques, France
csiro_mk3_0	Commonwealth Scientific and Industrial Research Organisation (CSIRO) Atmospheric Research, Australia
csiro_mk3_5	Commonwealth Scientific and Industrial Research Organisation (CSIRO) Atmospheric Research, Australia
gfdl_cm2_0	US Department of Commerce/ National Oceanic and Atmospheric Sciences Geophysical Fluid dynamics Laboratory
gfdl_cm2_1	US Department of Commerce/ National Oceanic and Atmospheric Sciences Geophysical Fluid dynamics Laboratory
giss_model_e_r	NASA/ Goddard Institute for Space studies (GISS), USA
inmcm3_0	Institute for numerical Mathematics, Russia
ipsl_cm4	Institute Pierre Simon LaPlace, France
miub_echo_g	Meteorological Institute of the University of Bonn, meteorological Research Institute of the Korea Meteorological Administration (KMA) and Model and data group, Germany/Korea
mpi_echam5	Max Plank Institute for Meteorology, Germany
mri_cgcm2_3_2a	Meteorological Research Institute, Japan
ncar_ccsm3_0	National Centre for Climate Research, USA
ukmo_hadcm3	Hadley centre for Climate prediction and research/Met office, UK.

Climate change projections for Nepal

The results presented below are based on GCM and RCM data that were easily available in the time available for this project. For GCMs, 15 models (Table 4.2) were chosen that had provided daily and monthly data from the CMIP3 archive, and for which outputs from three SRES emissions scenarios were available: A2, A1B and B2. Of these emissions scenarios, the A2 has the highest emissions and shows the closest match to observed emissions increases since 2000 (Rahmstorf *et al.*, 2007); thus for near term scenarios (out to the 2040s), the A2 data are considered more plausible in terms of forcing.

For RCMs, data from only two simulations are analysed (Table 4.3). The results from these simulations are not easily comparable, as they are at different spatial resolutions, driven by different GCMs outputs and have been run for different periods in the future. To enable comparison over the same time period, the results from PRECIS have been scaled to produce equivalent responses for the period 2040 – 2070. Given the above, the RCM outputs should be considered as *examples* of the types of local responses that *might* expected, given the larger-scale changes simulated by their "parent" GCMs. A far more comprehensive set multi-RCM-GCM simulations is required before a sense can be gained of the range of possible climate conditions that different regions Nepal might experience.

Summary of projections from GCMs for Nepal

Temperature

Data are summarised in Figure 4.4 and 4.5, Table 4.4-4.6, and then in further Figures in the supplementary material at the end of the document.

- Mean annual temperature across Nepal is projected increase by:
  - 0.5-2.0 °C, with a multi-model mean of 1.4 °C, by the 2030s.
  - 1.7-4.1 °C, with a multi-model mean of 2.8 °C, by the 2060s.
  - 3.0-6.3 °C, with a multi-model mean of 4.7 °C, by the 2090s.
- Increases in temperature are lower in the monsoon and post-monsoon season than winter and pre-monsoon, by up to 1.6°C by the 2090s; this

Table 4.3: **RCMs used to prepare climate projections for Nepal**

MODEL	SPATIAL RESOLUTION	DRIVING GCM	EMISSIONS SCENARIO	TIME PERIOD
PRECIS	0.44 degrees	HadCM3 + HadAM3	A2 (& B2)[a]	2070 - 2100
RegCM3	0.22 degrees	ECHAM5	A2	2040 - 2070

Only the A2 scenario runs were analysed for this report.

difference is at least partly due to the projected increases in monsoon rainfall and cloudiness, which will reduce incoming solar radiation and enhance cooling through evaporation.

- Projected temperature increases are lower in Eastern Nepal than Western and Central; by the 2090s this difference is about 0.7°C.
- The frequency of "hot days" (the hottest 5% of days in the period 1970-1999) in the pre-monsoon period are projected to increase by:
  - 15-55 % by the 2060s.
  - 26-69 % by the 2090s.
- The frequency of "hot nights" (the hottest 5% of nights in the period 1970-1999) in the pre-monsoon period are projected to increase by:
  - 15-55 % by the 2060s.
  - 26-69 % by the 2090s.
- "The frequency of "hot nights" (the hottest 5% of days in the period 1970-1999) are projected to increase most in the monsoon period:
  - 6-77 % by the 2060s.
  - 29-93 % by the 2090s.
- GCM outputs do not have sufficient spatial resolution to provide information on temperature changes across the different elevation zones.

Precipitation

Data are summarised in Figure 4.6 and 4.7, and Table 4.7 - 4.10, and then in further figures in the supplementary material at the end of the document.

- Projected mean annual precipitation does not show a clear trend with both increases and decreases:
  - -34 to + 22%, with multi-model mean of +0 % by the 2030s.
  - -36 to + 67 %, with a multi-model mean of +4 %, by the 2060s.
  - -43 to +80 %, with a multi-model mean of +8%, by the 2090s.
- Monsoon rainfall projections vary widely, but more models suggest an increase than a decrease towards the end of the century:
  - -40 to + 143%, with a multi-model mean of +2 %, by the 2030s.
  - -40 to + 143%, with a multi-model mean of +7 % by the 2060s.
  - -52 to + 135%, with a multi-model mean of +16%, by the 2090s.
- Eastern and Central Nepal monsoon rainfall is projected to increase more than Western Nepal, where the multi-model mean increase by the 2090s is only +6%.
- Winter precipitation projections show a tendency for a decrease, but with several models projecting an increase; the multi-model mean projection is -14 %.
- Heavy rainfall is projected to increase slightly in the monsoon and post-monsoon seasons, and decrease slightly in the winter and pre-monsoon seasons:
  - The proportion of total monsoon precipitation falling as heavy rain events is projected to change by -21 to + 34%, with a multi-model mean of +7 %, by the 2060s
  - Most models show an increase in maximum 1-day and maximum 5-day rainfall by the 2060s, in both the monsoon and post-monsoon periods, and little change in other seasons.
- GCM outputs do not have sufficient spatial resolution to provide information on precipitation changes across the different elevation zones.

Summary climate change projections from RCMs for Nepal

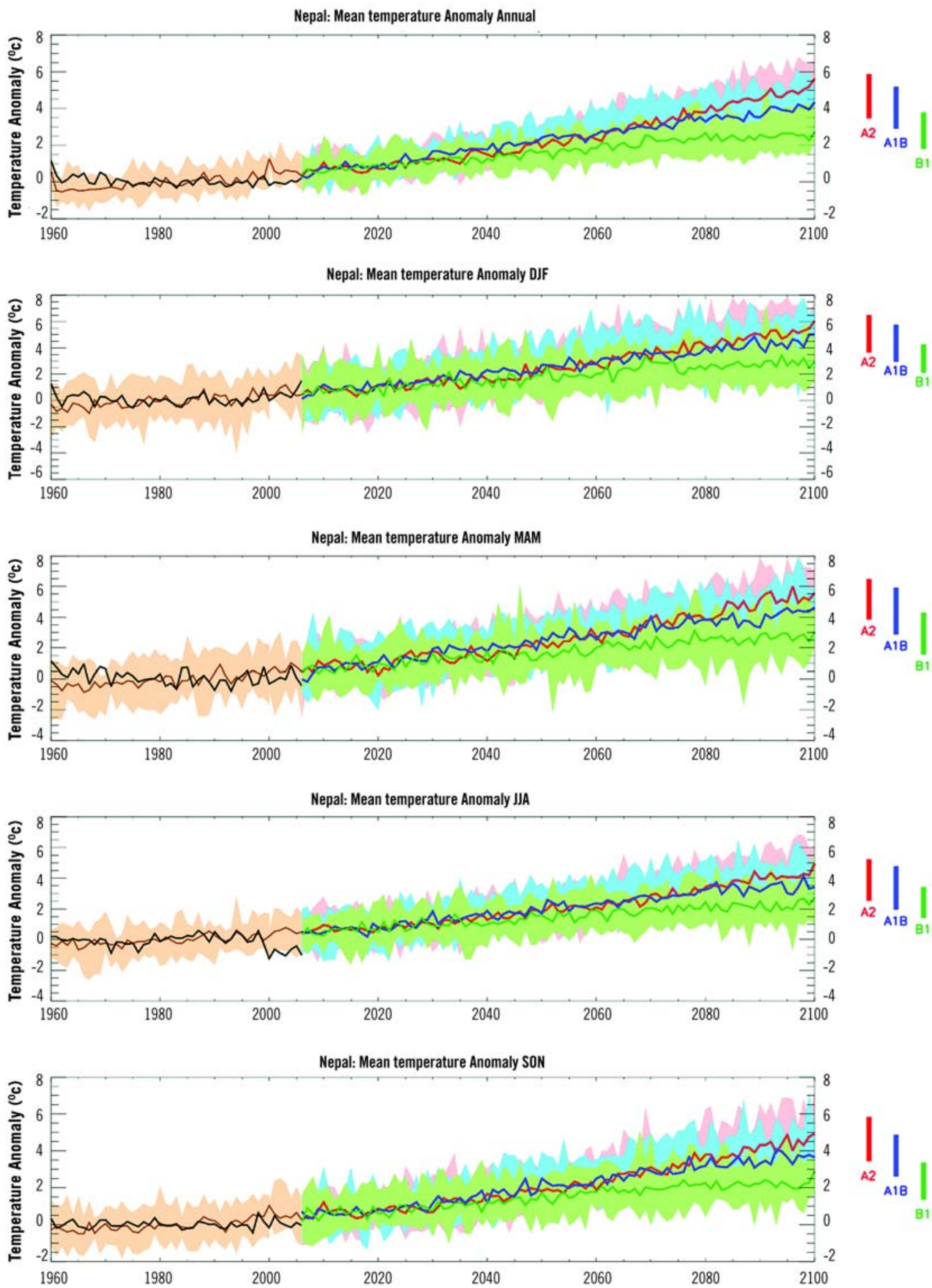
Temperature

- RCM projections for changes in mean temperature are consistent with 15 GCM outputs, falling within the range projected by GCMs.
- RCM projected changes in mean temperature tend to be greater than those for their "parent" GCM in the winter period, and lower or the same in the monsoon season, suggesting there are local feedbacks to surface warming that are not captured by the parent GCMs.
- RegCM3 and PRECIS show *significant* differences in the spatial patterns of temperature changes:
  - PRECIS has largest increases in the High Mountains and Tarai
  - RegCM3 has largest increase in the Middle Hills
  - Note that PRECIS data are from later in the century (2070-2100) than RegCM3 (2040-2070) so a larger snow/ice feedback effect may be coming into play in the High Mountains.

Precipitation

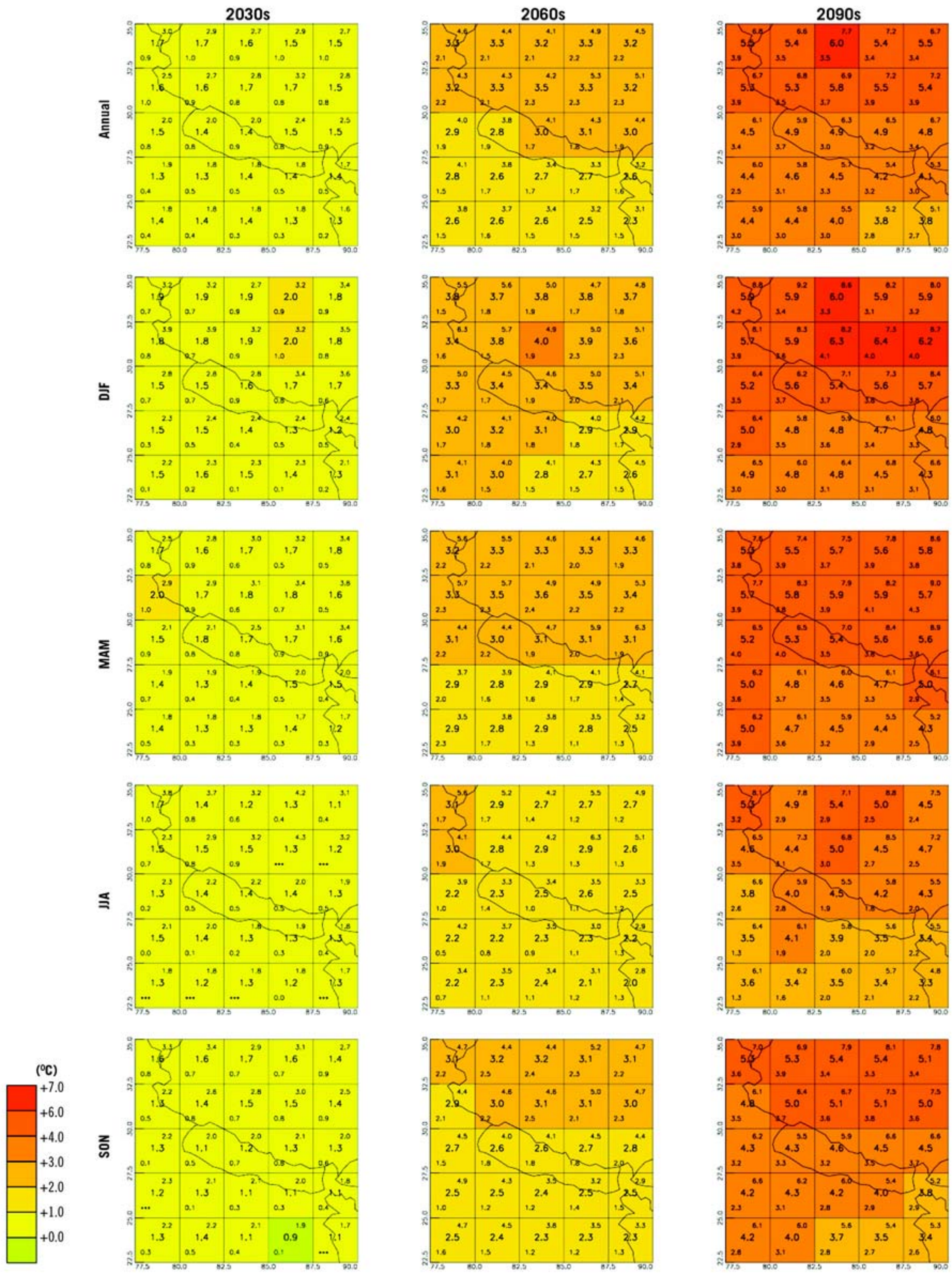
- RCM projections for precipitation are within the range projected by GCMs
- However, RCM projections for precipitation can differ from those of their "parent" GCMs - generally larger changes are simulated by the RCMs, and sometimes of opposite sign:
  - For RegCM3-ECHAM5, winter precipitation is projected to increase by 0.0-1.0mm/day while in ECHAM5 winter precipitation shows a small decrease over Nepal
  - For both RegCM3-ECHAM5 and ECHAM5, monsoon precipitation is projected to increase in western Nepal and decrease in eastern Nepal, but the changes projected for RegCM3 are larger, with decreases and increases of up to 8mm compared to 2mm/day for ECHAM5.
  - For PRECIS, winter precipitation in 2070-2100 is projected to increase by 1-2mm/day in the Middle Hills and decrease in the High Mountains of central Nepal; elsewhere, precipitation is projected to increase by less than one mm/day.
  - HadCM3 shows a relatively low winter precipitation over 2070-2100, compared to earlier decades in the century; hence the winter precipitation changes in PRECIS are likely to be larger in decades where HadCM3 has greater precipitation (see Figure 9 for scaled changes in 2040-2070).
  - PRECIS shows an increase in monsoon precipitation across the whole of Nepal, but increases are largest in the Middle Hills, and in central Nepal.
- RCM projected changes do not show a strong elevation dependence, although there is a tendency for the largest changes (both increases and decreases to be in the Middle Hills).

Figure 4.4: **Observed and projected changes in mean temperature over Nepal, 1960-2100.**



The black line shows the observed Nepal-wide temperature trend to 2006. The brown line and shading shows the multi-model mean and range for models forced with observed GHG and aerosols to 2006. The coloured lines and shading from 2006 onwards show multi-model mean and range of changes under three different emissions scenarios.

Figure 4.5: **Spatial pattern of GCM projections of mean temperature over Nepal and surrounding areas, for the A2 scenario, for three 10-year periods in the future.**



Shading shows the multi-model mean change. Figures in each grid box show the multi-model mean, as well as the range across the multi-model ensemble.

