# 5 Responses to Climate Change

## Stakeholder Perceptions of Climate Change

The questionnaire surveys carried out in the North East states of India and Bhutan as part of this assessment came up with some enriching insights into what ordianry people perceive as climate change and the perceived impacts on their livelihoods and livelihood strategies. Although perceptions were varied depending on place, ethnicity, culture, and socioeconomic background, there was a clear idea among participants of the atypical changes in the environment. Most of the participants immediately talked about changes in weather patterns, shortages of water for irrigation and household use, increasing uncertainty in rainfall, and the emergence of new, and increase in the incidence of existing, pests and diseases in humans, animals, and plants. Such changes are evidenced by cases like the soya bean failure in Manipur due to excessive rain in the 2004/05 growing season; the decline in the number of indigenous fish with the introduction of brown trout in Bhutan; wild mushrooms growing in unexpected places; and increasing incidence of wild forest fires. On the positive side, there are reports of more areas becoming suitable for the cultivation of staple cereals, increases in the productivity of oranges in Helipong village in Tuensang, and improvements in apple quality in Bhutan in places where previously low temperatures in late summer cut short the fruit development stage. People are mostly concerned about the adverse changes that may disrupt the flow of ecosystem services that sustain rural communities ensuring food security, curing illness, and providing cash income and spiritual comfort by being at peace with nature.

Many communities have adapted and continue to adapt to environmental changes. In food production, they maintain a portfolio of crop species and varieties to adjust the cropping pattern and crop calendar to the prevailing and anticipated changes in the growing environment. In extreme cases, people migrate to more benign environments and reconnect with new sets of ecosystem services.

Awareness of climate change is fairly high in terms of relating natural hazards to perturbations in the environment as a result of anthropogenic interventions and disturbances linked to the indiscriminate use of natural resources. The participants' understanding of the adaptation and mitigation aspects of dealing with such environmental threats is, at best, tenuous as their experiences with problem resolution are not always limited to climate considerations. This was expected as coping mechanisms in terms of adjustments and interventions cannot be elucidated meaningfully from the climate change perspective alone, because most impacts we attribute to climate change are indeed consequences of several interacting stresses. People have always responded to changes in the environment and, in the process, have accumulated a vast amount of indigenous and appropriate knowledge and technologies for minimising adverse impacts while taking advantage of new opportunities.

Deductions from people's perceptions, however, are limited to a time scale within the range of human memory, while climate change impacts may become evident only after hundreds of years. In documenting people's perceptions, it is important to be mindful of the accuracy of the information that is provided and reasons why some information cannot be provided. Of course, perceptions are likely to be biased toward the response of agricultural crops or components of ecosystems that impinge on livelihoods or that are conspicuous enough to be considered. A verification means must be integrated into the information collection system. Perceptions are mostly associated with climate variability, rather than change.

Specific and relevant to the EH, a series of consultative workshops with stakeholders, partners, and government actors identified several impacts attributed partially or wholly to climate change based on informed perceptions and investigative research on aspects confined to or of relevance to the EH. Examples of the impacts of climate change are listed in Table 20, without taking into account any changes or developments in adaptive capacity or mitigation measures. The impacts listed are not exhaustive for the region, but merely restricted to the ecosystem resources and services within the scope of the project intervention.

Table 20: **Perceptions and projected impacts of climate change in the Eastern Himalayas identified in stakeholder consultations and case studies**

