

# Nepal



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## General Climate<sup>1</sup>

Nepal's climate is strongly influenced by its topography, which varies greatly. The northwestern border has very high altitudes in the Himalayan mountain range while the southeastern edge sits on the northern rim of the Gangetic plain – only around 300m above sea level.

The climate of Nepal is broadly separated into three bands that run horizontally through the country. The lowlands (the Terai Plateau) have a warm and humid sub-tropical climate, with temperatures around 22-27°C in summer months, dropping to 10-15°C in winter. The Middle Mountains, or mid-hills, are subtropical towards the bottom of valleys, but experience a cooler, more temperate climate as altitude increases up the valley sides and on higher ridges (Kansakar *et al.*, 2004). The high altitude mountainous regions (the Himal) are considerably colder, at 5-15°C in summer and remaining below zero in winter.

Nepal has four climatic seasons, which can be characterised as follows:

- Pre-monsoon (March to May): a hot, dry season with little rain but occasionally strong winds; conditions become more humid towards the end of the season, particularly in the Terai (ibid).
- Summer monsoon (June to September): provides 70-85 percent of annual rainfall, varying with the topography of Nepal (WWF, 2005). Monsoon rainfall arrives in June and continues until August or September, beginning in the southeast before moving northwest with diminishing intensity (ibid). The

<sup>1</sup> McSweeney, C. *et al.* (2008) unless otherwise stated

summer monsoon brings 250-450mm of rainfall per month in most of the country, though only 100-150mm in the northwestern mountain regions.

- Post-monsoon season (October to November): a very dry season follows the monsoon, with November typically the driest month of the year (Kansakar *et al.*, 2004).
- Winter (December to February): the winter is largely dry; however, although comparatively small, winter rainfall is significant for northwest Nepal. The majority of winter precipitation falls as snow, contributing to snowpack and glaciers, which in turn feeds rivers as melt water in the spring (WWF, 2005).

**Key climate vulnerabilities:** Flooding; landslides; infectious disease epidemics; drought; severe storms.

## Observed Climate Changes

Because of Nepal's highly variable topography, gridded climate data with a coarse resolution (i.e. a large-scale grid over which a single average value is given for each square), will not accurately represent large local climatic changes.

### Temperature

Analysis of local station data shows that mean annual temperatures for Nepal have been increasing steadily since the mid-1970s (See Figure 1). Increases are largest in the more elevated regions in the North – highlighting the sensitivity of mountainous regions to climate changes (Shrestha *et al.*, 1999) –, while changes in the Terai are small (WWF, 2005). Warming has been concentrated in the period immediately following the monsoon, through into winter (ibid).

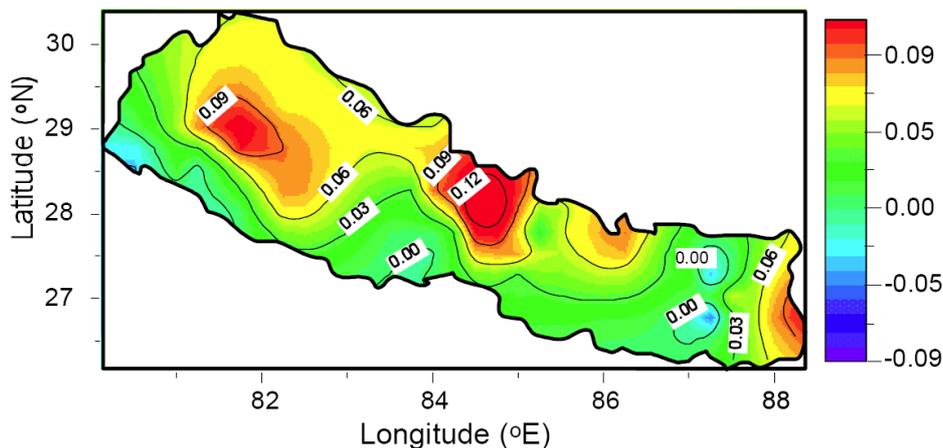


Figure 1 – Decadal changes in mean annual temperature for Nepal: 1977-94 (WWF, 2005).