Table 4.4. **Change in mean temperature (°C, relative to mean of 1970-1999) from GCM projections.**

Time Period	Annual	Pre-Monsoon	Monsoon	Post-Monsoon	Winter
EASTERN NEPAL					
2030s	1.4 (0.5, 1.8)	1.5 (0.5, 2.0)	1.3 (0.3, 1.9)	1.1 (0.3, 2.0)	1.3 (0.5, -2.4)
2060s	2.7 (1.7, 3.3)	2.9 (1.7, 4.1)	2.3 (1.1, 3.0)	2.5 (1.4, 3.2)	2.9 (1.8, 4.0)
2090s	4.2 (3.2, 5.4)	4.7 (3.3, 6.1)	3.5 (2.0, 5.6)	4.0 (2.9, 5.4)	4.7 (3.4, 6.1)
CENTRAL NEPAL					
2030s	1.4 (0.9, 2.0)	1.7 (0.8, 2.5)	1.4 (0.5, 2.2)	1.2 (0.7, 2.0)	1.6 (0.9, 2.8)
2060s	3.0 (1.7, 4.1)	3.1 (1.9, 4.7)	2.5 (1.0, 3.4)	2.6 (1.8, 4.1)	3.4 (1.9, 4.6)
2090s	4.9 (3.0, 6.3)	5.4 (3.5, 7.0)	4.5 (1.9, 5.5)	4.6 (3.2, 5.9)	5.4 (3.7, 7.1)
WESTERN NEPAL					
2030s	1.4 (0.8, 2.0)	1.8 (0.8, 2.1)	1.4 (0.5, 2.2)	1.1 (0.5, 2.0)	1.5 (0.7, 2.8)
2060s	2.8 (1.9, 3.8	3.0 (2.2, 4.4)	2.3 (1.4, 3.3)	2.6 (1.8, 4.0)	3.4 (1.7, 4.5)
2090s	4.9 (3.7, 5.9)	5.3 (4.0, 6.5)	4.0 (2.8, 5.9)	4.3 (3.3, 5.5)	5.6 (3.7-6.2)

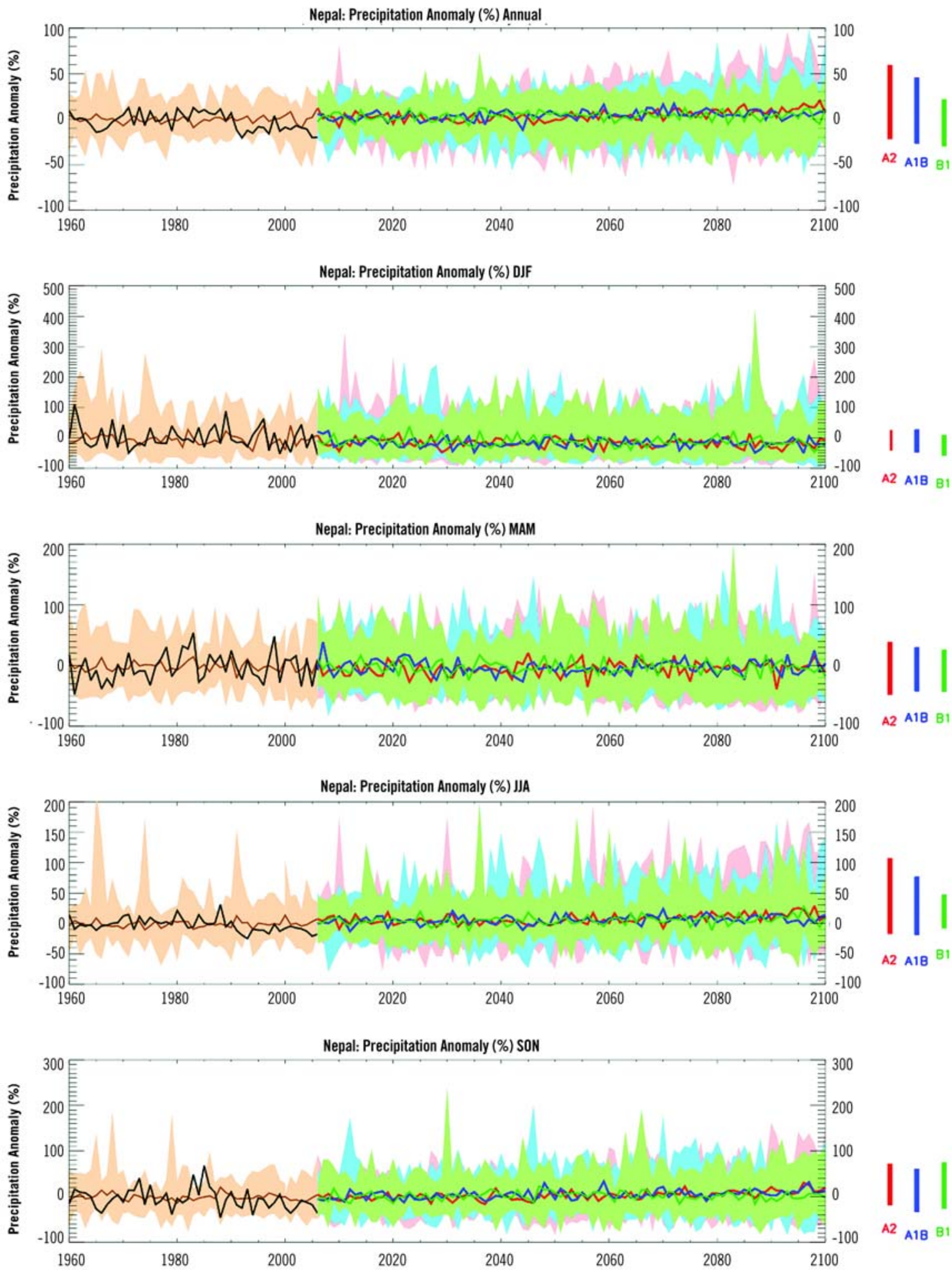
Table 4.5. **Change in frequency of hot days (%, relative to mean of 1970-1999) from GCM projections.**

Time Period	Annual	Pre-Monsoon	Monsoon	Post-Monsoon	Winter
EASTERN NEPAL					
2060s	16 (12, 35)	26 (16, 45)	24 (10, 66)	24 (10, 66)	26 (19, 80)
2090s	22 (14, 45)	43 (29, 62)	35 (8, 84)	35 (8, 84)	53 (31, 91)
CENTRAL NEPAL					
2060s	18 (10, 41)	25 (17, 52)	25 (14, 75)	26 (9, 49)	37 (18, 65)
2090s	29 (16, 49)	48 (27, 66)	43 (14, 85)	45 (28, 61)	68 (35, 79)
WESTERN NEPAL					
2060s	17 (12, 39)	26 (18, 55)	21 (11, 63)	23 (7, 48)	33 (17, 89)
2090s	23 (16, 48)	40 (26, 69)	39 (16, 84)	45 (19, 58)	64 (33, 94)

Table 4.6. **Change in frequency of hot nights (%, relative to mean of 1970-1999)**

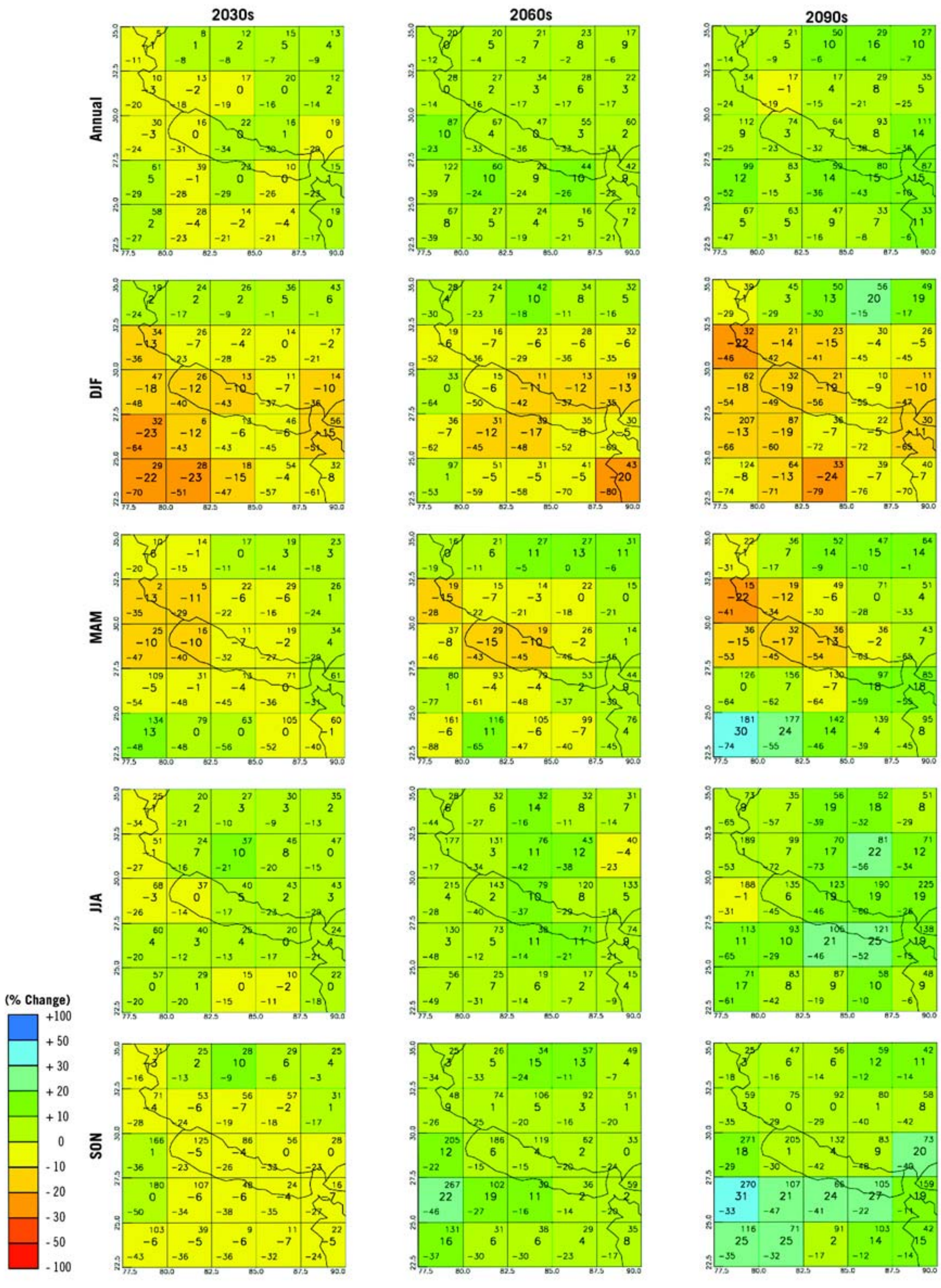
Time Period	Annual	Pre-Monsoon	Monsoon	Post-Monsoon	Winter
EASTERN NEPAL					
2060s	6 (7, 30)	26 (4, 37)	56 (6, 77)	27 (9, 32)	29 (9, 41)
2090s	37 (22, 44)	45 (19, 60)	85 (29, 93)	44 (31, 56)	53 (14, 88)
CENTRAL NEPAL					
2060s	23 (13, 26)	26 (3, 34)	55 (25, 71)	23 (16, 36)	28 (10, 40)
2090s	33 (20, 38)	45 (6, 56)	77 (44, 89)	38 (25, 51)	54 (14, 86)
WESTERN NEPAL					
2060s	23 (8, 26)	25 (2, 36)	48 (12, 61)	22 (8, 32)	27 (6, 40)
2090s	32 (17, 39)	42 (9, 58)	81 (40, 87)	38 (18, 51)	54 (9, 77)

Figure 4.6. **Observed and projected changes in mean precipitation over Nepal, 1960-2100.**



The black line shows the observed Nepal-wide temperature trend to 2006. The brown line and shading shows the multi-model mean and range for models forced with observed GHG and aerosols to 2006. The coloured lines and shading from 2006 onwards show multi-model mean and range of changes under three different emissions scenarios

Figure 4.7. **Spatial pattern of GCM projections of mean precipitation change over Nepal and surrounding areas, for the A2 scenario, over three 10-year periods in the future.**



Shading shows the multi-model mean change. Figures in each grid box show the multi-model mean, as well as the range across the multi-model ensembl

Table 4.7. Change in monthly precipitation (%, relative to mean of 1970-1999)

Time Period	Annual	Pre-Monsoon	Monsoon	Post-Monsoon	Winter
EASTERN NEPAL					
2030s	0 (-26,10)	0 (-36, 71)	0 (-17, 20)	-4 (-35, 24)	6 (-45, 46)
2060s	10 (-26, 44)	2 (-37, 53)	11 (-21, 71)	2 (-14, 36)	-8 (-52, 35)
2090s	15 (-43, 80)	18 (-59, 97)	25 (-52, 121)	27 (-22, 105)	-5 (-72, 22)
CENTRAL NEPAL					
2030s	0 (-34, 22)	-7 (-32, 11)	5 (-17, 40)	-4 (-26, 86)	-10 (-43, 13)
2060s	0 (-36, 47)	-10 (-45, 19)	10 (-37, 79)	4 (-15, 119)	-11 (-42, 11)
2090s	7 (-32, 64)	-13 (-54, 36)	19 (-46, 123)	4 (-42, 132)	-19 (-56, 21)
WESTERN NEPAL					
2030s	0 (-31, 16)	-10 (-40, 16)	0 (-14, 37)	-5 (-23, 125)	-12 (-40, 26)
2060s	4 (-33, 67)	-15 (-43, 29)	2 (-40, 143)	6 (-15, 186)	-6 (-50, 15)
2090s	3 (-23, 74)	-17 (-45, 32)	6 (-45, 135)	1 (-30, 205)	-19 (-49, 32)

Table 4.8. Change in precipitation as heavy events (%, relative to mean of 1970-1999)

Time Period	Annual	Pre-Monsoon	Monsoon	Post-Monsoon	Winter
EASTERN NEPAL					
2060s	2 (-8, 5)	2 (-13, 9)	3 (-4, 20)	1 (-5, 2)	-2 (-32, 5)
2090s	6 (-4, 23)	4 (-34, 12)	6 (-6, 34)	7 (0, 28)	-5 (-21, 9)
CENTRAL NEPAL					
2060s	4 (-7, 12)	0 (-14, 12)	4 (-6, 17)	3 (-9, 24)	-4 (-10, 6)
2090s	6 (1, 21)	-1 (-17, 16)	8 (-21, 30)	8 (-12, 26)	-1 (-13, 13)
WESTERN NEPAL					
2060s	3 (-6, 9)	-2 (-14, 14)	5 (-4, 12)	3 (-11, 26)	-6 (-15, 10)
2090s	7 (-1, 11)	-3 (-15, 16)	9 (-13, 15)	8 (-15, 30)	-3 (-27, 15)

Table 4.9. Change in maximum 1-day rainfall (mm, relative to mean of 1970-1999z

Time Period	Annual	Pre-Monsoon	Monsoon	Post-Monsoon	Winter
EASTERN NEPAL					
2060	2 (-10, 57)	0 (-7, 12)	2 (-3, 61)	1 (-1, 5)	0 (-18, 5)
2090	10 (0, 91)	3 (-12, 10)	9 (-2, 98)	11 (0, 57)	-2 (-7, 7)
CENTRAL NEPAL					
2060	3 (-10, 38)	0 (-13, 7)	3 (-3, 43)	2 (-2, 13)	0 (-9, 4)
2090	12 (-1, 61)	0 (-10, 4)	5 (-4, 67)	8 (0, 20)	0 (-6, 11)
WESTERN NEPAL					
2060	4 (-9, 43)	0 (-11, 8)	2 (-3, 45)	2 (-4, 17)	-2 (-8, 6)
2090	11 (-4, 40)	-1 (-7, 5)	4 (-14, 43)	9 (-2, 16)	0 (-7, 7)

Table 4.10. **Change in maximum 5-day rainfall (mm, relative to mean of 1970-1999**

EASTERN NEPAL					
Time Period	Annual	Pre-Monsoon	Monsoon	Post-Monsoon	Winter
2060	7 (-18,119)	1 (-14, 20)	6 (-17, 22)	3 (-3, 22)	2 (-30, 8)
2090	25 (-2, 224)	6 (-22, 25)	32 (-2, 210)	18 (0, 135)	-4 (-12, 9)
CENTRAL NEPAL					
Time Period	Annual	Pre-Monsoon	Monsoon	Post-Monsoon	Winter
2060	10 (-27, 95)	1 (-29, 16)	8 (-8, 100)	4 (-7, 33)	-2 (-19, 2)
2090	15 (0, 170)	0 (-22, 12)	18 (-9, 168)	15 (-6, 63)	-2 (-17, 14)
WESTERN NEPAL					
Time Period	Annual	Pre-Monsoon	Monsoon	Post-Monsoon	Winter
2060	8 (-24, 70)	0 (-21, 21)	9 (-16, 75)	4 (-6, 20)	-2 (-17, 6)
2090	14 (-6, 75)	-2 (-12, 13)	14 (-31, 65)	16 (0, 36)	-2 (-23, 17)

Figure 4.8. **Projected changes in winter and monsoon mean temperature and precipitation from the RegCM3-ECHAM5 simulations, A2 emissions scenario, for the period 2040-2070.**