| Climate change stress | Change types | Perceptions and impacts |
|---|---|---|
| Higher Temperature | • Ecological shifts<br>• Biomass productivity<br>• Habitat alteration<br>• Forest fires<br>• Biodiversity<br>• Species composition<br>• Glacial retreat<br>• Human health<br>• Phenological changes | • Loss of agricultural productivity with shortening of growing season (maturity period)<br>• Success of $C_3$ plants under agriculture, forest, pastureland, rangeland, horticulture (vegetables) at higher elevations; increased productivity of 'Phumdis'/wetlands<br>• Loss and fragmentation of habitats<br>• Vertical species migration and extinction<br>• Decrease in fish species (in Koshi river)<br>• Reduced forest biodiversity<br>• Changes in ecotones and micro-environmental endemism<br>• Reduced availability of medicinal plants for traditional health systems<br>• Increase in vector-borne diseases (malaria, dengue)<br>• Formation and expansion of glacial lakes and wetlands at high altitude<br>• More liquid precipitation at higher altitude<br>• Peculiar tendencies in phenophases in terms of synchronisation and temporal variabilities |
| More precipitation | • Siltation<br>• Drainage<br>• Flooding<br>• Human health<br>• Fire incidence | • Decrease in controlled and prescribed burning under shifting cultivation and other forest use areas (North East India)<br>• Wetland degradation (Umiam Lake, Barapani in Meghalaya) (climate attribution is strongly contested)<br>• Degradation of riverine island ecosystems (Majuli) and associated aquatic biodiversity (refuted, but not overlooked)<br>• Widening of river basins (Brahmaputra breadth widened from 1.8km to 20km near Kamakhyaa Temple) eroding agricultural land<br>• Increase in water-borne diseases (kala-azar, cholera, diarrhoea)<br>• Riverbank erosion<br>• Flood-water related sedimentation<br>• Increase in landslides and landslide dam outburst floods<br>• Flood-water inundation (Dibrugarh and Dhubri)<br>• Shallow water table pollution |
| Less precipitation | • Snowfall<br>• Drying<br>• Drought | • Reduced, delayed, and unseasonal snowfall affecting winter crops<br>• Reduced forage availability resulting in change from dzo (yak/cattle cross) to horses as pack animals<br>• Loss or degradation of natural scenic beauty<br>• Drying up of water spouts and reduced flow in streams/springs (in Mizoram)<br>• Frequent incidences of dry spells and agricultural drought<br>• Lower humidity and less cloud at high altitudes<br>• Shift in rainfall arrival from March to April<br>• Increasing salinity from groundwater pumping |
| Higher temperature, more precipitation | • Biomass productivity<br>• Biodiversity<br>• Species composition<br>• Flooding | • Increased pest infestation and disease outbreaks<br>• Decline in orange yield (North East India)<br>• Increased agricultural productivity (in Helipong in Tuensang)<br>• Reduced agrobiodiversity<br>• Change in utility values of alpine and sub-alpine meadows<br>• Loss of species<br>• Seasonal/interannual change in flow patterns<br>• Soil erosion, especially topsoil<br>• More landslides<br>• Risk of snow avalanches<br>• High rate of siltation with increased sediment<br>• Increase in exotic, invasive, noxious weeds (mimosa in Kaziranga) |

| Climate change stress | Change types | Perceptions and impacts |
|---|---|---|
| Higher temperature and less precipitation | • Biomass productivity<br>• Forest fires<br>• Habitat alteration<br>• Invasion<br>• Biodiversity<br>• Drought<br>• Desertification<br>• Eutrophication | • Decline in snowfall period, depth, and persistence<br>• Decline in other resources (forage and fodder) leading to resource conflicts<br>• Successional shift from wetlands to terrestrial ecosystems and shrinkage of wetlands at low altitudes (Loktak Lake, Deepor Beel)<br>• Increase in forest fires (in Bhutan)<br>• Invasion by alien or introduced species with declining competency of extant and dominance by xeric species (e.g., Mikania, Eupatorium, Lantana)<br>• Increased crop diversity and changes in cropping patterns<br>• Drying and desertification of alpine zones<br>• Increased flow in summer/decreased flow in winter<br>• Change in land use patterns<br>• Soil fertility degradation<br>• Increased evapotranspiration and reduced moisture content<br>• Less infiltration affecting groundwater recharge<br>• Decrease in river discharge<br>• Nutrients in the floodplains increase productivity |
| Higher temperature and more or less precipitation with more extremes and hazards | • Human health<br>• Food security<br>• Livelihood<br>• Socioeconomic upheaval | • High species mortality<br>• Human migration due to extreme hydrological events and seasonal displacement<br>• Increase in instances of cloudburst<br>• Risk to hydropower plants, irrigation infrastructures, drainage systems, and municipal and industrial water supplies<br>• Unpredictable water availability, environmental pollution (acidic rain in Manipur), and decline in water quality and quantity<br>• Unpredictable rain with impacts on harvesting and cropping patterns<br>• Increased GLOF potential<br>• Erratic season transitions<br>• Rural-to-urban and male out-migration<br>• Labour shortages for agriculture<br>• Reduced livelihood options<br>• Heavy loss of life and property |
| Elevated GHG concentration ($CO_2$) | • NDVI<br>• Methane emission<br>• $CO_2$ source | • More growth/biomass production in forests, variable productivity in agriculture (oranges)<br>• Net methane emission from wetlands (Thoubal, Vishnupur)<br>• Increased degradation and destruction of peatland (bog, marshland, swamps, bayous)<br>• Land use change that increases soil degradation |

## Vulnerability of Biodiversity to Climatic Threats

A detailed assessment was carried out to explore the vulnerability of mountain ecosystems to climate by investigating their exposure level to climate variability and potential change in the immediate future, the sensitivity of the components of mountain ecosystems, and the adaptive capacity of the coupled human-environment system. Some of the highlights of the research process, results, and conclusions drawn from the study are presented here.