### Precipitation

Observed changes in precipitation in Nepal (both nationally and regionally) over the second half of the 20<sup>th</sup> century (1959-1994) show a large amount of interannual and decadal variability, but no overall trend (Shrestha *et al.*, 2000). While an overall increasing trend would be expected for the most recent decades (in response to higher global temperatures), it is likely that this driver is countered by higher concentrations of atmospheric sulphate aerosols from fossil fuel emissions in Asia (ibid). Increases in atmospheric sulphate aerosols cause a reduction in the amount of solar radiation reaching the Indian Ocean and therefore a reduction in evaporation from the ocean surface (Ramanathan *et al.*, 2005). The result is less moisture in the atmosphere to drive the summer monsoon rains (ibid).

The variability that has been noted correlates well with the El Niño-Southern Oscillation (ENSO); warm ENSO events (El Niño) tend to be associated with a reduction in summer monsoon strength, while cold ENSO events (La Niña) are associated with increases in the monsoon (ibid). However, the driest year of the latter half of the last century (1992) is linked to the aftermath of the eruption of Mount Pinatubo (in 1991) rather than a warm ENSO event in 1992 (ibid; Meehl, 1994).

In recent years there has been a noted delay in the onset of the monsoon (DIFD, undated). While rainfall totals have remained consistent, the time period over which the monsoon falls is reduced, thus in these instances the intensity of the monsoon is higher.

## Current Climate Vulnerability

Table 1 shows the environmental hazards that have affected Nepal most in the past 20 years. Flood events, landslides and disease outbreaks have been a particular threat for Nepal over this period, causing the most severe loss of life. Such hazards are a threat across the country; for example, the Terai is particularly at risk of flooding during the monsoon, while the Himal is under threat from flooding from glacier lake outbursts.

Hazard	Number of Events	Deaths	Total of Population Affected
Drought	1	-	200,000
<i>Average per event</i>		-	200,000
Earthquake	1	-	285
<i>Average per event</i>		-	285
Epidemic (unspecified)	3	685	50,242
<i>Average per event</i>		228	16,747
Epidemic (bacterial)	2	1,648	104,215
<i>Average per event</i>		824	52,108
Epidemic (viral)	9	995	4,669
<i>Average per event</i>		111	519
Extreme Cold	3	126	200
<i>Average per event</i>		42	67
Flood (unspecified)	3	455	120,552
<i>Average per event</i>		152	40,184
Flood (flash)	2	1,816	704,650
<i>Average per event</i>		908	352,325
Flood (general)	14	1,292	1,988,673
<i>Average per event</i>		93	142,048
Avalanche	1	95	-
<i>Average per event</i>		95	-
Landslide	8	916	367,618
<i>Average per event</i>		115	45,952
Storm (unspecified)	2	26	184
<i>Average per event</i>		13	92
Forest Fire	2	88	54,000
<i>Average per event</i>		44	27,000

Table 1 – Natural Hazards in Nepal (1991-2010) (CREG, 2010)

Nepal is already experiencing the impacts of a changing climate. For a country with over 85 percent of the population relying on agriculture, even small changes have substantial impacts on farming practices. Perhaps the most notable change is the late arrival of the monsoon rains. The monsoon traditionally begins around the middle of June, but in recent years the monsoon season has been seen to start later– even into mid-August. The result is that the growing season is shorter and local varieties of rice lack sufficient time to mature. Many farmers have therefore been forced to switch to hybrid varieties, for which they have to buy the seeds each year. Crop types have also changed, with some farmers changing to grow vegetables rather than wheat or maize. However, this option is only available where a farming community is sufficiently close to market to sell the produce, and where farmers have access to the knowledge and technical services needed to diversify.