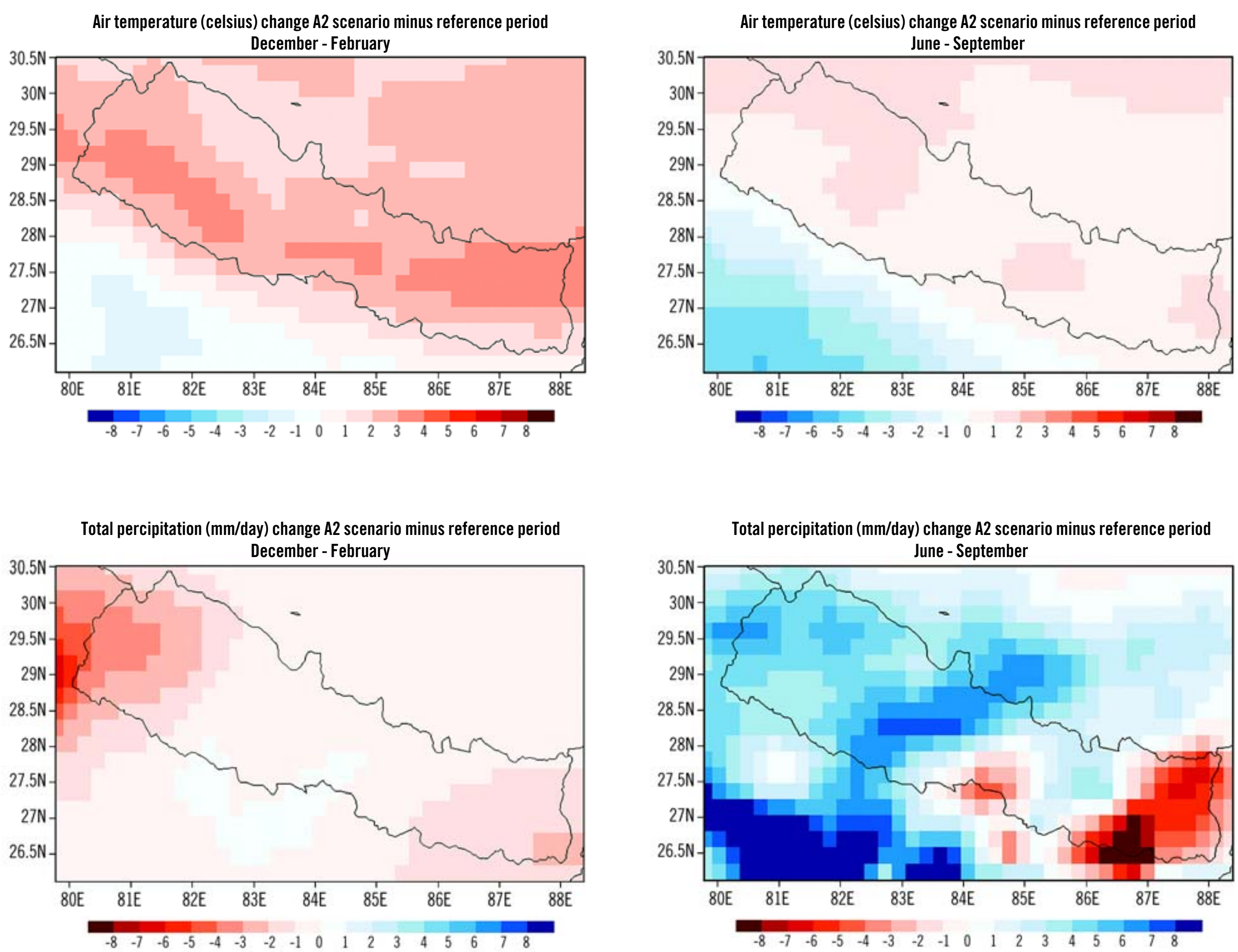
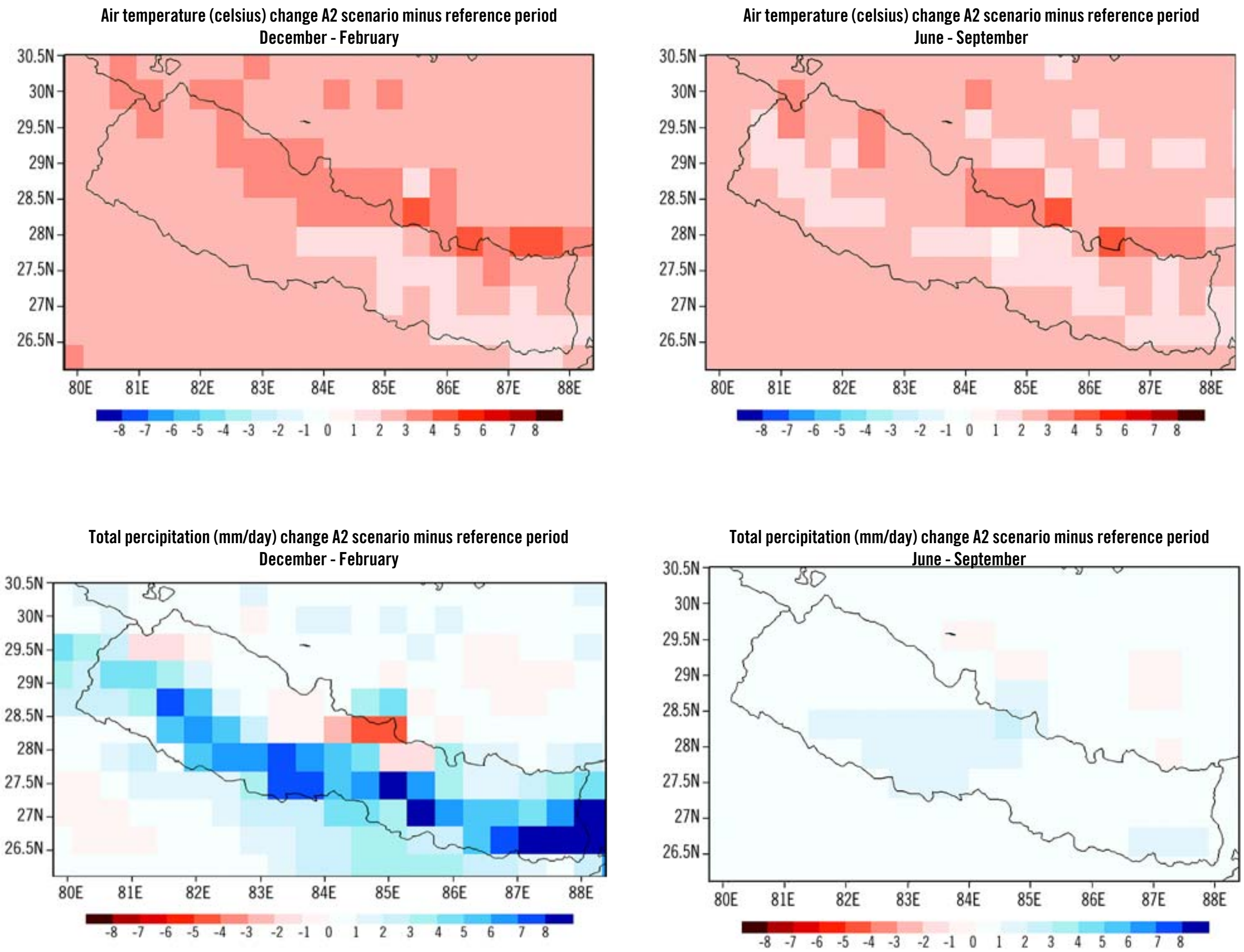
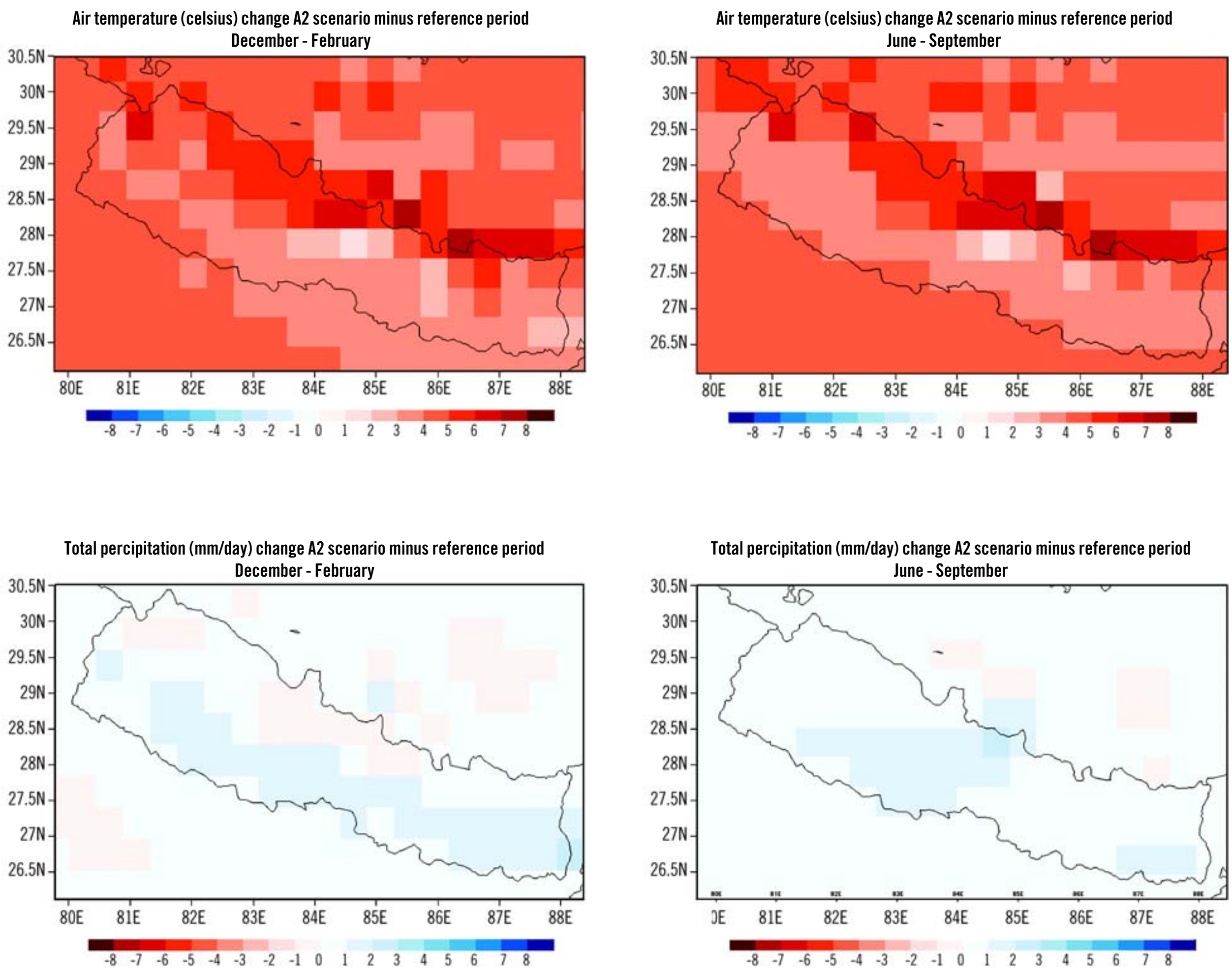


Figure 4.9. **Projected changes in winter and monsoon mean temperature and precipitation from the PRECIS-HadCM3 simulations, A2 emissions scenario, for the period 2040-2070**



Scaled from the 2070-2100 outputs; see text for details.

Figure 4.10. **Projected changes in winter and monsoon mean temperature and precipitation from the PRECIS-HadCM3 simulations, A2 emissions scenario, for the period 2070-2090.**



Supplementary Figures

Figure 4.11. Spatial pattern of GCM projections of change in frequency (in %) of "hot days" relative to hot day frequency over 1970-1999, under the A2 emission scenario.

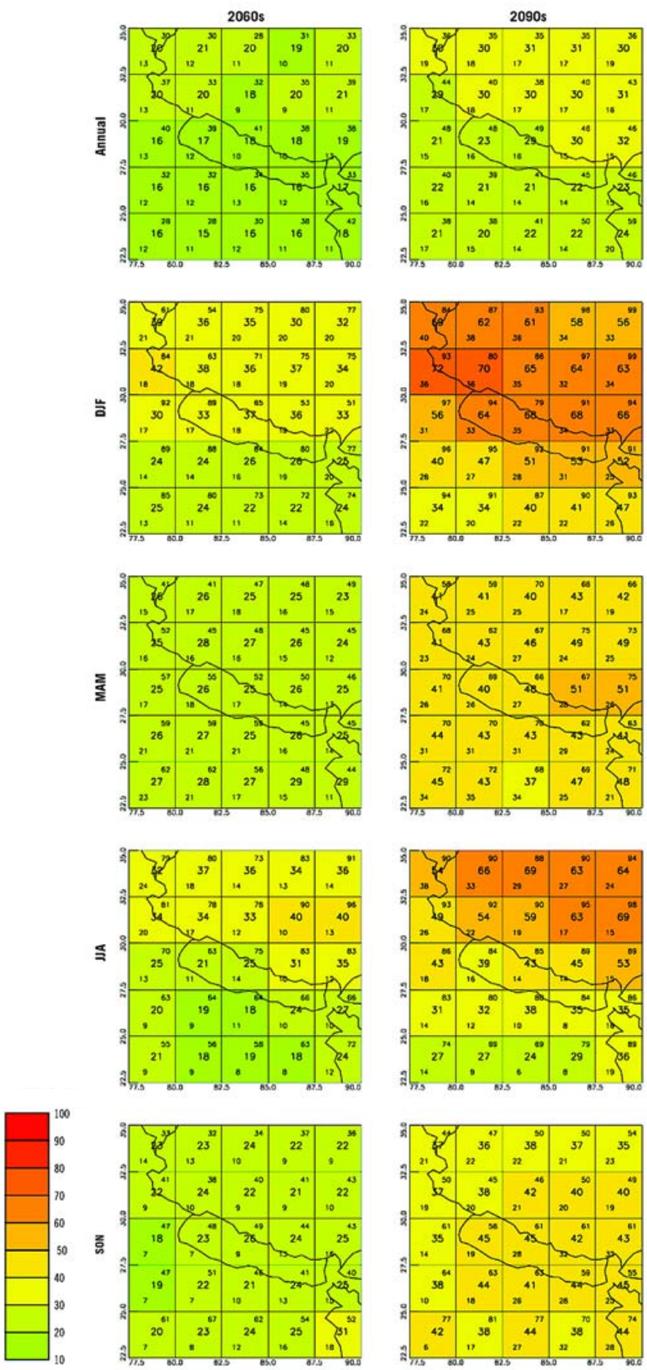
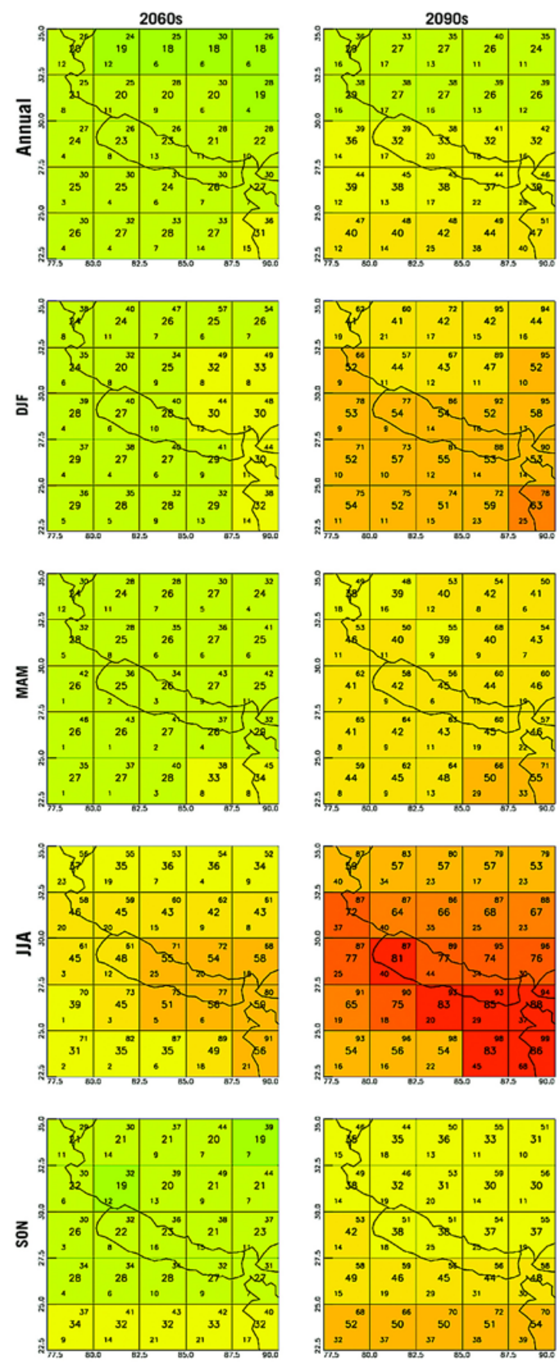


Figure 4.12. Spatial pattern of GCM projections of change in frequency (in %) of "hot nights" relative to hot night frequency over 1970-1999, under the A2 emission scenario.



Shading shows the multi-model mean change, while numbers in each grid box show the multi-model mean, as well as the range across the multi-model ensemble.