### Concepts of vulnerability

Reviews of the interpretations of 'vulnerability' in climate change research have generally identified two different vulnerability concepts. O'Brien et al. (2004a) made a distinction between an 'end-point' (top-down) and a 'starting-point' (bottom-up) interpretation of vulnerability. Vulnerability according to the end-point interpretation represents the net impacts of climate change taking into account feasible adaptations. This positivist concept is most relevant for the development of mitigation policies and for the prioritisation of international assistance. The Assessments of Impacts and Adaptations to Climate Change (AIACC) studies investigated vulnerabilities to climate impacts of a variety of natural resources, including ecosystems and biodiversity, and identified nine key messages for adaptation: (i) adapt now, (ii) create conditions to enable adaptation, (iii) integrate adaptation with development, (iv) increase awareness and knowledge, (v) strengthen institutions, (vi) protect natural resources, (vii) provide financial assistance, (viii) involve those at risk, and (ix) use place specific strategies (AIACC 2007).

Vulnerability according to the starting-point interpretation takes a different approach using modelling and scenario analysis to investigate climate change impacts. This interpretation assumes that addressing vulnerability to current climate variability will also reduce vulnerability to future climate change. This approach incorporates human and economic dimensions of local communities, particularly livelihood aspects and inter-sectoral relationships. Climate drivers are treated as important, but with a weaker attribution to future climate change; while drivers related to demographic, social, economic, and governance processes are given sufficient attention. This interpretation is largely consistent with the social constructivist framework and primarily addresses the needs of adaptation policy. An example of this approach is the UNFCCC's National Adaptation Programmes of Action (NAPAs) for Least Developed Countries (LDCs) to prioritise their urgent adaptation needs. The NAPAs examine vulnerabilities to current climate variations and extremes, building upon existing coping strategies at the grassroots level, for insights into vulnerability to future climate change. The involvement of different stakeholders is an integral part of this assessment process to identify interventions that might reduce vulnerability most effectively.

### Information requirements

Assessing the impacts of and vulnerability to climate change and identifying adaptation needs requires good quality information. This information includes climate data, such as temperature, rainfall, and the frequency of extreme events, and non-climatic data, such as the current situation on the ground for different sectors including water resources, climatic hazards, agriculture and food security, livelihoods and human health, terrestrial ecosystems, and biodiversity. Lack of reliable data has invariably been cited as a major constraint in developing any meaningful insight into climate change in the EH. In addition, limited, highly regulated, and sometimes no, access to existing data is frustrating efforts to improve the situation of data paucity. The situation is no less challenging for vulnerability assessment at the coupled human-ecosystem level, and especially when trying to separate the potential impact of climate change from a myriad of real and interacting stresses. Equally important, and very much lacking at present, is the need for accurate socioeconomic data. This data needs to come from across sectors and is an important complement to existing climate-only assessments, particularly given that poverty has been recognised as a major factor in vulnerability.

### Sources of vulnerability

It may be argued that the environmental vulnerability of the EH is an established reality, and further treatment of the issue is unwarranted. However, one cannot discount differentials in the degree of exposure, level of sensitivity, and adaptive capacity within the region, depending on the biophysical and geographic setting, accumulated social capital, and economic status. The region is also the focus of growing concern over biodiversity loss and ecosystem destruction, with all major causal drivers in unsettled flux from unprecedented socioeconomic change. There is an emerging consensus that the vulnerability of biodiversity in the mountain ecosystems reflects the vulnerability of coupled human-environment systems in the region to perturbations, stresses, and stressors. Mountain ecosystems are valued for their services (MEA 2003), which are quantifiable, making them obvious candidates as vulnerability indicators for sectors like human wellbeing, biodiversity, and water resources. The in depth inquiry into the current scientific understanding of vulnerability carried out for this report revealed subtle differences in what sets apart the two terms: 'biodiversity' and 'ecosystems.' For the purpose of this report, the treatment of biodiversity is limited to qualifying, and quantifying wherever possible, the structure, function, and services of ecosystems at different levels of aggregation. As a central element of sustainablility, biodiversity will be assessed as an inherent index of the natural vulnerability of mountain ecosystems.