In addition to the late arrival of the monsoon rains in the summer, some farmers in Nepal have also experienced the failure of winter rains in the past 5 years. Though the winter rainfall is substantially less than the monsoon, it is nevertheless important for both agriculture and as a resource of drinking water.

## Climate Change Projections<sup>2</sup>

The climate change projections presented here use a grid for which only a few cells encompass Nepal; as noted earlier, using a grid of rather coarse resolution can mask some more extreme local changes. Therefore,

<sup>2</sup> McSweeney, C. *et al.* (2008) unless otherwise stated

this should be taken into account when interpreting results. Projections are presented with reference to four seasons of 3-month duration each: March-April-May (MAM), June-July-August (JJA), September-October-November (SON) and December-January-February (DJF).

## Temperature

- Central estimates of mean annual temperature show increases of between 2.0 and 2.9°C by the 2060s, and of 2.6 to 4.8°C by the 2090s (see Figure 2). Maximum increases in mean temperature are projected to be 3.8°C and 5.8°C for the 2060s and 2090s respectively.
- The projected rate of warming is most rapid in DJF and MAM.
- All projections indicate increases in the frequency of days and nights that are considered hot<sup>3</sup> in current climate.
- Annually, projections indicate that both hot days and hot nights will occur on up to 28 percent of days by the 2060s, and up to 39 percent of days by the 2090s. The most rapid increases are projected for DJF and JJA (see Figure 3 for DJF example).
- All projections indicate decreases in the frequency of cold<sup>4</sup> days and nights. In some projections, cold days and nights do not occur at all by the 2090s for much of the country.

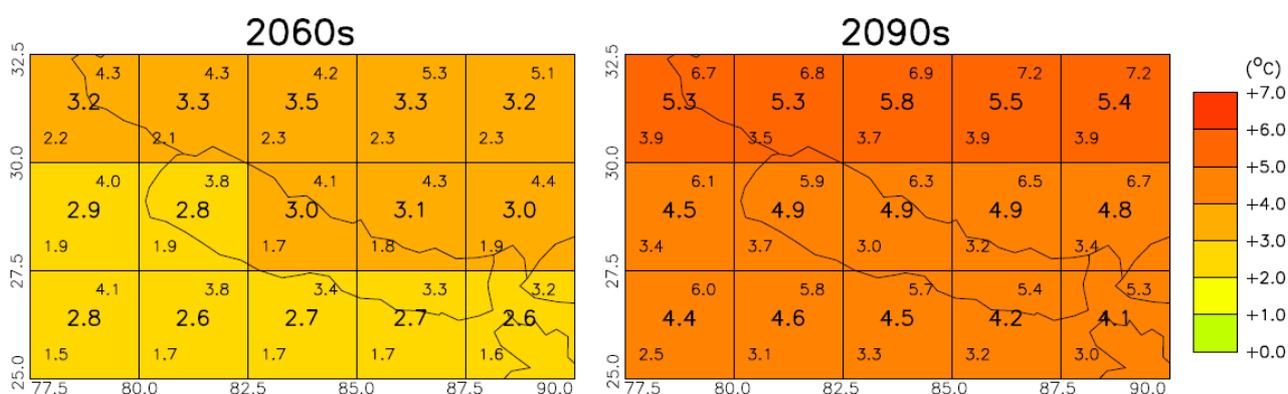


Figure 2 – Projections of mean annual temperature for Nepal for the 2060s and 2090s (the central value in each grid box gives the central estimate of the model projections, and the values in the upper and lower corners give the maximum and minimum respectively) (McSweeney *et al.*, 2008). See 'A note on the projections' at the end of this document for more information on these maps.