Figure 4.13. **Spatial pattern of GCM projections of change in proportion of precipitation falling in heavy events, relative to 1970-1999, under the A2 emission scenario.**

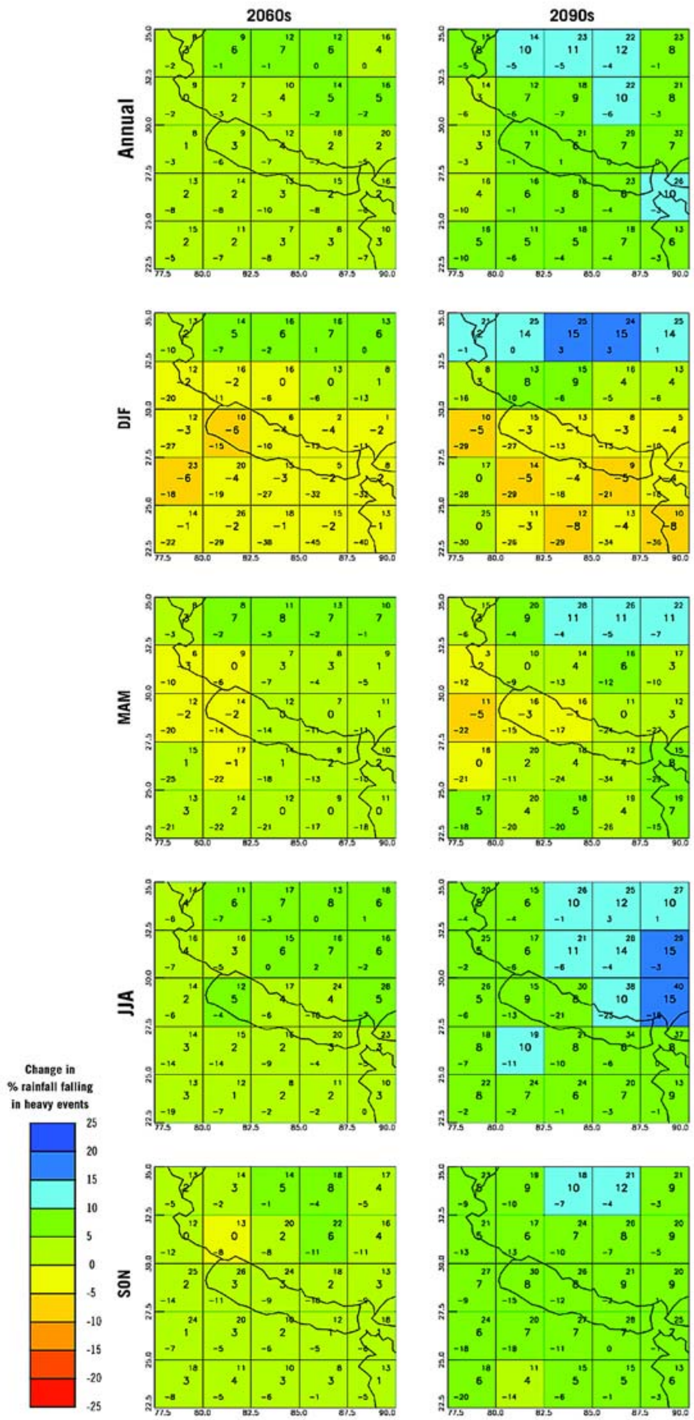
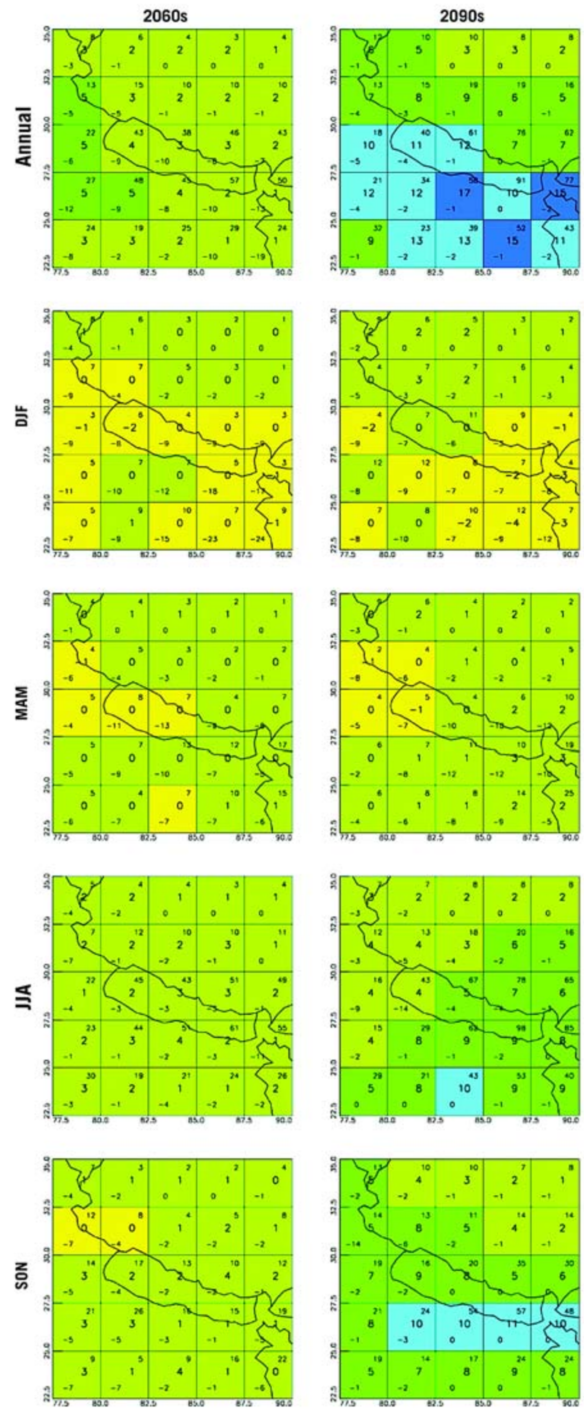
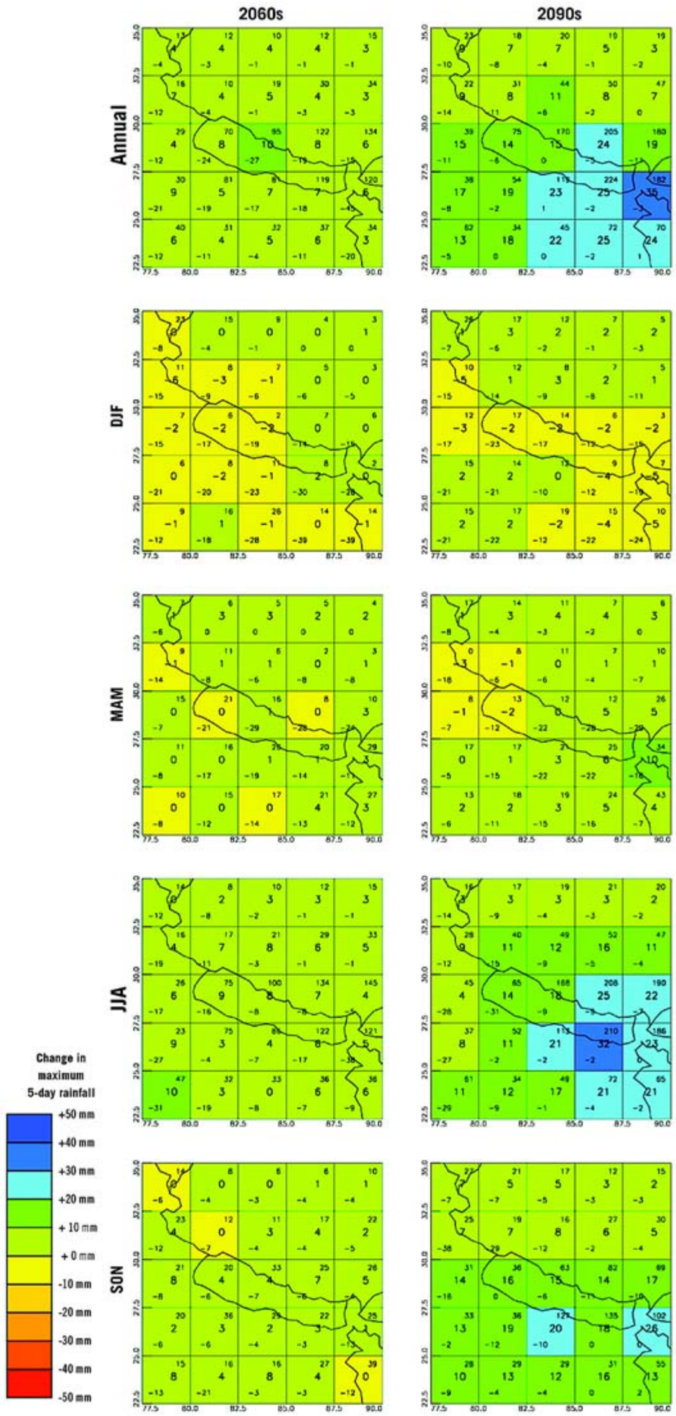


Figure 4.14. **Spatial pattern of GCM projections of change in maximum 1-day rainfall, relative to 1970-1999, under the A2 emission scenario.**



Shading shows the multi-model mean change, while numbers in each grid box show the multi-model mean, as well as the range across the multi-model ensemble.

Figure 4.15. **Spatial pattern of GCM projections of change in maximum 5-day rainfall, relative to 1970-1999, under the A2 emission scenario.**



Shading shows the multi-model mean change, while numbers in each grid box show the multi-model mean, as well as the range across the multi-model ensemble.

NOTES

[1] These differences from the observation based gridded data may arise at least in part due to inaccuracies in the CRU data which, for the High Himalaya, are interpolated from lower elevation stations.

THE SOCIO-ECONOMIC SCENARIO FOR COMPENSATING ADAPTATION

5 CHAPTER

As described earlier, climate change will have profound and widespread socio-economic impacts. However, the inability to identify all impacts and their consequent implications, and because of the uncertainties associated with climate science, there are few estimates of the economic cost of climate change at the global level. The first such study was the 2006 Stern Review, which opened a floodgate of debate about economic analysis (Heal, 2009) and its limitations, but the resultant qualitative improvement in techniques of estimation has not led to improved numbers. Some country-level studies about sectoral impacts have been conducted (Schlenker *et al.*, 2006), but there are no estimates of the economic impact on developing countries such as Nepal.

The Stern report states that under an optimistic scenario (a 2-3ºC increase in global temperature), developing countries would lose more than 3 per cent of their GDP, and if the temperature rise reached 4-5ºC, the loss would exceed 10 per cent. Nepal is one of the ten most vulnerable developing countries because of its geography, poor physical infrastructure and the low level of development of its social sector (OECD, 2003). Extrapolating from the Stern figures, the total cost to Nepal could reach over a billion dollars at current prices and possibly more because of the country's overall socio-economic fragility.

Although global and macro statistics like those of the Stern review are a cause for alarm, they provide little information about the specific details of country-level impacts. Such analyses also offer very little guidance in identifying cost-effective, immediately applicable strategies to build resilience and to increase in-country adaptive capacity in the face of the impeding impacts of climate change. The Himalayan "white spot" in the fourth IPCC report implies that we need much better assessments of the physical climatic processes in the region. The averaging out of extreme conditions that may prevail (e.g. heavy rains in the monsoon, a severe drought in the other months or delayed rain during the monsoon) in national level statistics will give a very misleading picture of the actual stress experienced by the populace in a complex and unique physical-environmental-social system. Mendelsohn, *et al.* (2006, pp 174) suggest that national level analysis and those done by the poor at the bottom of the pyramid are different, emphasising the point made throughout this report that the "eagle's-eye view" of the climate change problem is very different from a "toad's eye perspective".

"Although these national results are insightful, they do not necessarily predict what will happen to individual poor people. That is, many countries are large enough so that different regions will have different effects within national borders. Further, what happens to some countries in aggregate does not necessarily indicate what will happen to the poor residents of a country. However, alternative studies such as rural income analysis (Mendelsohn et al., 2006) can identify how effects are distributed within a nation."

This chapter attempts to assess the socio-economic impacts of global warming at the micro and meso levels in Nepal by estimating the costs of impact of some of the signature impacts discussed in Chapter 2. It attempts to correlate the insights of global climate change scenario models with observations on the ground, and to identify the types of future investigations and socio-economic analysis to aid our understanding of impacts and cost-effectiveness of adaptation options. The chapter does not aim to provide exact answers. Indeed, in the absence of fundamental and path-breaking research, such analysis cannot be attempted at this stage; but aims to sketch the broad canvas to pave the way for future analysis that can help us to ask better questions and guide us towards identifying effective adaptation strategies for Nepal. Some lessons with policy implications are drawn at the end for adapting the energy sector, prioritised on the basis of the reality of an average Nepali household.

The Nepali household

While it is often argued that there is no such thing in reality as an average ("Mr. Per Capitan has not been actually sighted who experiences average conditions!"), an analysis of an average Nepali household, instead of the Nepali economy as a whole, provides a different picture of reality and can be an improvement over the discussion of national aggregates (see Table 5.1). The Fourth Household Budget Survey done by the Nepal Rastra Bank in 2005-2006 shows that an average Nepali household earns NPR 27,391 per month, which translates to just over two[1] dollars a day per person. The median income, a better indication of the real situation, is even lower as Nepal's relatively high inequality of income distribution indicates[2]. According to the Asian Development Bank, 31 per cent of the population survive below the poverty line (ADB, 2008). Moreover, average rural income is 30 per cent less than urban income, rendering rural households extremely vulnerable to natural hazard, not just because of their reliance on an unpredictable supply of natural resources because of their extreme poverty. Together, these facts along with the escalating consumer price index, suggest that the average income of NPR. 27,391 underestimates the actual scale of poverty in the country.

Impacts

Table 5.1 provides a useful entry point to begin analysing the impact of climate change on a Nepali household. It also opens a logical line of inquiry to explore what consequences the signature events may have on such an average Nepali household. Using past studies, field observations and bottom-up consultations, we can calculate the burden per household and extrapolate it to the entire population exposed to flood hazards. Nonetheless, this approach must be treated with utmost care because while some of impacts of floods can be minimised relatively quickly, those of forest fires have long-term effects; nature takes

Table 5.1: **Average monthly household income by sector (in %)**

SECTOR	RURAL-URBAN RURAL	URBAN	ECOLOGICAL REGIONS TERAI	HILLS	MOUNTAIN	OVERALL
Agriculture, Livestock & Fishery	8	7	9	6	8	7
Salary, Allowance, Wage & Pension	23	45	24	31	24	28
Business/Service Enterprise & Other Related	29	43	27	30	44	30
Remittance	21	19	21	13	9	16
Imputed Rent	8	17	8	11	10	10
Miscellaneous	9	12	11	8	5	9
Total in NRS	**22,225**	**31,935**	**25,546**	**29,023**	**24,754**	**27,391**

Source: Fourth Household Budget Survey, Nepal Rastra Bank

a long time to recover. The context of a flood also highlights both conceptual and methodological difficulties. A flood generally affects crops in land close to rivers and in low-lying areas. The extent of loss depends upon whether the land is inundated, the bank is eroded, or if sand is deposited on the land. Paddy can benefit from temporary inundation and the region may yield an overall surplus production though other assets may be lost. Depending on how mature it is, paddy can withstand inundation for up to 10 days. If nutrient silt is deposited by floods, the crop yield will increase. Prolonged water logging, however, is undesirable because the plant will rot. Bank cutting permanently takes away land and if flood deposits sand on the fields, long term loss of assets, livelihoods and human capital development such as education and health are the outcomes. Those impacted by Koshi floods in 2008 are facing such adverse conditions. Yet another challenge is imposed by the fact that the nature of flood hazards in mountains and Tarai is different. Hence, it is difficult to quantify the impacts in their entirety. This study attempts to qualitatively glean lessons to estimate the losses.

Floods: Not only is the data available on the damage and costs of past floods in Nepal's mountains, hills and plains scarce, but such historical records tell us nothing about the likely frequency and intensity of floods in the future. Developing a future scenario requires downscaling climate models, creating hydrological models of rivers, and using simulations to estimate flood areas and damages. One such study attempted these measures in Rohini River, a trans-boundary river that begins in Nepal's Chure hills and joins the West Rapti in India (see The Risk to Resilience Study Team, 2009). Though the study focused on lower regions of the basin in Uttar Pradesh, the findings can help estimate impacts of climate change in Nepal for three reasons:

- The physical proximity of the Rohini basin to Nepal's Tarai region,
- The validity of the climate downscaling model in the basin for the Tarai and
- The similarity of land-use, livelihood and settlement patterns.

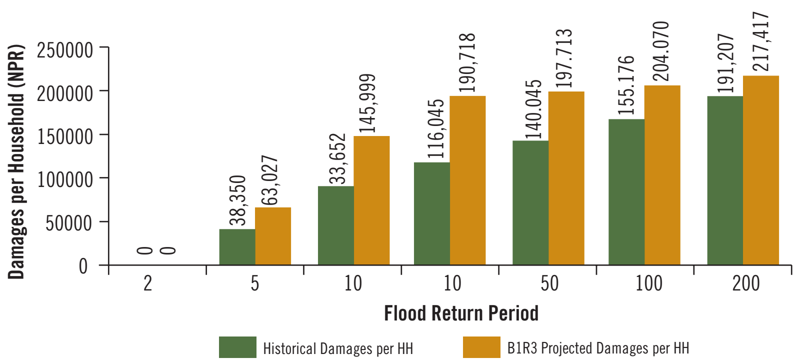
Yet, the geomorphologic differences between the upper (Nepal) and lower (Uttar Pradesh) regions of the Rohini basin need to be recognised. In particular, since the gradient of Nepal's flood plain is slightly higher than that of Eastern Uttar Pradesh, the area of inundation will be lesser in Nepal. Since damage is proportional to both area and depth, however, losses are likely to be similar.

The Rohini flood model provides some key indicators and simple yet relevant figures for assessing the quanta of the impacts due to flooding under "with and without" climate change scenarios. Even with the caution mentioned earlier in transposing the numbers across boundaries, they do make a case for undertaking further analysis to help develop cost-effective, pro-active strategies for reducing damages due to floods. The model calculates flood damage to housing, crops, seed, livestock, fodder, debt servicing, wages, health and

Table 5.2: **Projected damage to an average Nepali family (in NPR)**

ELEMENTS	HISTORICAL/CURRENT CONDITIONS	B1R3 CLIMATE CHANGE PROJECTIONS
Projected basin-wide damages /km² in million rupees	0.464	0.938
Per head	541	1,094
Average household size	5.21	5.21
Per household	2,813	5,581

Figure 5.1: **Impact of climate change on flood damages**



medical services, food and grain stock and supply, and public infrastructure as well as the number of lives lost. (Placing financial costs to human deaths does raise ethical issues such calculations bring up but are useful in understanding the overall economic picture of risk and insurance involved.). Table 5.2 presents damages likely to occur in the Nepali section of the basin.

Applying the results from Rohini River Model to the entire Nepal Tarai suggests that the basin-wide cost of recurrent floods that occurs with historic frequencies is NPR 2,813 per household per year. Using the median climate change scenario projection the loss will almost double to NPR 5,581 per household per annum. These averages are useful for estimating basin-wide loss, but to get a household's perspective we need to look more closely at the households likely to be directly affected.