Using this approach, poverty and biodiversity have emerged as sources of vulnerability, predicated on the synergy between human and biophysical subsystems of mountain ecosystems. Biodiversity is still valid as a measure of ecosystem resilience, and poverty metrics are still relevant for evaluating the autonomous and adaptive capacity of human systems. An attempt has been made to explore the biodiversity-poverty nexus in profiling the vulnerability of mountain ecosystems to the adverse impacts of climate change stresses. The following analytical framework gives an assessment of current vulnerability and its trajectory into plausible futures with climate change.

## Assessment framework and indicators

Vulnerability is a function of context and exposure, and therefore, cannot be generalised. Functional vulnerability, which includes natural resilience, is the baseline measure to be assessed in formulating and implementing external adaptations. For the purpose of this report, the IPCC concept was adopted in developing and applying a vulnerability assessment framework for the mountain ecosystems in the EH (Figure 17). Within this implementation framework, the impacts of climate change on natural and managed ecosystems were assessed, integrating feedback mechanisms within the human-ecosystem-climate continuum. Finally, practical measures of vulnerability were defined. Integrating information across these factors into a unified vulnerability indicator is one of the challenges this report attempts to address in the process of characterising vulnerability.

A variety of exposure, sensitivity, and adaptive capacity indicators were used in the assessment of current vulnerability in the EH. Baselines for ecosystems and biodiversity were fixed with GIS-implemented spatial datasets prepared by several organisations under various initiatives inventorying biophysical resources on global, regional, and national scales. The rationale for such baselines is the need to focus on existing conditions in order to assess the capacity to deal with the actuality or eventuality of potentially adverse impacts in the future. The indicators are organised around the sources of vulnerability identified for focused assessment under the project based on the state and evolution of ecosystem sectors – water resources, ecosystem biodiversity, and human wellbeing. Besides their functional relationship with the three dimensions of vulnerability as understood by the IPCC, ie., exposure, sensitivity, and adaptive capacity, the indicators can also be grouped into five different sources of vulnerability as shown in Table 21. The rationale for including these sources in a vulnerability index is outlined in the following paragraphs.

Figure 17: **IPCC framework for vulnerability assessment**

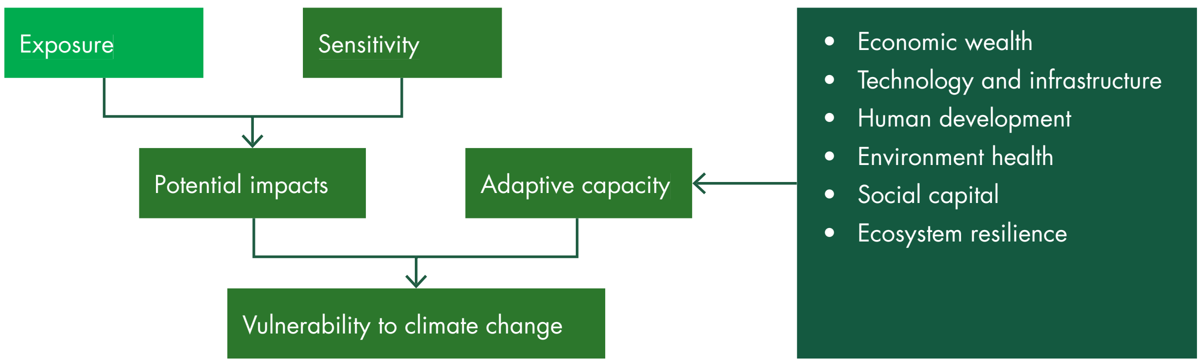



Table 21: **Sources and indicators of vulnerability**

| | Indicators of vulnerability grouped under the IPCC dimensions | | |
|---|---|---|---|
| **Source of vulnerability** | **Exposure** | **Sensitivity** | **Adaptive capacity** |
| Climatic | • Temperature mean and variance change<br>• Precipitation mean and variance change | | |
| Demography | | • Infant mortality rate<br>• % underweight children below age 5<br>• % urban population | • Population density<br>• Literacy rate |
| Food and water | | • Pop. with access to sanitation/safe drinking water<br>• Human appropriation of net primary prod. (NPP)<br>• % land managed<br>• Water use | • Cereal production/ area |
| Occupation | | | • Economic activity rate<br>• Dependency ratio |
| Environment | | • Human influence index<br>• Species under IUCN categories, VU, EN and CR<br>• Carbon storage<br>• Renewable water supply and inflow | • % tree cover |

Note: VU - vulnerable; EN = endangered; CR = critically endangered

Key biophysical vulnerabilities to climate change, variability, and extreme events vary widely across the region due to differences in physical, social, and economic circumstances. An attempt is made in this assessment to identify socioeconomic and environmental conditions that adversely affect the ability of human populations to adapt to climate change, climate variability, and extreme weather events, while focusing on mountain ecosystem sectors and components like biodiversity, water resources and hazards, wetlands, and human wellbeing (including livelihood and health). The National Communications to the UNFCCC and NAPAs of EH countries reveal that the key biophysical vulnerability contexts are livelihoods and food security, water resources, natural ecosystems and biodiversity, hazards and natural disasters, and human health.