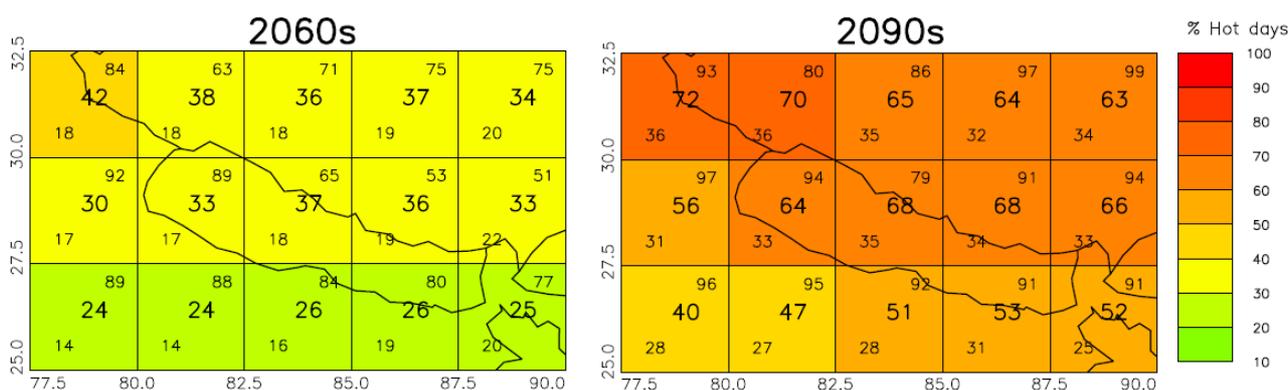


Figure 3 – Projections of percentage changes in frequency of 'hot' days in the DJF season for Nepal for the 2060s and 2090s (see Figure 2 for details) (McSweeney *et al.*, 2008).

## Precipitation

- Projections for mean annual rainfall broadly indicate increases in rainfall for Nepal as a whole. Central estimates show increases of between 1 and 17 percent by the 2090s, but the upper end of the

<sup>3</sup> 'Hot' day or 'hot' night is defined by the temperature exceeded on 10% of days or nights in current climate of that region and season.

<sup>4</sup> 'Cold' days or 'cold' nights are defined as the temperature below which 10% of days or nights are recorded in current climate of that region or season.

projections show this increase could be as much as 58 percent, equivalent to an increase of 59mm per month annually.

- Seasonal changes in rainfall are more substantial, with projections indicating increases during the monsoon (JJA and SON) and decreases in winter rainfall (DJF).
- Rainfall for JJA and SON is projected to increase by 5 to 11 percent and 2 to 6 percent respectively for the 2060s, and by 10 to 21 percent and 5 to 16 percent for the 2090s. The increases in JJA rainfall are largest in the southeast (see Figure 4).
- The upper end of the projections (i.e. maximum) show much larger changes, with increases of 61 and 104 percent for the 2060s and 2090s respectively for summer rainfall (JJA), equivalent to increases of 132mm and 224mm per month respectively.
- Reductions are projected for winter (DJF) rainfall; with decreases of up to 34 percent by the 2060s, and 63 percent by the 2090s. These decreases are particularly serious for the northwest, which rely heavily on winter rainfall (see Figure 5).
- The proportion of total rainfall that falls in heavy<sup>5</sup> events is projected to increase, particularly in JJA and SON (see Figure 6), with decreases in DJF.
- Projections indicate that maximum 1- and 5-day rainfall totals are expected to increase, and that these increases may be dramatic – up to twice what they are currently for 5-day maxima, for example. These increases are most prominent in JJA and SON.
- Recent research also suggests that warmer temperatures may cause an eastward shift in the monsoon circulation, causing both a delay of its arrival, and even a decrease in rainfall totals (Ashfaq *et al.*, 2009). For Nepal, projected changes in local rainfall are indeed uncertain.