According to simulation results (The Risk to Resilience Study Team, 2009), up to 19 per cent of all households in the basin are directly affected by a flood occurring with a return period of 200 years. However, for all the flood frequencies/intensities combined, on average 40 per cent more households will be affected when the effects of climate change is included.[3] The average damage per directly affected household is shown in Figure 5.1. It is clear that the effect of climate change is more pronounced for 5 and 10-year return period floods. This means that impact of climate change in terms of damages will be felt more strongly in the frequently occurring events.

The cost of the historic five-year flood damage (NPR 38,350.00) is almost twice the average monthly income of rural Nepali households (NPR 22,250.00), while the cost under the climate change scenario (NPR 63,027.00) is equivalent to its three months of income. With a ten-year historical flood, losses per household would be about a third of annual income in the historical case and the same frequency flood with climate change would result in losses in excess of more than half of a households' annual income. The average household with income above the poverty line cannot recover from such a shock. Any flood of higher than a 10-year return period would devastate the average Nepali household.

Though these scenarios for Nepal are interpolated from studies done in downstream Uttar Pradesh, and cannot be said to be robust, the lessons they point to are more than enough to suggest that a systematic approach to calculating losses must be adopted. Collecting the data needed to make such estimates can help in both identifying cost-effective adaptation strategies and fine tuning the methodology.

Forest Fires: A total of 508 families were affected when 206,042 acres (83,382 hectares) were destroyed in the fires which raged across the Nepal Mid-Mountain in the spring of 2009. The University of Freiburg's website has stated that the total loss to personal properties was NPR 123,415,000 which amounts to NPR 243,000 per family.[4] This number does not include the families that indirectly depend on the forested areas, and the impact is probably spread over a much larger population. Table 5.3 shows that the real impact of forest fires extends far beyond the loss of trees alone and can be severe enough to almost wipe out the total capital assets of an average family. Though the figure might seem counter intuitive because a forest contains very few man-made assets, it does have abundance of natural resources which the households use. Thus, the loss incurred is not just assets worth two years of income but the loss of an entire natural asset base, that provides income and livelihood support throughout the year. The one-time value of timber losses due to a forest fire may turn out not to be large but given that about 80 per cent of the population depends on forests for daily fuel wood supply and 42 per cent for livestock fodder (Regmi and Adhikari, 2007), the overall impact can be devastating. Over 39 per cent of Nepal's total geographic area is classified as forest, of which at least 23 per cent is forested (WB, 2008a). It has been estimated that a quarter of the country's forest area is heavily degraded leading to increased landslides and soil erosion that add to regional sedimentation impacts reducing the life spans of reservoirs and posing a threat to all infrastructure on or along the rivers. Other long-term effects are even harder to quantify. For example, if groundwater recharge is lowered and winter rainfall reduced, less water will be available and drought conditions may be exacerbated. With carbon deposition from forest fires, glacial melt may increase too. Much more rigorous methods than used in this study need to be followed to work out this calculus.

Table 5.3: **Impact of forest fires**

LOSS	IMPACT
Timber losses based on the area of land burnt or partially burnt	83,382 hectare x commercial timber/hectare x average price of timbre from that forest type + partially burnt x formula above = total commercial value
Revenue loss	NTFP estimates/hectare x 83,382 x 50 yrs until regeneration
Impact on soil moisture	Groundwater recharge reduced
Loss of life and cattle	From reports
Bio-diversity loss	Some measured in NTFP losses; others not valued yet
Carbon emission/reduced carbon banking	Increase in greenhouse gases and reduction in sequestering
Black soot	Health burden and increased rate of glacial melt
Added erosion/mass wasting	Loss of land
Increased regional sedimentation	Decreases in reservoir life spans, damage to irrigation appurtenances and turbines.
Decline in the functioning of embankments	Increased flooding downstream and risk of breaching (see energy section)
Decreased fuel load and production of forests	Less fuel and productivity per unit area of the forest Reduction in sequestering potential
Regeneration and stock management	No benefits
Smoke	Health impacts

Since dry winters create conditions ideal for forest fires, forests carrying large amounts of fuels are more likely to burn intensely and completely, while only those carrying less fuel may survive. Over a period of time, the average fuel density of the forests will decline as the thicker forests burn, changing the balance due to reduction in timber and non-timber forest products (NTFPs). This change is likely to reduce the income streams from forest and the carbon sequestering capacity of forests.

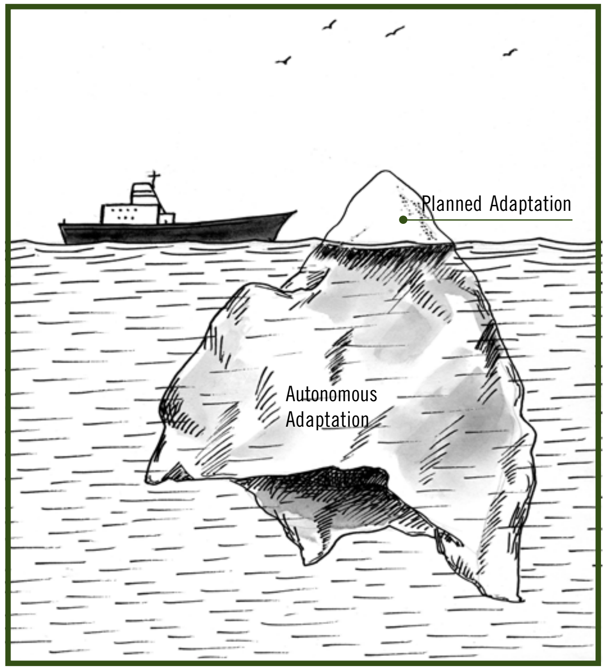
Crop loss due to heat stress and disease vectors: Crop losses, whether partial or total, are other threats associated with current weather pattern. The average household could lose almost half its income because of the complete failure of one crop in an area with 200 per cent cropping intensity; partial failures or mixed cropping would incur proportionally smaller losses. Nepali families whose derive their primary income from agriculture will suffer more. Areas with single rather than diversified crops will be most likely to fall victim to the predicted increases in heat stress, diseases and pest loads.

Adaptation strategies

Given that stresses attributable to climate change are inevitable, a fundamental question emerges: how will Nepal and Nepali people adapt? This begs a question about adaptation. According to UNFCCC, adaptation is "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities." While this definition is useful, it offers little tangibility to translate into the daily lives of a Nepali. We begin by making a distinction between *adaptation* and *coping* as articulated by Adaptation Study Team (2008). Adaptation is more than "coping." In well-adapted systems, people are "doing well" despite changing conditions. They are doing well either because they shift strategies or because the underlying systems on which their livelihoods are based are sufficiently resilient and flexible to absorb the impact of changes. As a result, at its core, adaptation is about the capacity to shift strategies and develop systems that are resilient yet sufficiently flexible to enable vulnerable people to respond to change.

Planned Adaptation: Planned adaptation includes programs and projects that governments, NGOs, and international donors implement as a result of specific climate impacts and vulnerability assessments. Planned adaptations are generally made to respond to predicted impacts on ecosystem and hydrological system and to minimise human vulnerability by focusing on sectoral interventions, such as those related to water management and flood control.

Autonomous Adaptation: Autonomous adaptation includes actions that individuals, communities, businesses and other organisations undertake on their own in response to the opportunities and constraints they face as the climate changes. Autonomous actions are individual or collective responses, almost entirely in the poorly recorded informal sector. These may involve changes in practices and technologies, diversification of livelihood systems, access to financial resources (e.g. micro-insurance, micro-credit), migration, reconfiguring labour allocation or resource rights, and collective action to access services, resources or markets. Social capital and access to skills and knowledge can be particularly important to enable these responses. The difference between planned and autonomous adaptation



Adaptation Iceberg

can be conceptualised by using the analogy of an iceberg: the submerged invisible part representing autonomous adaptation is substantially larger than the visible tip above the water level which is akin to planned adaptation.

Autonomous adaptation takes place at the community and household levels while planned adaptation includes those strategies and actions initiated by a government to shape its policies, programmes, and projects in response to global climate change impacts. Most planning decisions work in the long term and are path-dependent, whereas autonomous or indigenous adaptation is short-term and spontaneous as communities or households respond immediately to the social, political and institutional stresses associated with the changing climate. The market, both formal and informal, is an important avenue where the response is autonomous; and many of the opportunities visible and available at the household's level is often invisible or beyond the ken of national or international level of planning. The massive rural outmigration seen in Nepal during the last decade is one such example of market provided opportunity for adaptation.

Hayek (1945) has described the market's ability to set prices as the outcome of cumulative knowledge of the numerous transactions and decisions made by individual players with limited but intimate information about both unique socio-economic, political and institutional pressures as well as opportunities. Similarly, the quanta of aggregate autonomous adaptation decisions made at the local scale cannot be matched by planning for adaptation at the national level. In an economy like Nepal, dominated by the informal sector and with weak formal institutions, autonomous adaptation has a particularly strong influence on the direction of future courses of action.

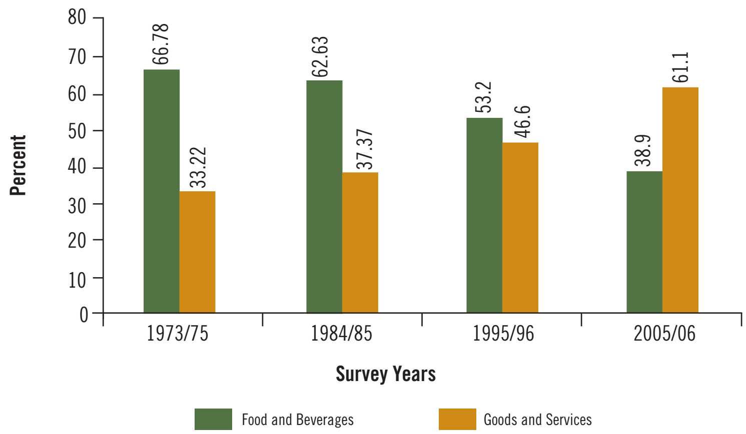
Most economic activities in Nepal are not recorded as they happen in the informal sector. Although the actual size of the informal economy is difficult to measure, the Labour and Trade Union Congress of Nepal estimates that its share is 56 per cent of the formal economy. Other sources suggest that it is around 20 per cent, while some place the figure at 70 per cent, depending upon the assumptions used. In terms of climate change adaptations, what is more important than the size of the informal economy is the number of individuals (see Table 5.4) who do not benefit from the social security that only the formal sector can provide. It is those Nepalis in the informal agricultural

Table 5.4: **Labour force in the formal and informal sectors (in '000)**

SECTOR	BROAD FORMAL	BROAD INFORMAL
Total	879 (9.3)	8584 (90.7)
Male	655 (13.8)	4,082 (86.2)
Female	224 (4.7)	4,502 (95.3)

Source: NLFS, 1999.

Figure 5.2: **Household consumption patterns**



Source: Household Budget Surveys, Nepal Rastra Bank

sector who are the most vulnerable to the shocks associated with climate change.

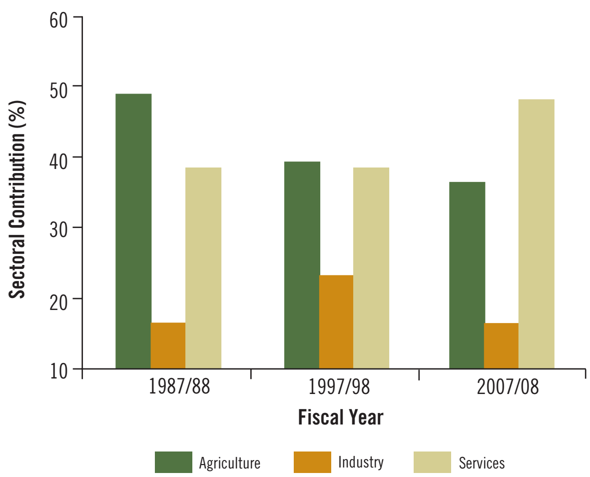
The continued lack of formal safety nets and the ongoing stresses of all kinds make the average Nepali household more vulnerable than it was a few decades ago though its dependence may have shifted away from the natural resource base. Figure 5.2 shows the change in household consumption patterns over time and indicates that while incomes have increased and livelihoods diversified, expenditure on food that was once a major portion of the average household expenditure has shrunk to about 39 per cent. Analysing household expenditure trends, Rankin (2004) suggests that expenditure on consumer items has increased. This shift is also is one the factors for increased incentives for non-agriculture based livelihoods. Income from sources such as jobs and businesses now constitutes 58 per cent of the total household income. A 2006 study suggests that the proportion of holdings that produce mainly for sale is not even 1 per cent, while little over 21% farm families use their farm produce almost equally for both sale and home consumption (CBS, WB, DFID, and ADB, 2006). For this population whose primary occupation is agriculture the vagaries of climate change is a direct cause of increased vulnerability. The extent of impact of climate change on those people whose primary occupation is not agriculture remains to be examined further.

This shift indicates the preference of Nepali households towards the service sector and away from their dependence on the natural resource base subject to climate related shocks. This trend is also changing the nature and functioning of traditional institutions but is yet to be proxied by formal social safety nets (DST, 2008). Whether this shift is building or depleting household's resilience needs much deeper analysis than this study is able to provide. Throughout history, Nepalis have shown resilience and grit in surviving in a difficult landscape and the present time is indeed a period of risk but can also be one of opportunity.

The face that the structure of the Nepali formal economy mirrors global trends is reflected by the household level characteristic discussed above. Approximately 66 per cent of the national population is engaged in agriculture which contributes only 36 per cent to the nation's GDP.[5] In 1987-1988, this share was almost 50 per cent and in two decdes has declined to 36 per cent. During the same period, the contribution of the service sector has increased from 35 per cent to almost 50 per cent (see Figure 5.3). The contribution of industrial sector has remained constant. The service sector is growing faster than industry is, leading the country along a development pathway slightly different from the industrial development paradigm most developed nations followed.

Historically, agrarian economies first turned into industrial economies by investing agricultural surpluses into industry before investing on the service sector. The trend in Nepal, however, is to import manufacturing products even while local demands for services have increased. Increased remittance income may also be a

Figure 5.3: **Sectoral contribution to GDP**



driver of the demand for services. Nepal also lacks space for the growth of industry: after all, it is landlocked and has only limited and fragile natural resources. Unlike Japan and South Korea, with their many sea ports, Nepal cannot afford to bring large amounts of inputs into the country and export is constrained by its neighbours, India and China, both of which are on the fast track to industrial development. Nepali industries cannot compete with their immense economies of scale or their unquenchable thirst for basic inputs. A service sector-based pathway to development, in contrast, might well suit Nepal as it will not stress its already fragile natural environment with the harmful externalities of industrialisation and it can keep the ecological footprint of its economy small. The autonomous sector's response indicates that this is happening already.

While Nepal's development targets still aim for growth in the manufacturing sector, this planned trajectory has very little actual effect on the shape of the economy (see Table 5.6). This disconnect may be due to the weaknesses of the institutions and instruments which should control the economy, including planning infrastructure, and fiscal and monetary policies, or simply be a mismatch between real and desired opportunities. This disjuncture has great significance: it illustrates the momentum of autonomous strategies compared to the stagnancy of planned responses. In terms of planned adaptation response, a good strategy may be to make resilience building a key objective and avoid areas such as heavy manufacturing that would increase national-level vulnerabilities. This discussion brings us to the question of what can be done in terms of short- and long-term adaptation strategies.

Adaptation to climate change

The following section presents options for adaptation by concentrating on two signature events, flood and energy which may become more vulnerable as a result of climate change.

Floods: As qualitative studies show, to ward off the damage associated with floods, Nepalis act autonomously by raising plinth levels and building grain storage facilities etc. (Dekens, 2008). Planned interventions usually involve large infrastructures which tend to be useful in the short term but controversial in the long term once negative externalities begin to overwhelm the benefits. Depending on the density of assets in a particular area at risk and the adaptive capacities of the people living there, one or the other strategy may be better (The Risk to Resilience Study

Table 5.5: **Actual and targeted sectoral growth rates of GDP (at 2000/01 prices)***

SECTORS	2006/07	2007/08	TARGET RATE OF GROWTH
Agriculture	1.0	5.7	3.6
Non Agriculture (overall)	4.1	5.6	6.5
Industries	3.9	1.8	6.8
Services	4.2	6.9	6.4

**Before deduction of financial intermediation services indirectly measured (FISIM)*
Source: National Planning Commission and Central Bureau of Statistics.

Team, 2009). Cost-benefit analysis shows that autonomous adaptation has better returns than embankment building in the lower Rohini basin but that in the urban confluence of Islamabad and Rawalpindi, it is structural measures built outside the densely populated areas that are more cost-effective than environmental rehabilitation in densely populated areas prone to flooding.

Assessing cost benefits of flood mitigation measures in lower Bagmati basin, Dixit, Pokhrel and Moench (2008) have found that constructing embankments for flood control has different implications for different groups. While some people do benefit from embankment in the short-term, many in the downstream and in other locations not directly protected lose out (The Risk to Resilience Study Team, 2009). Strategies such as range planting of forest buffers, raising of houses and villages, development of early warning systems and the expansion of existing local strategies (such as the provision of boats) for coping with floods appear relatively resilient to the impacts of climate change.

Before a decision about investment is made, it must be recognised that some flood protection strategies, like embankments, are path-dependent and irreversible (The Risk to Resilience Study Team, 2009). They represent a technological "lock-in" with built in rigidity, while other choices (e.g. flat roofs, houses on stilts, etc.) present greater flexibility in strategy switching if unforeseen surprises occur. The cost effectiveness of different strategies available to Nepal for flood protection must be explored further in light of social and technological flexibility (Thompson, 1994).