Climate variability and change directly increase the vulnerability of people through flooding, drought, changes in average temperatures, temperature extremes, and extreme weather events. Variability in precipitation affects crop production directly, as well as through impacts on soil, pest and disease outbreaks, and other mechanisms. Trends and variance in temperature and precipitation based on historic data are crucial to vulnerability. Large seasonal and inter-annual variability heightens the vulnerability of an impact entity.

The demographic determinants of vulnerability are captured by five indicators: population density, urban population, literacy rate, infant mortality rate, and underweight children. Rates of mortality and underweight children depend on quality of life and are the most relatable metrics of human wellbeing embodying the combined influence of multiple factors. Literacy implies the quality of human capital and is significant in defining socioeconomic vulnerability. Population (number and density) is a reliable measure of vulnerability as well as adaptive capacity. A population that is literate is more likely to be resilient due to their ability to draw on alternative entitlements in the face of shock.

Food and water are part of livelihood security. Five indicators are identified to represent the food and water situation in the region, with four providing a holistic look at the sector sensitivity from an ecosystem services perspective and one as a measure of the adaptive capacity of the people to deal with food and water risks. These indicators are: cereal production; population with access to sanitation and safe drinking water; access to water for other uses; human appropriation of net primary production; and percentage of land managed. Cereal production captures the state of development in the agriculture sector and the access of farmers to production inputs. People's access to sanitation and drinking water, and water use situations shed light on human health standards and the state of water resources in terms of demand and supply. Human appropriation of net primary production presents a composite picture of food security, resource degradation, and population pressure in the ecosystems.

The composition of the labour force (occupational structure) reflects the social and economic resources available for adaptation. The two indicators used as proxies are the economic activity rate and the dependency ratio, which reflect labour productivity, risk level to natural hazards, and the social cost of dependencies. A highly productive labour force indicates high institutional strength and stable public infrastructure, and reduced social vulnerability. Hence, a stable and diverse occupational structure means that the labour force is utilised optimally. The absence of infrastructure services seriously increases vulnerability levels and reduces adaptive capacity.

Indicators of the vulnerability of the environment, ecosystems, and biodiversity are measured by the human influence index, which represents human-induced disturbances in ecosystems; the proportion of species listed as vulnerable (VU), endangered (EN), and critical (CR) as an indicator of the biodiversity vulnerability of an ecosystem; carbon storage and renewable water flows as regulating services with an inverse relationship to vulnerability; and the percentage of tree cover as an indicator of an ecosystem's natural adaptive capacity, assuming that less fragmented forests have higher resilience to external stresses.

The data required for the analysis were obtained from diverse sources and in a variety of formats, which were then transformed into spatial data layers for processing in a common GIS environment. Table 22 describes the data sources and format, and the indicators derived from them. Each indicator is dimensioned into component indices of comparable scale and further aggregated to construct the composit indices for the project focal areas of the mountain ecosystems. A higher index value represents higher vulnerability of the impact entity. The sectoral profiles of vulnerability to climate change were constructed under the assumption that the selected proxy indicators adequately describe the fundamental attributes of human ecology and the sociopolitical economy of the region, and that climate exerts a significant influence on their present state and transformation in the future. Finally, the composite indices of biodiversity, human wellbeing, water, and environment and ecosystem services were integrated into a vulnerability index of mountain ecosystems through clustering and principle component analysis.

Table 22: **Data used to describe indicators for producing indices of the three dimensions of vulnerability (exposure, sensitivity and adaptive capacity)**