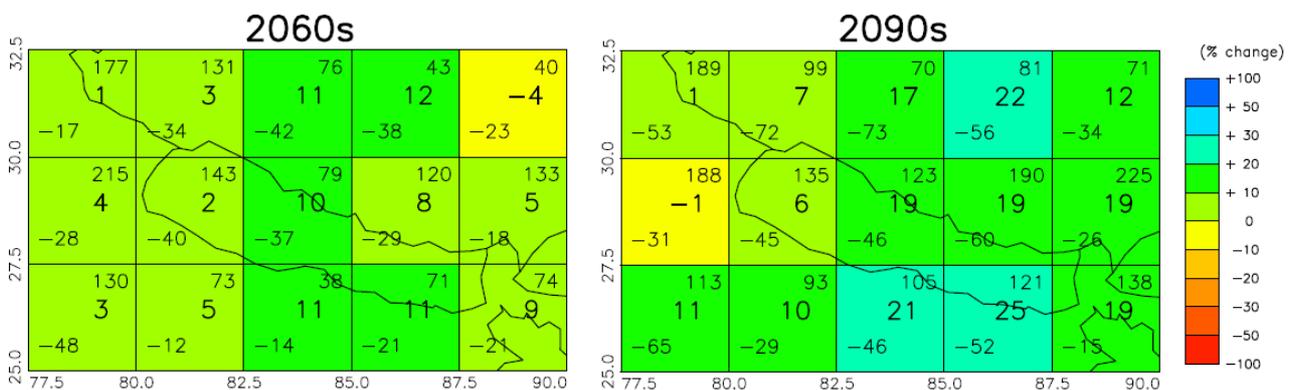


Figure 4 – Projections of percentage changes in rainfall for the JJA season for Nepal for the 2060s and 2090s (see Figure 2 for details) (McSweeney *et al.*, 2008).

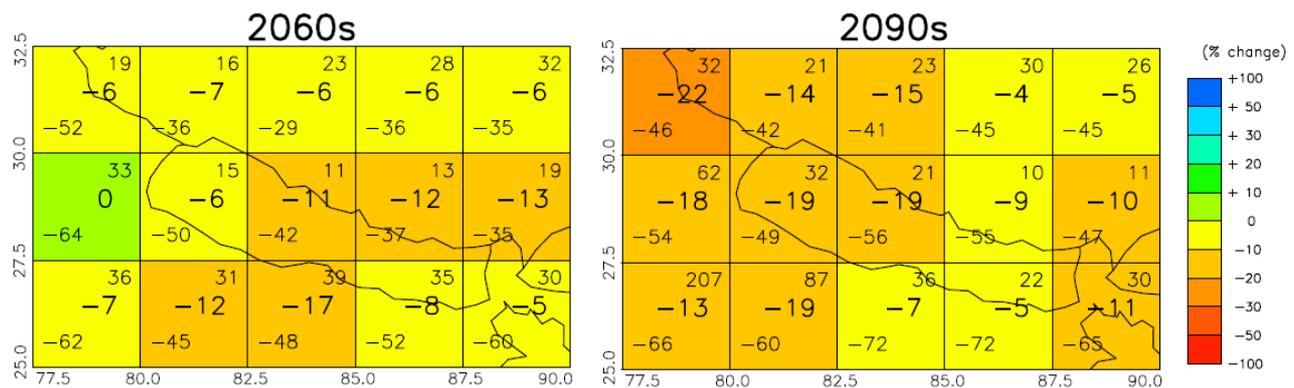


Figure 5 – Projections of percentage changes in rainfall for the DJF season for Nepal for the 2060s and 2090s (see Figure 2 for details) (McSweeney *et al.*, 2008).

<sup>5</sup> A 'Heavy' event is defined as a daily rainfall total which exceeds the threshold of the top 5% of rainy days in current the climate of that region and season.