Crops: Although it is true that pests and the changing growing seasons are a menace to current agricultural practices, global warming and climate change can also provide opportunities for growing new species. Crop and integrated pest management trials can lead to planned adaptation solutions but until their results are seen, farmers can diversify to reap the benefits of multiple crops or simply to spread risk. Crop diversification can help reduce the burden of pests caused by the increase in temperatures and humidity at certain times of the year. In the long run, Nepali households need to reduce their reliance on agriculture, and the government has to increase food security through various planned measures, which may include better storage and distribution of food and unhindered access to markets.

Fires: Forest fires, if they continue unabated, will upset the current balance of fuel in forests. In particular, the energy balance will decline as the climate grows drier and hotter, and causes fires in dense forests that are sustainable only under the current climate. If rising temperatures mean increased forest fire hazard, it may decrease the ability of forest to function as carbon banks and may put a question on the strategy of reforestation as a mitigation measure. This adjustment may be the true residual loss caused by climate change as is pointed out by the Stern Review (2006). The resultant decrease in energy brings to the fore the crucial issue of increasing resilience and exploring the link between planned and autonomous adaptation.

This quest brings to the fore the issue of energy security of an average Nepali household, about 85 per cent of whose energy comes from biomass. Any reduction in that biomass due to forest fires will reduce energy availability and could force maladaptive trends. Decreased income from forest may result in their overexploitation and further degradation. People may also resort to using coal and other imported fossil fuels unless they are provided with alternatives. Options for autonomous adaptation in terms of energy sources are limited unless planned adaptation measures help achieve energy security.

Energy for adaptation

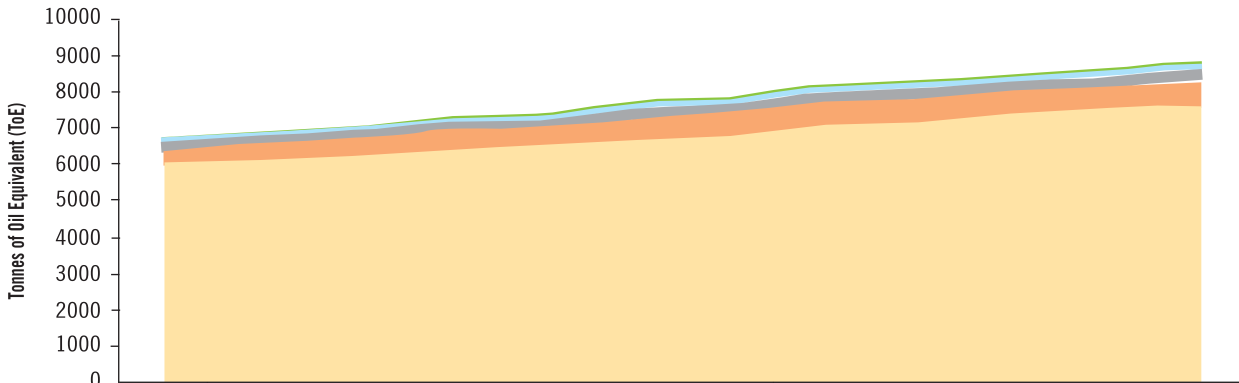
Energy is a key input in making the shift towards more non-agriculture-based livelihood pathways essential for social and economic well-being not subjected to climate change risks. Non-agricultural livelihoods are dependent on access to affordable energy systems. This is also the case with value added activities in agriculture – commercial milk production, for example, requires both refrigeration and transport. If this transition is managed only on the basis of cost-effectiveness of the energy system, the outcome could be very polluting and mal-adaptive. Forests are already under threat of a drier climate and continued dependence on this source will be further debilitating. In the short term, given the long-term gestation period of indigenous hydro development, thermal generation based on imported fossil fuels may be a cost effective method of production available to the private sector through independent power producers. The local effects of thermal generation may not be of concern to developing countries because of Nepal's current low emissions, but such a strategy implies high risk to Nepal. Because its fragile economic base may not be capable of coping with increased external dependence on a volatile fossil fuel market, this path makes the economy vulnerable to exogenous shocks as prices and availability of fossil fuels fluctuate in the global market. Dependence on fossil fuel will exacerbate the fiscal incontinence of the government owned monopoly para statel Nepal Electricity Authority (NEA).

Climate-based factors can significantly affect the performance of energy systems in use. In the winter of 2008/2009, for example, Nepal's integrated power system (INPS) faced a daily power cut of almost 16 hours because of a variety of reasons, including gap between demand and supply, poor maintenance, reduced rainfall, and, less significantly, the disruption of the transmission line due to Koshi embankment breach flood. An economy shifting away from the agricultural sector has the need for numerous gateway systems to make that shift meaningful. Access to reliable sources of energy is often a pre-requisite for such a shift. On the other hand, the state needs to devise appropriate policies to prevent local and national food insecurity, which is made worse if it is built upon an even more insecure and volatile energy system.

Taking a view of energy use in the poor rural household allows us to step back and take a look at the big picture of energy use in Nepal. Nepali households have little energy security, a situation that can only be ameliorated with serious government efforts. The national planned adaptation strategy must ensure, as a fundamental priority, the easy and reliable availability of affordable energy. According to the 2008 Operations Plan of the Asian Development Bank, 20 per cent of households in urban areas and only 5 per cent of households in rural areas have electricity, while for the majority, bio-mass remain the primary source of energy (see Figure 5.4).

Figure 5.4 shows that bulk of energy use in Nepal comes from biomass. Although the burning of biomass is considered carbon neutral because the carbon released is equal to the carbon absorbed as biomass grows, this fuel source is not a clean source: it has a major negative impact on the health of users and its over-exploitation can put additional stresses on the

Figure 5.4: **Nepal energy mix by source**



1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
7.5	10.5	13.6	16.6	19.7	23.8	28.9	34	39	42	46.6	50.4
66	72	77	83	89	99	108	119	129	139	157	168
67	72	60	61	68	246	175	152	134	172	152	241
449	506	555	680	661	709	734	758	754.5	741.5	707.08	724.09
6,059	6,185	6,268	6,403	6,540	6,681	6,824	7,088	7,241	7,397	7,558	7,721

Year

Renewable · Electricity · Coal · Petroleum · Biomass

natural environment. It is also limited in that it cannot provide the type of energy necessary for modern information flow including working, reading, communicating and meeting other basic services. At the household level, the provision of electricity is one of several essential gateway services necessary to help build adaptive capacities.

Despite the theoretical potential, economic feasibility, and the availability of financiers for developing hydroelectric projects in Nepal, progress in this sector is slow. Social, political, environmental and institutional constraints have retarded the construction of hydroelectric dams. At the same time, climate variability does not bode well for this mode of energy production either. For example, the 2008 drought reduced river flow and also contributed to the daily 16-hour power cuts. With all but one of Nepal's plants being run-of-river types, annual as well as seasonal electricity output is vulnerable to climate change. Another disastrous scenario is the case of the Kulekhani Dam: in 1993, a cloudburst in the catchments resulted in the dislodging of mountain slopes that washed away its penstock. This single massive deposition of sediment in its 12th year of operation also filled out more than half its 100-year dead storage capacity. Large-scale hydropower plants, whether they are run-of-river or storage type, are vulnerable to extreme climate events. What was considered a freak event in the case of the Kulekhani catchment may become the norm if even the more moderate climate change predictions come true.

With such scenarios, the sediment budget of a river basin can be greatly altered by extreme events. According to Mahmood (1987), "in the Koshi the average annual sediment yield based on measured suspended load is 2,800 t/km^2" He later noted that during an extreme event on the 23rd and 24th of June 1980, an estimated 55-56 million tons of sediment, an almost 200-fold increase over the annual average, was transported as mudflow within 14 hours. Such events can greatly reduce or even end the life of a proposed storage reservoir because changes in sediment budget mean much higher rate of sedimentation shortening the economic life. Given that climate change models predict an increase in the number of such extreme events, it is clear that the construction of large-scale infrastructure projects, and the economic analysis of the impact of climate change on them become fraught with greater risks and uncertainties.

Decentralised and renewable methods with less geographic exposure offer a more resilient system of achieving basic electrification for most of Nepal. These include distributed electricity generation with small and medium projects owned and operated at the local level both by communities as well as local governments, and can include biogas, solar, hydro and wind energy systems. Besides the increase in risk resilience compared to single large entities, their other benefits are a small ecological footprint and the promise of reducing the use of biomass and thereby conserving forests (Sathaye and Ravindernath, 2008).

The use of renewable sources of energy, especially hydro, photovoltaics and biogas, has witnessed a significant growth in the ten years from 1996 to 2006. From a negligible share in the total energy use in 1975, they have grown seven-fold. The small and medium generating stations now comprise about a third of the total hydro production, which saw a three-fold increase in the same period. In the autonomous sector, the installation of peltric set of a few hundred Watts (or pico hydro) has seen significant growth which has not been adequately assessed. As recounted earlier, another area where renewable energy promises much is in hydroelectricity-based transport. Nepal's success in replacing fossil fuel based three wheelers with electric ones or the success with goods carrying ropeways (Gyawali, Dixit and Upadhya, 2004) needs better policy support both from the national government as well as international development agencies. It is safe to assume that such initiatives in renewable energy, including photovoltaics and biogas, have served many more households per unit of energy production than has the national grid and that the distribution is more equitable. Nepal's natural potential—there are plenty of streams, year-round sunshine and many heads of cattle and the low average need for energy per household – are not the only reason for its success.

Large power producing enterprises have not served either nations or consumers well in developing countries. Despite the "too-good-to-be-true" economics of large-scale projects, which can theoretically recover investment costs within a couple of years of their coming online, their actual performance is poor if assessed in terms of actual return on investment or services provided. Losses in such large integrated systems are high and their controlling agencies typically demand subsidies for distributing electricity to the poor. Eventually, the utilities become so inefficient that they cannot even survive without getting government subsidies for meeting their obligations to even their current customer base. As a result, the wealthy elite benefit from subsidised electricity while the non-served poor pay for it through indirect taxation.

Pakistan's Water and Power Development Authority (WAPDA), with technical and managerial losses of around 30 per cent, is one of the largest burdens on the national exchequer but is not able to supply local demands. NEA is not doing well either and exhibits losses higher than 24% (ADB, 2008). Though it charges about nine cents per kilowatt-hour, NEA is still unable to pay for the capital costs of the installed hydro-electric capacity. On the other hand decentralised systems supplying electricity may be more expensive than large systems per kilowatt of installed capacity but they provide reliable electricity at rates that consumers are willing to pay (WB, 2008). Such energy systems will

BOX 5.1: KAGBENI WIND TURBINE EXPERIMENT[1]

In 1989, Nepal Electricity Authority (NEA) attempted to produce electricity from wind energy in Kagbeni, Mustang District. The Kagbeni Wind Power Project (KAWIPOP) was a costly venture (NPR 6.8 million, including administrative costs, in 1989 prices) for two 10 kW wind turbine generator sets to supply 60 houses with an estimated annual energy production of 12,000 kWh. The production value was just NPR 40,000 per year, while the cost inclusive of 10 operation, maintenance and administration staff was NPR 200,000 per year. The turbines both began operations on 20 December, 1989, but were damaged within a few months (Turbine 1 on 20 February, 1990; and Turbine 2 on 12 May, 1990).

An evaluation of KAWIPOP conducted by Dangrid Consult in July 1992 reached the following conclusions:

- Not enough background information about the wind conditions at Kagbeni was collected;
- The winds were stronger and more turbulent than anticipated;
- To cope with the stronger winds, the turbine blades were cut on the site and were not properly balanced afterwards;
- The yaw brake was too weak to prevent fast yawing because there were heavy gyro-forces.

In its conclusion, Dangrid observed that, "The important outcome of the Kagbeni project is that reliable wind data are now available." However, data collection was discontinued in 1997.

Sins of unsustainability (or the virtues of sustainability)

The KAWIPOP experience provides seven sins that Nepal must avoid in its approach to build a climate resilient future, particularly in choosing a softer energy path. Christensen and Koukios (1997) argue that many soft energy projects that could compete with oil at current prices have failed to take root, that is, to become self-sustaining and self-generating. Drawing from the lessons of several demonstration projects implemented in the rural areas of various Greek islands, they conclude that many well-meaning ventures have systemic problems that have nothing to do with the prices of competing forms of energy. Christensen and Koukios help us examine these issues in the context of the sustainability of renewable energy enterprises and their conclusions have relevance for those who strive to pursue non-fossil fuel dependent pathways in Nepal (Also see Chapter 6). They highlight 'seven sins' (or conversely seven virtues): a) Irresponsible money, b) Dysfunctional institutions and policy, c) Engineering and engineering ideologies, d) Technical disintegration, e) Social disintegration f) Project learning disability and g) Policy learning disability. In the following section we explain these seven sins—and their corresponding seven virtues.

First sin: irresponsible money
Many times the problem is not one of insufficient money but rather of its inverse: too much money flowing too freely from remote sources through planners and initiators with no long-term commitment to on-going operations. The result of the initial largesse is that the recipients assume money will continue to flow in later stages, too. By the time the truth dawns on them, it is often too late to prevent the project from running aground.

Second sin: dysfunctional institutions and policy
All problems regarding equipment and construction are defined by institutional policies and practices devised in terms of what such non-renewable energy technologies demand, and little thought is given to the varying requirements for the operation and maintenance of different technologies. This sin can be rectified if substantial and systematic attention is devoted to identifying and modifying dysfunctional, anachronistic policies, institutional arrangements, and professional practices associated with older technologies.

Third sin: engineering and economic ideologies
Both engineering and economics have entrenched ideologies—'economies of scale' for the former and 'price incentives' through favoured taxes and subsidies for the latter—which foster designs that lean towards gigantism. When coupled with another belief in 'technological utopianism' or the unquestioned faith that equipment will function as designed, they produce rusting white elephants unable to survive in their social and environmental contexts. Rectifying this sin requires identifying and dealing with ideological blinders and associated professional practices that continue to foster dysfunctional approaches to the implementation of soft energy systems.

Fourth sin: technical disintegration
This sin can be avoided if the designs for the technical systems are made locally suitable after conducting an integrated technical analysis of resources, technologies, environmental relations, and economics.

Fifth sin: social disintegration

When plans and designs for hardware are developed without explicit and early considerations of the society that is expected to operate, maintain and live with the system, projects will be abandoned or forced to shut down. Operators are often an afterthought brought in only at the handover stage after all the crucial decisions from design to implementation are already a *fait acompli*. To avoid falling victim to this sin, the design and development of systems must be integrated with the design and development of effective social capacities—institutions—for the operation and maintenance of the systems.

Sixth sin: project learning disability

Failure to recognise and publicise mistakes ensures that errors will be needlessly repeated. A virtue to strive for, therefore, is to evaluate the results of programmes not just in terms of the hardware constructed but also in terms of whether an effective organisation is developed. Without a local body that is both able and motivated to engage in critical self-evaluation and learning, renewable energy projects are doomed to remain pilot schemes that fail as commercial schemes.

Seventh sin: policy learning disability

Charting a new pathway involves introducing new and renewable energy technologies. It demands that policy makers at the high end develop the ability to listen to critical evaluations of ongoing plans of actions. To promote learning, internal and external types of review should be published, widely distributed and discussed at the systemic level.

[1] The detail on Kagbeni Wind Turbine is based on Hydro Engineering Services (2002).

help these communities reduce the risks of deforestation (ICIMOD, 2009).

Nepal is at a cross road and faces important choices about its development pathways. The country has to make a choice about its energy path, a choice that developed countries made before the perils of increased carbon emissions become a global scourge, when that choice was all about economics. Nepal can either, in a business-as-usual manner, follow the path the industrialised West pursued, or can choose a cleaner development future. Coal, natural gas and nuclear power sources may cost as low as one to five cents per kilowatt-hour (Chetri *et al*., 2008) but this energy pathway has additional costs in the form of climate change and environmental externalities that developed countries did not pay when they opted for such systems.

The additional cost of implementing such systems, however, remains to be examined. The current selling price of electricity in Nepal offers a basis for making estimates. To compare globally, Foster and Yepes (2006) found that any recovery above eight cents per kilowatt-hour contributes to capital costs of electricity generation, which includes a mix of thermal and nuclear power plants. These additional costs should be borne by those very developed countries which closed fossil fuel options for Nepal. Such payment may be called “energy compensation” and should be paid in return for Nepal’s employing clean technology options. The current Clean Development Mechanism (CDM) approaches do not favour small-scale production for Nepal to alter its energy pathway.

At this stage it is prudent to estimate, however simplistically, the scale of investment necessary to make this shift. The new technologies depending on the mix of small and medium-hydro, solar and wind could cost anywhere between 5–25 c/kWh. Let us assume that on an average this cost is 15c/kWH and given Nepal’s terrain and considering the price of technology transfer this cost can go up to as high as 20c/kWH. Currently Nepal sells electricity at an average rate of nine cents per kilowatt-hour. If the cost of taking a renewable pathway per unit produced is 20c/kWh then additional cost per kWh of about 11 US¢ will be necessary. To estimate the cost we take projections of NEA which says that next year the additional demand would be 400

GWh and that the growth rate will be 8% per annum. Using these figures we can calculate the additional costs of using alternative sources as energy compensation.