| Dimensions of vulnerability | Indicator | Source | Unit | Format |
|---|---|---|---|---|
| **Exposure** | | | | |
| | Change in temperature | WorldClim | °C | Raster grid |
| | Change in precipitation | WorldClim | % of base | Raster grid |
| | Temperature and precipitation variability | WorldClim | % of base | Raster grid |
| **Sensitivity** | | | | |
| Biodiversity | IUCN threatened species richness | WildFinder database (WWF 2006a) | count | MS Access |
| | Human influence index | LWP-2 (WCS and CIESIN 2005) | | Raster grid |
| | Urban population fraction | Various national level population and census data | % of total population | Tabular |
| | Human appropriation of net primary production | HANPP (Imhoff et al. 2004; CIESIN 2004) | tons/km$^2$/year | Raster grid |
| Human wellbeing | Sanitation facilities | Diverse national socioeconomic data | % of total population | Tabular |
| | Safe drinking water | Diverse national socioeconomic data | % of total population | Tabular |
| | Infant mortality rate | CIESIN (2005) | deaths/10,000 live births | Ascii grid |
| | % underweight under age 5 | CIESIN (2005) | % of under 5 count of children | Ascii grid |
| Water systems | Annual precipitation | ATLAS data, IWMI | mm | Asci grid |
| | Annual evapotranspiration | ATLAS data, IWMI | mm | Asci grid |
| | Moisture availability index | ATLAS data, IWMI | | Asci grid |
| | Global map of irrigation area | Land and Water Digital Media Series 34 (Bruinsma 2003) | ha/grid cell | Ascii raster |
| | Global composite runoff | UNH-GRDC Composite Runoff Fields v1.0 (Fetke et al. 2000) | | Arcview grid |
| | Global weltands, lakes and reservoirs | GLWD Ver 3 (Lehner and Doll 2004) | coverage | Polygon feature |
| Ecosystems | Percentage tree cover | PAGE (Matthews et al. 2000), WRI | % | Raster grid |
| | Carbon store in soil and above- and below-ground live vegetation | PAGE (Matthews et al. 2000), WRI | t/hectare | Raster grid |
| | Area of managed land | Ecoregions Data (WWF 2006b) | km$^2$ | Excel sheet |
| **Adaptive capacity** | | | | |
| Economy | Cereal production/capita | From sub-national socioeconomic data | kg/capita | Excel sheet |
| | Economic activity rate | From sub-national socioeconomic data | % | Excel sheet |
| Human development | Literacy rate | From sub-national socioeconomic data | % | Excel sheet |
| | Dependency ratio | From sub-national socioeconomic data | % | Excel sheet |
| Environment | Population density | GPW Version 3-alpha (CIESIN/CIAT 2005) | person/km$^2$ | Ascii grid |
| | Percentage tree cover | PAGE (Matthews et al. 2000) | % | Raster grid |

Note: IWMI = International Water Management Institute, Sri Lanka

## Vulnerability in the EH

An overall depiction of vulnerability averaged across ecosystem elements uncovered large areas in the EH that would likely be impacted by adverse exposure to climate change stresses. Figure 18a shows the collective relative vulnerability integrated across components of mountain ecosystems and dimensions of susceptibility to climate change impacts. The most vulnerable areas are the whole stretch of the Brahmaputra valley, segments of the lower Gangetic plain falling within the EH, the Terai-Duar tract from Nepal to eastern Bhutan, and the vicinity of Loktat lake in Manipur. Population pressure and devastation of natural biodiversity are the main factors that make these places highly sensitive to climate change. Although agriculturally the most productive area in the region, the people suffer from low per capita human development assets, and from regular disturbances from natural hazards like floods and disease epidemics. Biodiversity is at enormous risk of being degraded further as resource extraction is intensified to cope with the threats to food security and in improvised strategies for relief and recovery following each disastrous event.

In these areas of high vulnerability, the resilience of ecosystems is stretched to the limits, and the adaptive capacity of the resident population is also being eroded in their daily struggle to break out of the poverty trap. These are also potential sites for carbon emissions, offsetting the gains in sequestration offered by the forests in the adjacent mountain areas. Besides intensive agriculture, this stretch of land is also the site of much of the industrial activity in the region, with dense urban settlements and various resource use infrastructure. it is overcrowded with roads. This accounts for the high human influence index associated with high energy consumption and intense disturbance to ecosystems. The carbon balance in terms of the human appropriation of net primary production is already negative in this part of the region.

The least vulnerable places are in Bhutan, the Zhongdian of China, the Chin and Kachin states of Myanmar, Mizoram, and pockets in Sikkim and Nepal. Low vulnerability scores in places could be largely attributed to the values assigned to human pressure, biodiversity, and forest cover. Factor weightings could have reduced the bias and improved the overall interpretation, but identifying reliable weights would add a whole new methodological dimension to this assessment. Nonetheless, weighting indicators could be considered for similar studies in the future. The spatial descriptions of these sectoral and system vulnerabilities are illustrated in Figure 18b.