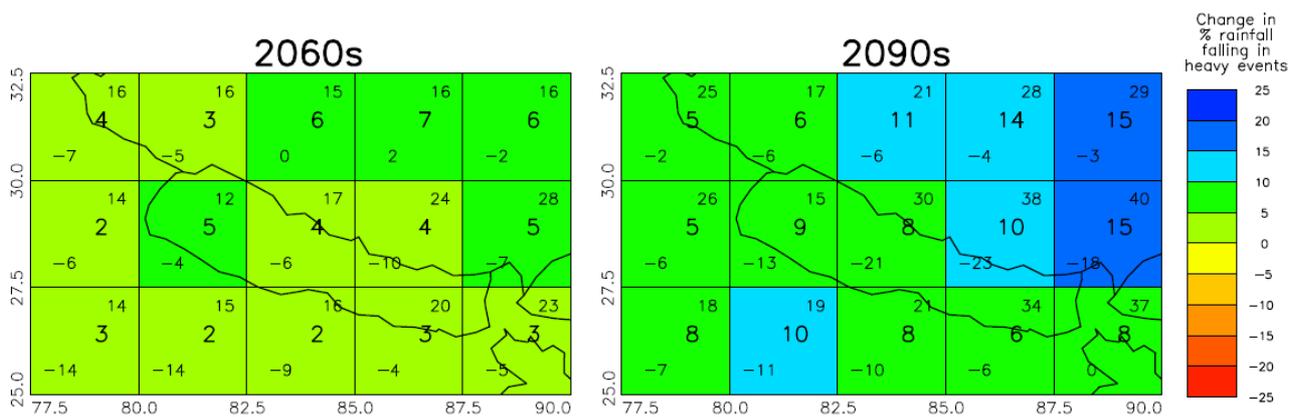


Figure 6 – Projections of percentage changes in the amount of rainfall falling in 'heavy' events during the JJA season for Nepal for the 2060s and 2090s (see Figure 2 for details) (McSweeney *et al.*, 2008).

## Climate Change Impacts

### Flooding

Flooding and associated landslides are a major threat for Nepal, and with increasing rainfall totals and intensity projected for the whole country, the risk of flood events is likely to increase.

Nepal is also at risk from melting glacier and snow pack from the Himalayas. Rising temperatures will accelerate this melting, adding to the water accumulating in the 3,252 glaciers and 2,323 lakes at or above 3,500 metres above sea level in Nepal (Mool *et al.*, 2001). Of these lakes, 20 have been found to be at high risk of glacier lake outburst (*ibid*). Higher run-off will also increase river flows in the short-term, adding to the risk of flooding events.

### Water Resources

Nepal has relatively large resource of water, with over 6,000 rivers – of which the large ones are fed by snowmelt from the Himalayas and are perennial (UNEP, 2001). Though Nepal theoretically has sufficient surface water resources for the whole country, this is dependent of sufficient water storage from wet season to dry. In the short-to-medium term, run-off from snowmelt will increase with rising temperatures, resulting in an initial increase in river flow and water resource. However, towards the end of the century the depletion of glaciers and snowpack will have a knock-on effect on run-off and water availability.

Projections for Nepal's rainfall show an increasing trend, yet rainfall is likely to fall in increasing heavy events, which is only beneficial for water resource if storage is available. Increasing temperature will cause an increase in evapotranspiration, which will offset increases in rainfall. Reduced winter snowfall and retreating glaciers will also reduce the water available to feed river systems originating in the Himal.

### Agriculture & Food Security

The Nepalese rely heavily on rain-fed agriculture for subsistence (around 80 percent of the population) and climate change is likely to cause further food insecurity than currently experienced (GoN, 2004). Drought in Nepal has implications for agriculture, food prices and food security. The drought in 2009, for example, caused food insecurity for around 2.5 million people, with the World Food Agency (WFA) stating that a further 3.9 million would be at risk if the situation worsened (IRIN, 2009). In that same drought, thousands of people from the western regions of Jajarkot, Humla, Rukum, Bajura, Gorkha, Mugu and Darchula were forced onto the road to walk in search of food (Parajuli, 2009). Food insecurity also fuels the annual seasonal migration of many people to India, SE Asia and the Gulf States in order to meet their families' basic needs.