Energy compensation = incremental cost/kWh x additional annual generation
= 11c/KWh x 400 GWh
= 44 million USD/yr increasing at 8% annually

Since most of the proposed technologies would be decentralised, the cost of distribution will be less than compared to that from centralised agencies, and it will be cost effective for Nepal to expand its services. According to the NEA, the expansion of transmission systems to smaller communities in remote areas with only 14-400 households using very little energy per capita is not economically viable.

In addition, as the solar and wind power technologies improve, production cost is likely to drop. The wind energy potential of Nepal is estimated to be 3,000 MW and places like Kali Gandaki gorge may possess potential of developing wind farms.[6] But this experiment, as Box 5.1 shows, failed and in its wake provides seven sins of sustainability that must be avoided. On the basis of assessment of global radiation on the horizontal surface of Nepal, Rijal (1992) has estimated the potential of solar energy in Nepal to be 32.15 X 10^6 MW. According to Asian Sustainable and Alternative Energy Program of the World Bank, 3-4 kilowatt-hours of electricity can be generated from every square metre of solar panel if an average of 300 sunny days and eight hours of light is available.[7] According to Pokharel (1998), solar energy availability in Nepal is between 3-5 Kwh/m^2/day on the average whereas it can reach up to 6.2 Kwh/m^2/day on bright sunny days. Because the sun shines for about 300 days in average in a year Nepal has a high potential for tapping solar energy too. Despite the promise, solar energy has not been harnessed. Only 3,328.42 kWp (per peak kilowatt) of installed solar PV (Piya, 2006) and 130 KW of solar electric systems have been installed in about 1,200 households (AEPC, 2006). Globally, total installed solar PV harness about 12 GW of energy (REN 21, 2007). Similarly, the installation the cost of concentrated solar is also expected to drop significantly.

Besides funding, Nepal needs to develop policies and procedures for scaling up the installation of renewable energy sources. Private sector participation, management procedures, and policies for selling excess electricity to the national grid need to be developed. Incentives for Nepali households to invest in climate-resilient energy sources must be linked with project funding and mechanisms for sharing the profit associated with their production need to be defined. Energy compensation funds can be used as up-front investments for making decentralised systems commercially viable and to share dividends with the investing families. A mechanism for insuring such schemes needs also to be designed in order to pool risk caused by climate hazards.

Due to the increasing rate of migration of Nepali labour outside Nepal, especially to the Persian Gulf states, a sizable amount of foreign exchange is remitted. The average Nepali household receives 16 per cent of its income from abroad, or almost twice its income from agricultural pursuits. In the aggregate, remittances amount to a potentially large resource for investment. Remittances are currently being spent on conspicuous consumption and the speculative buying of land and other assets. While such investments may enhance an

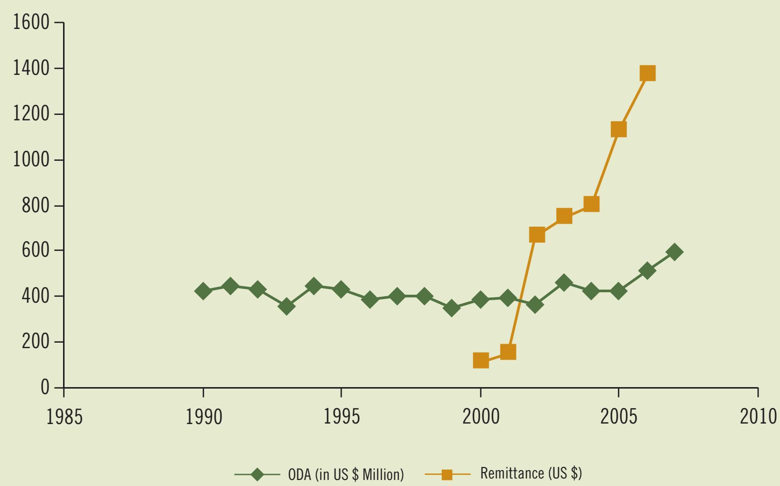
BOX 5.2: **REMITTANCES**

Remittances have increased dramatically over the past few years. According to the World Bank (2006), remittances to middle- and low-income countries amounted to about $30 billion in 1990. Fifteen years later, remittances had reached almost $170 billion, implying annual growth rates well above 10 per cent. Remittances account for about 30 per cent of total financial flows to the developing world and provide significant foreign exchange earnings (Acosta *et al.,* 2007). According to a 2008 study by the World Bank, the share of remittances in Nepal is 16 per cent of its GDP and Nepal has the 14th highest share of remittances in the world (WB, 2008) and the highest in South Asia (it is followed by Bangladesh at 8.8 per cent and Sri Lanka at 8.7 per cent).

In 2006, Nepal received 1.6 billion US dollars as remittances. Figure 5.5 shows that remittances in Nepal increased substantially after 2002, growing from 147 million US dollars in 2001 to 655 million in 2002 and then 1,373 million in 2006. This is much higher than the Overseas Development Assistance (ODA) or FDI in Nepal. In 2007, through various international sources, Nepal received ODA amounting to 598.4 million US Dollars[1] (see Figure 5.5). According to the ADB (2008), in 2006 Nepal received a net Foreign Direct Investment (FDI) of 6 million US Dollars which was 0.024 per cent of the total FDI in South Asia. India received about 80 per cent of the total that year.

The increase of remittances reflects the high rates of out-migration to various countries by Nepali labourers. Estimates of migrant Nepalis are variable. Some studies suggest 1.3 million registered as migrant workers with government, while another one million may be unregistered. [2]

Figure 5.5: Trends in Nepal's remittance Flow



1 http://data.un.org/Data.aspx?d=MDG&f=seriesRowID:632(Accessed on August 25, 2009)

2 Migration News, 2008, Voulme 14 No. 2 available at : http://migration.ucdavis.edu/mn/more.php?id=3357_0_3_0,(Accessed on August 25, 2009)

individual household's social status, they are an unproductive use of the surplus capital. In the year 2000, remittances amounted to 111 million U.S. dollars, less than one-third of all official foreign aid and development assistance (see Box 5.2). In 2007, just seven years later, they stood at 3.645 billion U.S. dollars, almost three times the total of official assistance to Nepal (WDI database, April 2009). This amount is also more than ten times the annual investment (44 million dollars per annum) in bringing clean energy to Nepal. Remittance is a fragile and un-sustainable source in the long turn, subject as it is to global shocks like the 2008 financial meltdown. In the short run, creating systemic incentives for its diversion to productive sectors, such as for achieving energy security, would be a prudent decision.

While hydropower or other renewables mitigate green house gas emission, access to electricity is one of the most effective gateway services for adaptation (ISET,

Table 5.7: **Comparison of approaches to energy, growth, resilience and climate-proofing**

ISSUES	TOP-DOWN APPROACH (CURRENT)	BOTTOM-UP APPROACH (PROPOSED)
Financing of energy expansion	Aid and loans (598 million USD/year) Economies of scale in production, Private sector participation	Decentralised energy investment through energy compensation (44 million USD/year)
Guiding principles for expansion	Target Foreign Direct Investment (7 million US $ currently available) and local Private Service Providers	Number of households connected (adaptation gateway services)
Other resources to be tapped	Formal institutions (e.g. NEA) replace old ones. Issues like access of the poor (current 5% in rural areas) and accountability remain.	Target remittances (3.6 billion USD available) New institutions (local electric supply associations) build on current local institutions with local shareholding
Institutional options	Energy is spread among poor (assumed impact)	Energy is spread among poor(planned target)
Assumptions for poverty reduction, growth and energy security	Growth is spread among poor (assumed impact)	Adaptive capacity is spread among poor (planned target)
Risk profile in terms of climatic variability	Energy security measured in volume produced in-house	Local energy security enhanced
Insurance options	Climate risk accumulates geographically through large integrated infrastructures Only self-insurance possible	Climate risk spreads geographically through decentralised energy systems Risk-pooling option available

2008; ICIMOD, 2009.) Electrification brings information and services, and expands capacities for diversifying livelihoods in those areas toward which the Nepali economy is already leaning. Decentralised services can strengthen the local social capital needed for building resilience against climate change (Agarwal, 2008; ICIMOD, 2009) and mobilise investment injections into the local economy. Investing in locally-managed energy systems not only increases the number of Nepalis served but also provides those with access to remittances with returns on their investments. Such an investment can also provide "green jobs" to those involved in the installation, repair and maintenance of such systems. The result may be enough growth in Nepal's economy to reduce poverty as well as a significant step toward energy security.

Table 5.7 has shown fundamental differences between the business-as-usual approach to development policy-making and one that is better adapted to respond to the impacts of climate change. The later pathway may require up-front investment in developing renewable energy system because in the long run, fossil-fuel strategies have negative costs. If the costs of fossil fuels rise in the future and climate change decreases the life of large-scale reservoir projects, renewable energy may well become a comparatively cheaper option. Despite the dilemma, Nepal needs the additional resources upfront to change its energy pathway which developed countries need to compensate. At the same time, focus must made in developing local capacity to adopt and adapt technology. This focus must move beyond rhetoric to pursue a substantive approach to incubate local entrepreneurship.

Conclusions

This chapter took a bottom up view of what climate science means to an average Nepali household. We saw that a flood which does not result in huge aggregate damage at a basin-wide scale can nevertheless destroy the livelihoods of those directly affected by it. With median climate change scenarios, the damage per individual household will double and the number of households affected will increase by 40 per cent. Although fire damage could not be calculated due to lack of data, the cost of the timber and income streams lost is very large indeed. The knock-on effects of increased snow-melt and regional sedimentation and reduced groundwater recharge are among the indirect costs. Higher regional sedimentation will permanently decrease the volume of water stored in both natural and man-made bodies. Additional costs will be incurred through the increase in disease vectors and crop losses.

Autonomous adaption to these impacts is taking place on a massive scale, though the elements of that adaptation have yet to be captured fully as it should be. Planned adaptation strategies, in particular large infrastructure-dependent pathways, also need to be carefully evaluated. From the preliminary analysis of the Rohini and lower Bagmati rivers, we have seen that people-centered approaches to flood adaptation are cost-effective. Short-term strategies promoting pest control and crop diversification can minimise the burden of agriculture related-impacts.

Nepal needs reliable and sustainable sources of energy for two basic reasons: first, to foster economic growth and, second, to build the resilience of communities in the face of climate-induced disasters by promoting income diversification. Energy that is available to all—solar, micro hydroelectric, wind and biogas—does not strain the natural environment and can help with the sequestering greenhouse gasses in the forests. Decentralised renewable energy systems are viable options if developed countries offset the initial set up cost in the form of "energy compensation" to the tune of 44 million U.S. dollars per year. The NEA estimates an increased demand of 8 per cent per annum for next fifteen years. If this were to be coupled with a target of 8 per cent increase in number of household connections, all of Nepali households would be connected in 20 years. Adopting local investor friendly policies can also create incentives to promote such systems by diverting income sources like remittances towards clean energy production. Currently, remittances are ten times the amount of investment needed to shift to a climate-resilient development pathway. Those who have no remittances can still benefit from the essential gateway system services put in place to foster growth in renewable energies and may be able to find alternative livelihoods in the numerous "green jobs" that will be generated. Ultimately, the real debate is about climate-friendly, household resilient pathways to development versus the inflexible and mal-adaptive one pursued in the past fifty years.

NOTES

1 Calculated in actual dollar value (1 USD =82 NPR) not purchase price parity.
2 Income inequality has grown, with an increase in the Gini coefficient from 0.34 to 0.41. Some 78% of the poor depend on agricultural sector as the mainstay of employment (NPC, 2007). Disparities in poverty between urban and rural areas and between different geographical regions and groups have widened over the same period (*ibid*) and the level of poverty is high.
3 Average of number of households inundated weighted by probability of the flood under B1R3 climate change scenario.
4 http://www.fire.uni-freiburg.de/GFMCnew/2009/04/0427/20090427_np.htm accessed 18 August 17, 2009
5 Agriculture contributes barely 4 per cent to the world's GDP
6 A wind survey needs to be carried out.
7 http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/EASTASIAPACIFICEXT/EXTEAPASTAE/0,,contentMDK:21042047~menuPK:2900825~pagePK:64168445~piPK:64168309~theSitePK:2822888,00.html accessed August 17, 2009

TRANSITING FORWARD ALONG RESILIENT PATHWAYS

CHAPTER 6

Two key issues are known about climate change in Nepal. First, at the level of high science, there is a fair amount of confidence that average temperatures are rising, more in the high mountains than in the lowlands. Second, the Nepali farmers, ISET-Nepal and Practical Action consulted across the country, claim that the vagaries in weather patterns are growing more and more pronounced outside of their experience range or that handed down from their parents and grandparents. The rapid and visible "within one generation" melting of Himalayan glaciers is a proof to seriously consider the predictions of climate scientists, and the observation that lowland pests and toxic weeds have appeared at ever higher elevations, mostly in the last five to seven years, is a grassroots confirmation of the warming trend, even though high science has yet to investigate, collate and pronounce definitive judgment on these observations.

This study, as the title "Vulnerability Through the Eyes of the Vulnerable" indicates, is an attempt to give salience to the grassroots view, or what we have chosen to call the "toad's eye view" of those that experience the painful point of the harrow and hoe. High science, in contrast, is akin to the view of the eagle above, which sees wider and farther. At the lower end is civic science as practiced by the Himalayan farmers toiling in their fields, which is not only the carrier of immediate experience but also one that relates it to the wisdom shaped by generations of traditional knowledge. Though unconfirmed by high science and unaware of national and international policy debates, it is also that knowledge which millions upon millions of households use to make everyday decisions that affect their livelihoods, the national economy and even the global demand for fossil fuels.

The socio-economic dynamics observed in the Nepal Himalaya indicate that, on the one hand, the uncertainties of the weather system are a major factor pushing farmers away from farming, while on the other, the attraction of high-paying jobs is pulling them abroad. The end result is that the national GNP rests on a fragile and consumerist remittance economy. While it has been stated (in Chapter 5 earlier) that a development pathway that skips industrialisation and opts for a service sector oriented growth may have environmental benefits for Nepal, it is far from clear if the same can be said for giving up on hill agriculture. While it may make little business sense for Nepal to try and compete with its northern and southern neighbours in heavy industry, there is a case to be made for intermediate industries that enjoy comparative advantage or are based on agro-processing. The dominating revenue share that national TV stations get from advertizing package noodles is proof that a niche market for creative, service-related medium-scale industrialisation does exist for Nepal. It is with this in mind that our national and district-level consultations focused on climate science and the need to improve not just the high and low ends of it but also to foster better linkages between the two. Science is most valuable when it is solving actual problems, and nothing is more real to the farmers of the Himalaya than the implications of the climate vagaries that are threatening their livelihoods, especially in agriculture and the production of food.

Key concerns

As the signature events and national as well as grassroots views indicate, the problems that need urgent attention can be summarised as follows:

Climate science: Across the world, a better understanding of the interaction between the atmosphere and geo-physics and the impacts that follow is necessary if we are to predict the characteristics of future changes in the climate, what these changes might portend and how the country needs to prepare for them. For Nepal, improving our understanding of meteorological processes, particularly monsoon dynamics and their interaction with the Himalayan mountain system, where the orographic effect is pronounced, is vital. Significant changes in elevation in Nepal's hills and mountain regions result in dramatic variations in temperature, humidity and evaporation, depending on whether one is in the foothills, on ridges, in valleys or on the wetter aspect of a slope. This micro-scale variation in the Himalayan climate systems are not captured by general circulation models (GCMs), which have higher grid resolutions. To improve scientific data about the region will require investment in strengthening and expanding the existing network of data-gathering stations and supporting institutions. Applying creative approaches using civic science, such as installing stations in schools and in village-level organisations such as farmer-managed irrigation systems can help make sure the funds are well spent.

At the same time, we must improve our ability to analyse, synthesise and disseminate the knowledge we gather. Improvements in analysis will increase the security of farmers and horticulturists, trekking operators and implementers of development programmes as they struggle to cope with the uncertainties the impacts of climate change have added to an already uncertain existence. Improving data will also require the continuous monitoring of the discharges of the springs and other water sources that feed small systems, particularly at the level of water user associations. Such micro-level tracking will help us understand how the decentralised, unmapped sources upon which the vast majority of Nepalis depend for their drinking water and other domestic needs respond to global climate change. Only if we develop this understanding can we effectively operate and maintain the drinking water and sanitation systems which are the basic elements at the core of adaptation. Overall our current understanding at the field level is very limited; a sustained effort needs to be made in order to get a better picture of the impacts of global climate change on local climates and livelihoods.

Farming stress: Climate change-induced impacts such as extreme weather events as well as pest and weed infestation seriously debilitate agriculture. In the future, households dependent on agriculture for their livelihoods are likely to face a variety of additional stresses and threats, forcing them to stop farming and migrate to already overpopulated cities. Government policies need to provide rural households with options for more climate-robust livelihoods as well as the means to make this strategic transition. At the same time, it must ensure national food security by enhancing the capacity of local food systems to face the stresses associated with climatic vagaries. Encouraging Himalayan farmers to grow more and better food in their immediate vicinities will reduce the uncertainty inherent in a food system dependent on imports transported using fossil fuel. Because farmers are vulnerable to climate change, they need to be confident about whatever new strategies are introduced. These strategies should include establishing centres which will monitor and study diseases and provide support in diverse geographical locations.

Food system: Many families are exiting agriculture not only because they prefer to do something else but also because it is growing less and less profitable and characterised by drudgery. Income from remittances has given people in the hinterlands the cash they need to buy food from distance markets and to send their children to school with the expectation that they will get good jobs. The fact that climate change will alter the regional water balance of, for example, the sub-river systems of the Ganga basin, suggests that reliance on external markets for food is fraught with threats: prices will be volatile and distribution may be disrupted, whether by flood damage to roads and bridges or politically-motivated strikes. At the same time, it may be that drought-prone areas have reached a tipping point. There is a need to explore ways of rebuilding farmers' confidence.