From all the vulnerability analyses, one common aspect that stood out was the consistent projection of vulnerability for the Terai belt in south-east Nepal extending between the districts of Parsa and Jhapa. This might be considered a hotspot of vulnerability in the EH. There are several possible reasons for this outcome ranging from intense human pressure, low socioeconomic services, few productive livelihood assets, poor health and chronic disease outbreaks, land degradation, and deforestation, the impacts of which are further aggravated by extremes of weather and climatic variability including recurrent floods. Other important locations of vulnerability are the Brahmaputra valley, the lower Gangetic plain of North East India, and a few highly localised sites that may be a true manifestation resulting from the complex physiography and diversity in nature and society, or artifacts from raster data integration. Other factors that could predispose areas to vulnerability include the following:

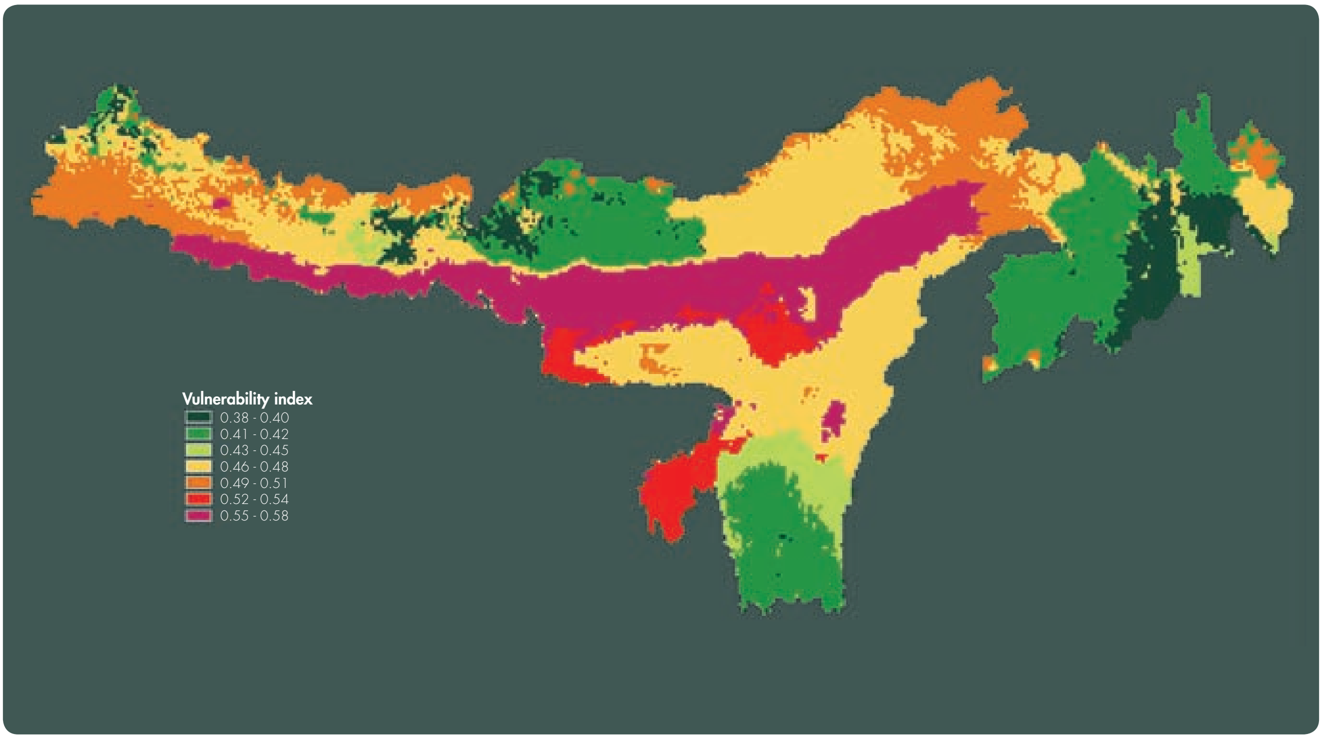
- Poverty and low human development, which make the poor intrinsically vulnerable because they have fewer resources with which to manage risks. There is a two-way interaction between climate-related vulnerability, poverty, and human development.
- Disparity in human development – inequality within countries is another marker for vulnerability to climate shocks. Gender inequalities intersect with climate risks and vulnerabilities. Women's historic disadvantages, such as their limited access to resources, restricted rights, and muted voice in shaping decisions, make them highly vulnerable to climate change.
- Lack of climate-defence infrastructure that could serve as a buffer between risk and vulnerability; for example, flood defence systems, water infrastructure, early warning systems, and so forth.
- Limited access to insurance against climate related losses. There is an inverse relationship between vulnerability, which is concentrated in poor areas, and insurance, which is concentrated in more affluent, urban places.