Soil productivity will also be at increasing risk from the loss of fertile topsoil from soil erosion caused by extreme rainfall, flooding and landslides (WWF, 2005).

### Public Health

Nepal is endemic for malaria, Japanese encephalitis (JE) and a form of leishmaniasis (known as kala-azar), all of which are affected by climate. As temperatures increase, the range for breeding mosquitoes (the vector for malaria and JE) will extend to higher latitudes, putting a greater number of the population at risk. Furthermore, these risk areas will suffer a higher level of morbidity and mortality from the disease as the newly exposed population has a lower natural immunity. With a greater number of heavy rainfall events

and associated formation of standing water, the endemic areas for malaria and JE are likely to experience an increase in mosquito abundance. The result of this is likely to be a greater number of outbreaks across the country.

Additionally, increasing mean temperatures invoke changes in the life-cycle of vectors such as mosquitoes and sand flies (which spread Leishmaniasis) and the bacteria that they carry, which could potentially cause an increase transmission (McMichael et al., 2003).

Drought and flooding can both be a factor in disease outbreaks, and an increase in the number and severity of flood events will likely also increase the incidence of water-borne disease such as cholera, dysentery and typhoid. Drought is common in Western regions, such as in August 2009, which led to an outbreak of dysentery that killed 321 people (Parajuli, 2009). More erratic rainfall may leave many more susceptible to periods of drought.

The arrival of the monsoon is also important for bringing cooler temperatures and some rest bite from the hot, humid conditions in the Terai basin. Therefore, with a later start to the monsoon, there is an increased risk of death from heatwaves in the lowlands areas.

## Housing & Communities

As the risk of flooding in Nepal increases, so does the threat to houses and community buildings. Flooding and associated landslides in October 2009, for example, saw over 20,000 houses lost or damaged (ReliefWeb, 2009).

## Biodiversity & Conservation

Despite its small size, Nepal is home to a disproportionate amount of important and diverse flora and fauna, spread between the dense tropical monsoon forests of the Terai, the deciduous and coniferous forests of the country's subtropical and temperate regions, and in the sub-alpine and alpine pastures and snow-covered Himalayan peaks (Bhujju *et al.*, 2007). 29 percent of Nepal is forested, though this is declining through land use change. This will be further affected by climate change as tropical and temperate rainforests disappear and are replaced by cooler, temperate vegetation, thus losing substantial diversity in habitat (GoN, 2004).

## Livelihoods

Nepal has relatively few natural resources, and the economy relies strongly on agriculture, forests and tourism. Agriculture accounts for around 40 percent of GDP, and associated industries process raw materials such as sugarcane, tobacco, jute and grain (GoN, 2004). Climate change is likely to increase the risk to crop yields of these key commodities.

## Energy

Nepal's energy sources are predominantly from hydropower (around 90 percent (DFID, undated)). Supply of electricity is fragmented and Kathmandu often experiences blackouts and load shedding. Nepal is exploiting less than one percent of its 83,000 megawatts of hydropower capacity (UNEP, 2001) and there is sufficient potential even without additional snowmelt and rainfall brought about by climate change. There may be an increase in the risk of damage from flooding and landslides to hydropower installations, as well as causing irregularities to the streamflow.

## Transport

Nepal's internal transport links are poor, and this can affect the speed and efficacy of aid. The road network in western regions is particularly bad and often not navigable. With increasing heavy rainfall events, glacier melt and associated flood risk, roads and other transport networks in Nepal will be at increasing risk from flood damage. This will inhibit economic growth, transportation of food, and the ability of aid to reach remote areas.

## Government Response

Nepal has prepared an Initial National Communication to the Conference of the Parties of the United Nations Framework Convention on Climate Change (UNFCCC), but is still to publish a National Adaptation Plan of Action (NAPA).