Social and Economic Vulnerability: The losses caused by increasing temperatures, humidity, and infestations of insects and diseases are poorly accounted for in the national GDP. In order to adequately assess the economic vulnerability of farmers, we need to develop new methods to include such losses. Caste, class, gender and other structural characteristics of local communities create multiple layers of social and economic vulnerabilities for agriculture-based livelihoods. Climate change will worsen these vulnerabilities as well as add additional layers of stresses. Dealing with these new risks adequately requires understanding and responding to these various socio-economic vulnerabilities. As it has been for decades, seasonal migration which provides financial returns from remittance continues to be a common, autonomous response to losses in local livelihoods. But migration is also associated with creating nuclear families and changing social values among family members. It has even given rise to socially unacceptable behaviour that has caused a rise in the incidence of HIV/AIDS cases.

Alternative livelihoods: Research of over a decade and a half (Moench and Dixit, 2004) clearly indicates that those who diversify their sources of livelihood survive floods and droughts best. One way to help people adapt to climate change is to help households whose livelihoods are based wholly or in large part on agriculture shift some family members into the less climate-vulnerable industrial and service sectors without abandoning farming altogether. Assuring such a happy state of affairs is dependent to a large extent on the existence of the effective transport and easy communication systems that grant both farm produce and rural labour, especially women, access to markets. These systems, in turn, depend on energy security. Nepal needs creative policies that will develop and make easily available indigenous energy sources which have low carbon footprints and which, in their operation and maintenance, will generate jobs.

BOX 6.1: **Bhattedanda Milkway**

The Bhattedanda Milkway, a goods-carrying cable car is used to transport milk to the roadhead quickly, before it curdles in the heat. The system has significantly alleviated poverty among marginalised farmers in Nepal's southern Kathmandu Valley. The ropeway was the brainchild of a few unconventional Nepali and European watershed managers. It emerged between 1994 and 1998, when several institutions favoured its installation (Gyawali *et al.*, 2004). Unfortunately, the political conditions conducive to the sustained development of this innovative technological approach to combating rural poverty did not and still do not exist in either the Nepali or the EU officialdoms and aid bureaucracies.

There are indicators that made this unconventional watershed management project a model of sustainable development: in its one-and-a-half years of operation between 1995 and 1996, the ropeway enabled a marginalised hinterland village to export one-and-a-half times more milk, vegetables and other rural products to the city than it imported urban goods—a highly unusual trade balance. The project obviated the need for farmers to boil milk for many hours a day (cutting down a lot of trees in the process) to convert it into the thick *khuwa* (solidified milk paste) that could be transported to the market without spoiling and instead enabled them to sell milk, a more profitable good, directly. Then, because institutional arrangements were not addressed properly and because a dirt road was constructed nearby, the ropeway fell into disrepair and ceased to function before the second-year mark was even crossed. After six years in a moribund state, the ropeway was revived when a cloudburst and a flood in July 2002 washed away the road, and farmers needed to take action so they could continue to sell milk and thereby sustain their improved livelihood.

The farmers' group eventually did manage to get the ropeway operating again. They also managed to connect to a nearby community-operated electricity distribution system and switch from non-renewable, diesel-generated power (which cost about NPR 34,000 per month to operate) to renewable hydroelectricity (for just NPR 7,000 per month). A comparison with an equivalent "green road" between two similar valley bottom to ridge top villages showed that it required 53 MJ to transport a tonne of goods on roads but only 34 MJ for a ropeway (Gyawali and Dixit, 2004).They are currently working to expand the ropeway to an adjacent valley without roads. A more successful story of adaptation that both alleviates poverty and is environmentally friendly is difficult to find.

The other major initiative towards shifting Nepal's transportation away from fossil fuel dependency has been the conversion of soot-belching diesel-run three wheelers into electric "safa (clean) tempos". Not only were imported fossil fuel vehicles replaced by locally manufactured electric-powered ones, but air pollution in Kathmandu was significantly reduced. Unfortunately, electric transport systems, including safa tempos and ropeways suffer from inefficiencies and planning failures as well as short-sighted taxation and other government policies. The question before policy-makers is whether or not they have the statesmanship needed to introduce such climate-friendly, adaptive technologies into Nepal's development policies. Transportation systems that are free of fossil fuel will help Nepal transit to a development path that is adaptive and resilient to the changing climate.

Access and vulnerability: An increase in the number of floods and landslides will make people more vulnerable as these disasters cut off their access to key services. In 1993, the scale of disruption was great: for more than three months, Kathmandu's food supply line with the Tarai was blocked after floods washed out bridges. The closure of parts of the East-West Highway following the Koshi floods of 2008 August is a more recent example. Any such disruptions, whether they are caused by landslides on mountain highways, GLOFs, or fuel price hikes, increase overall vulnerability. Access will be further reduced when climate change impacts cause food prices to soar. Ensuring mobility (more than providing transport itself) is crucial; to this end, Nepal must pursue a diversified, multi-modal transport system. In 1993, the country capitalised on its transport diversification: although the highway to Kathmandu was closed due to the unprecedented floods, the Kathmandu-Hetauda Ropeway was able to supply food to the capital. Another example of a climate resilient development pathway is the Bhattedanda Milkway, whose lessons for adaptation to potential climate change-induced stresses are captured in Box 6.2.

Climate-resilient infrastructure: Developing infrastructure resilient to the impacts of climate change is a challenge. Attention needs to focus on new ways of designing roads, bridges, culverts, barrages, embankments and reservoirs that will withstand climate-exacerbated extreme events. The accepted engineering methodology of designing such an embankment, for example, has required having historical data on flood discharges, river stages and sediment loads. As the climate grows more uncertain and erratic, it is unlikely that historical data, the statistical regression of which lies at the core of all hydro-technical design methodologies, will prove adequate for the future. Bridges, irrigation and power intakes, and public buildings need to be provided with sufficient safety margins to accommodate the impacts that that will result from intensified events related to climate change, whether they be floods or debris and sediment load.

Upgrading standards requires evaluating and improving existing design codes and construction practices and improving engineering education. It requires higher investments up-front so that these structures are climate resilient. While floods affect infrastructures such as bridges and culverts in specific locations, the impact of drought stresses farming systems across the country. Participants in the consultations saw drought as a major threat to drinking water and irrigation systems as low-river flows reduce the adequacy of water supplies and eventually harm crop production and health.

Adaptation and development: The discussions above show that efforts to adapt to climate change impacts are embedded within the broader challenges of development, which include poverty alleviation, equitable management of natural resources, and sustainability. If adaptation and development is considered as a continuum, at one end are development activities, such as the provisioning of drinking water and sanitation facilities, and energy and food securities, while at the other end, are efforts necessary to reduce vulnerability to climate change and build resilience (McGray *et al.*, 2007). Separating the two approaches is crucial in order to answer key questions such as what adaptation is, who will pay for it, how and who should generate and make national and international funds available, how access to such funds will be determined and how climate adaptations should be mainstreamed into the national and international development agenda. There are no elegant, neat or silver-bullet solutions to climate change because, according to climate scientist and founder of the Tyndall Center for Climate Research Mike Hulme, “wicked problems (such as climate change) are essentially unique, have no definitive formulation, and can be considered symptoms of yet other problems.” (Hulme, 2009: 334)

Hulme goes on to argue that “solutions to wicked problems are difficult to recognise because of complex interdependencies in the systems affected; a solution to one aspect of a wicked problem often reveals or creates other, even more complex, problems demanding further solutions” (p. 334) and suggests that “the description applies very well to what is conventionally understood as the ‘problem’ of climate change”. While arguing that the “wickedness” of climate change must be recognised, Hulme contends that elegant solutions will not solve it and “clumsy solutions” merely represent the limits of our human ability to respond. He argues that, since the idea of climate change is so plastic, it can be deployed across many human undertakings, especially as a resource of the imagination; it can stimulate new, creative thinking about technology, poverty reduction, demographic management, localised trade and many other such areas.

Building synergy between politics and citizens: The *2009 Human Development Report of Nepal* (UNDP, 2009) suggest that one challenge facing the country is to build a strong sense of citizenship and political community:

> "The restoration of democracy in Nepal in 1990 has increased people's aspirations without fulfilling their expectations. The rights enshrined in the Interim Constitution 2006 include the rights to food and work, the delivery of basic services, and above all, guarantees of internal peace and stability. None of these legitimate demands have been adequately met or addressed. This shortcoming has weakened the base of citizenship and increased clientelism. Many civil society actors, including private sector bodies, have become the clients of the political parties rather than true citizens. This has alienated the poor in general, especially among the country's farmers and agricultural labourers. If the Nepali state fails to address the basic needs and rights of these citizens, the country could well relapse into another conflict, especially after the immense growth of political awareness since the 1990s and its even more rapid increase during the Maoist insurgency. The state must promote development that is inclusive, humane, and just (HDR, 2009).

All sorts of political and administrative factors, including poor governance, low fungibility, weak institutional capacity and memory, poor technical and technological capacities, excessive dependence on donors, lack of coordination, vertical-structuring of agencies, centralisation and politicisation keep Nepal on the path of low-level development. For many developing countries, including Nepal, climate change presents an opportunity to re-evaluate the current approach to development. Nepal is particularly fortunate in that its political shift to a democratic republic and writing of a new constitution will enable it to embrace innovative pathways and reject the status quo as it transits to a re-crafted future. Even though the country is currently undergoing the difficult process of moving toward a more equitable and just social and state structure, the potential exists for interrogating past practices and charting out an alternative future.

The shift will also necessitate a re-orientation of its developmental trajectory. Nepal needs to engage the global community, while at the same time pursuing a development pathway that is inclusive, humane and removing barriers that could restrict its transition. If it does not change, Nepal will face a dual menace: the growing impacts of global climate change-induced vulnerabilities intertwined with an exclusive, un-humane and unjust development pathway. As Nepal writes a new constitution and re-defines the various components of local and national governance, the Constituent Assembly (CA) must take into consideration the challenges and additional stresses posed by climate change. In particular, decentralised development planning and management, quick local response and accountability, are the key ways to enhance adaptation to climate change, and must be built into the new governance structure.

Global negotiation: Nepal is already highly dependent on foreign aid and international cooperation for its development; in the future, assuring the flow of foreign investment will be even more crucial. In light of this need, it is necessary to build national capacity to engage more effectively at the global level. Whether it regards matters related to the mode of global carbon trade, compacts on bio-sequestration that will have a major impact on Nepal's development pathways, or other similar matters, Nepal's government agencies, civic organisations and the private sector need to enhance their capacity for international engagement so that the benefits that should accrue to Nepal in fact do so. This capacity is also necessary because global-level policy-making too needs to be aware of local-level concerns so that adverse impacts of global decisions are obviated at the very outset through such consultations.

Achieving this goal requires building Nepal's capacity for the economic and technical diplomacy. Therefore Nepal needs to engage more effectively with the global community. Such engagements should enable the government of Nepal to access the Adaptation Fund which has been proposed to support adaptive responses in developing countries. Accessing this fund will depend on the country's capacity to define the problem, and offer adaptive solutions to the problem of livelihood sustainability. At present, the understanding of local responses is limited: it is not known if such autonomous responses undertaken build or deplete resilience. Responses within Nepal's diverse socio-ecological niches need to be documented and local perspectives incorporated into the macro-planning process. Nepal needs long-term investments in its people to boost their capacities to deal with climate change and the global discourse that goes with it.

Adaptation fund: For countries like Nepal, which depend heavily on overseas development assistance funding to meet their basic development needs, securing additional funds for climate change adaptation is yet another challenge, one which Bapna and Macgray (2009) contend emerges from the "impossibility of disentangling adaptation from development complicating efforts to even estimate adaptation costs" (Bapna and Macgray, 2009). Our very preliminary analysis of the energy sector put this additional cost at about 44 million US dollars; obviously the amount will increase when the costs of adaptation in other sectors are added. While making an accurate assessment would need to examine the scale of autonomous adaptation, certain ballpark figures already exist. The five currently available estimates of the annual cost of adaptation (UNDP US $86 billion: 2007), (UNFCCC, US28-67 billion: 2007, World Bank, USD 9-41 billion: 2006 Oxfam, US $ 50 billion: 2007 and Stern Review, USD 4-37 billion) all run in the billions. Even without an exact number, it is clear that the cost of developing Nepal economically will increase at levels that current assistance doesn't even make a dent in. Again according to Bapna and Macgray (2009) "the current level of adaptation funding for developing countries is orders of magnitude below even conservative estimate of the costs".

Shared knowledge: While high science and modern information is important for responding to the impacts of climate change, it is equally important that the wisdom of ages contained in traditional forms of knowledge not be ignored. Such knowledge is based on generations of experience, and must be the foundation for the building of adaptive capacity that can respond to various stresses, including those associated with climate change. We need to conceive and develop a platform that enables different types of knowledge systems to find salience in the public discourse. Combining high science with the civic science of common, everyday Himalayan experience must be an iterative process wherein high science is communicated and transmitted to those at the local level, and local understanding is transmitted back to inform the ways in which high science, and development based on it, is practiced.

Research in Nepal has shown that high science and centralised development not sufficiently aware of civic and community concerns are, besides being ineffective, also very expensive. Sharma (2004), comparing four conventional donor-funded Nepal government programmmes in water supply and sanitation with that done by a Nepali technical NGO in partnership with village user groups, has shown that the latter's cost per household is almost three times cheaper and hence more cost effective than the former's even as the software to hardware ratio for the former is 66:33 and only 33:66 for the latter. Many local farmers are engaged in developing stress resistant varieties of crops. Such expertise needs to be identified and utilised to preserve and promote locally adapted varieties of crops. The examples shown by this research also indicate that a two-way feedback from civic science and development planning to the national and international bodies and vice versa is especially important given that millions upon millions of households are making everyday decisions based on their very local understanding of events, decisions that are currently not informed by the concerns of the high science of GHG emissions and climate change impacts.

Education: Improving climate science and developing climate-resilient infrastructure require re-crafting the education currently dispensed. Climate change is a complex problem that will need a broad, inter-disciplinary understanding of the issues involved. As is true elsewhere, Nepal's approach to development is based on gathering historical data within disciplinary boundaries to project future solutions, an approach that assumes that everything else remains the same. Climate change will likely make a mockery of such an approach. The current education system defines and imparts knowledge within disciplinary silos, but the impact of climate change, with its complex physical and social inter-linkages, demands much more. What will be demanded in the future is a better understanding of how both natural and social sciences impact each other and how changes in the assumptions of one area of study will have unintended and profound consequences for the assumptions in other areas. This osmosis and synthesis between the natural and social sciences will require redesigning curricula and teaching methods, and include the writing of textbooks that bring practical insights from the field into the classroom. This process must start at the school level and proceed right up to the tertiary level of education. The curricula should include emerging insights into the changing nature of ecosystem functioning as well as into its services and conservation.

Wicked problem, uncomfortable knowledge and clumsy solutions

The problem of climate change, based on the above discussions, can indeed be called a "wicked problem", one that is very difficult to define, and when attempted exposes underlying layers of many more underlying strata of nested and intractable predicaments. Complex inter-linkages among unforeseen elements and non-linearity that can quickly transform a small perturbation into a catastrophic event are the hallmarks of wicked problems. Because the signature events described earlier in the voices of villagers have such characteristics, any attempt to tinker with them and nudge the situation towards a solution requires "uncomfortable knowledge," or out-of-the-box thinking (WWAP, 2009) and a broad institutional environment that is conducive to bold intellectual forays. Comfortable knowledge has put us in the predicament of global climate change we are in and the built-in filters of existing knowledge generating establishments and their priority towards gate-keeping rather than new explorations is one element that has to change.

Change is inevitable, but it is not linear. It does not have one desirable and predictable destination; instead, it may reach pleasant or unpleasant ends with several mixes in between that are difficult to foresee (Thompson, 2008). And however desirable change may be, it does not just happen serendipitously or neatly. Indeed, efforts at development are themselves harbingers of planned change, which, if successful, will have been conceived and re-designed several times, and implemented through clumsy political compromises in a democratic terrain. The uncertainties associated with climate change are forcing us to re-think development paths and programmes.

Given the haze of unknowns, responding to climate change problem raises many questions. Should we opt for that one perfectly optimised solution, or should we opt for many 10 per cent solutions, some of which may fail while others may exceed our expectations? Should solving the problems of water scarcity and floods, problems that, it is widely believed, will be exacerbated by climate change, be attempted through one expensive scheme, a concrete dam for instance, or through a bundle of solutions pursued simultaneously, including water harvesting, groundwater management and wetlands preservation? Should embankments in critical locales be complemented with houses on stilts and villages with raised plinth levels generally? Should livelihood diversification, and providing opportunities for the same, be considered an intrinsic part of the adaptation strategy? How will the various voices of justice-seeking civic movements and of innovative (especially local) markets–voices that seem to listen more carefully to the grass root concerns than many official bureaucracies–be dovetailed into the programmes of national governments and international agencies? Should the problems raised by climate change be mainstreamed into sectors such as education and finance that have traditionally not considered them?

Climate change and its implications are perhaps the most serious issues of our times: there is a pressing need to amalgamate them with what has been, and continues to be, the main mission of countries like Nepal – development. This vital imperative calls for creating a new compact between government and development agencies on the one hand and local innovators and community-based civic bodies with the former set on the other. And this partnership needs to range across the spectrum, from hard physical to soft social sciences, from research to implementation, from centres to far-flung hinterlands.

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