During the UNFCCC Copenhagen negotiations in December 2009, the government held a special Cabinet meeting at Everest Base Camp to highlight the dangers of climate change to the Himalayas. At the meeting the ministers endorsed the 'Sagarmatha Declaration' ('Everest Declaration'), which outlined the risks posed to the Himalayas and pledged the government's commitment to tackle the problem.

## Likely Adaptation Options

The following are a selection of adaptation options identified in Nepal's National Communication as suggested areas for further research and development (GoN, 2004):

- Develop drought tolerant crop varieties and study the use of traditional varieties.
- Research into the role of agro-silvicultural systems in Nepal, which are regarded as carbon dioxide sinks and sources of GHG emissions.
- Research into the effect of different traditional cultural practices such as green manuring, continuous cropping with fertilizer, multiple cropping and modified alley-farming.
- Identify agro-ecological zones particularly sensitive to climate change impacts and potential vulnerable areas. Provide advice on the implications for farmers in those areas.
- Research into the effect of climate change impact on weed, pest and disease occurrence of cultivated crops and develop forecasting systems.
- Conduct research and development of appropriate protocols for community forest management for agroforestry type projects.
- Develop a database of biomass for different types of vegetation in Nepal. Data can be derived from direct measurements of biomass representing the main vegetation types in the country.
- Develop appropriate guidelines for sustainable management of water sheds and aquatic ecosystem.
- Conduct studies on epidemiological forecasting and early-warning systems using remote sensing and/or geographical information systems technology applicable in high-risk areas for Malaria, Japanese Encephalitis, diarrhoeal disease and nutritional disorders.

## Useful Websites

- UNDP Climate Change Country Profiles: <http://country-profiles.geog.ox.ac.uk/>
- UNFCCC NAPAs from Non-Annex I Countries: [http://unfccc.int/national\\_reports/napa/items/2719.php](http://unfccc.int/national_reports/napa/items/2719.php)
- UNFCCC First Communications on Climate Change for Non-Annex I Countries: [http://unfccc.int/national\\_reports/non-annex\\_i\\_natcom/items/2979.php](http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.php)
- Adaptation Learning Mechanism: <http://www.adaptationlearning.net/>
- IPCC Reports: [http://www.ipcc.ch/publications\\_and\\_data/publications\\_and\\_data\\_reports.htm](http://www.ipcc.ch/publications_and_data/publications_and_data_reports.htm)

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## A note on the projections...

The climate change projections used in this profile were developed as part of a UNDP project, carried out by McSweeney *et al.* (2008), to produce a series of climate change projections for individual developing countries. The study uses a collection, or 'ensemble', of 15 General Circulation Model (GCM) runs to produce projections of climate change for three of the SRES emissions scenarios (see Nakićenović & Swart (2000) for more details on emission scenarios). The three emissions scenarios used in the study were 'A2', 'A1B' and 'B1', which can be broadly described as 'High', 'Medium' and 'Low' respectively (McSweeney *et al.*, 2010).

The figures quoted here refer to the 'central estimates' (i.e. the median results) from the 15 GCMs across the 3 emissions scenarios. Where maximum figures are also quoted, they refer to the 'High' (A2) scenario model results. The maps shown are for just the 'High' scenario. Both figures and maps are described for two future 'timeslices' – i.e. decadal averages for the 2060s and 2090s.

For a more detailed description of the UNDP Climate Change Country Profiles, please see McSweeney *et al.* (2010). Complete projections (with maps, plots, supporting text and data files) for all 52 countries are available to download via the website at <http://country-profiles.geog.ox.ac.uk/>.

*Note: This profile is designed to give a brief, non-technical overview of the current and future climatic conditions of Nepal. The key climate impacts are summarised by sector; however, this should not be taken as an exhaustive list, and the corresponding list of adaptation options are as a guide of likely or possible strategies.*



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