### Vulnerability of protected areas

An attempt was made to assess the vulnerability of the existing protected area network (PAs) under a changing climate by overlaying PAs onto the map of vulnerability (Figure 19) and ranking according to their degree of vulnerability (Annex 1). Ranks are based on the sum of the vulnerability metrics that each protected area system covers. The vulnerability characteristics are guidelines only and, in some cases, will require refinement in order to form the basis for a quantitative, or even qualitative,

Figure 18: **Relative magnitude and spatial characteristic of vulnerability to climate change impacts in the Eastern Himalayas**

a) Collective vulnerability, i.e., vulnerability integrated across different components of mountain ecosystems and dimensions of susceptibility to climate change impacts




b) Relative vulnerability of biodiversity, water, ecosystems, and human wellbeing to climate change impacts

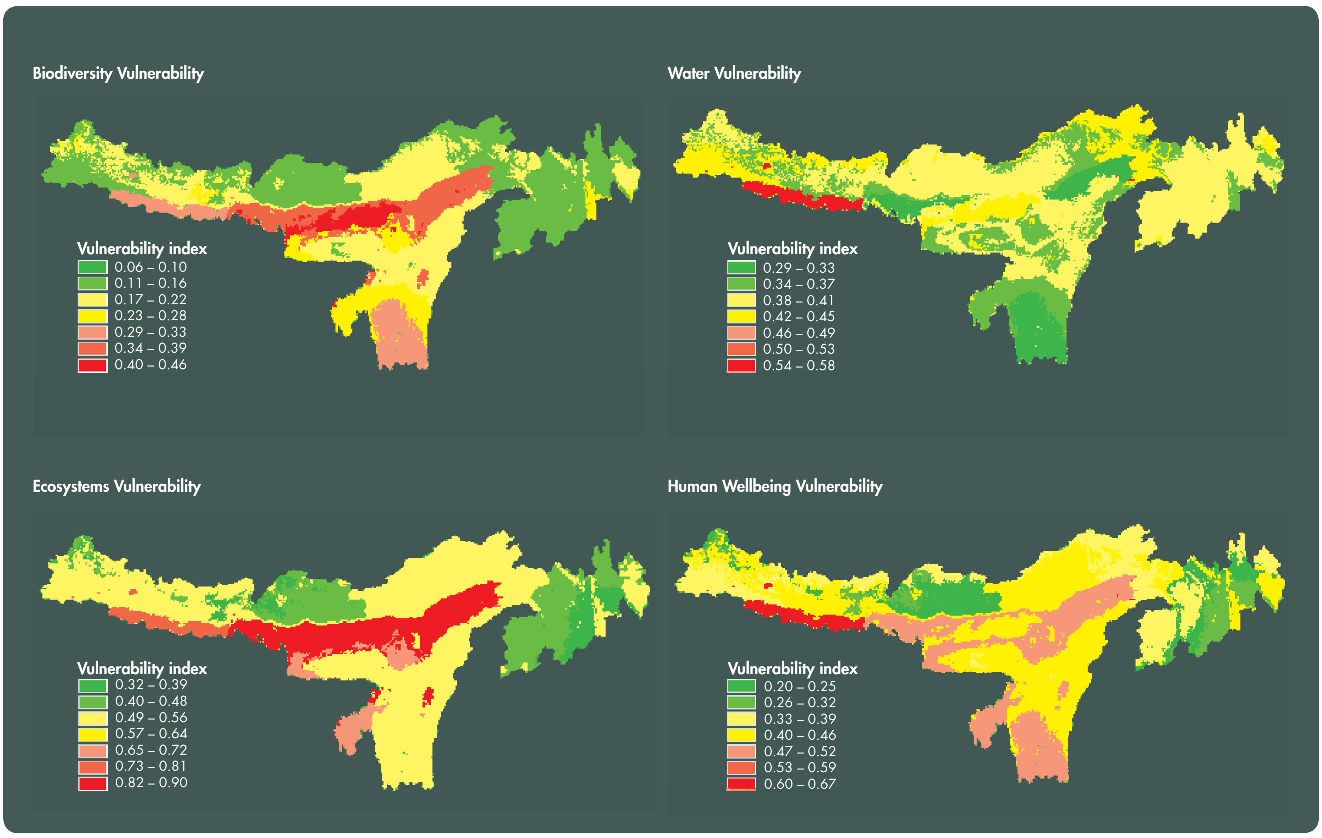
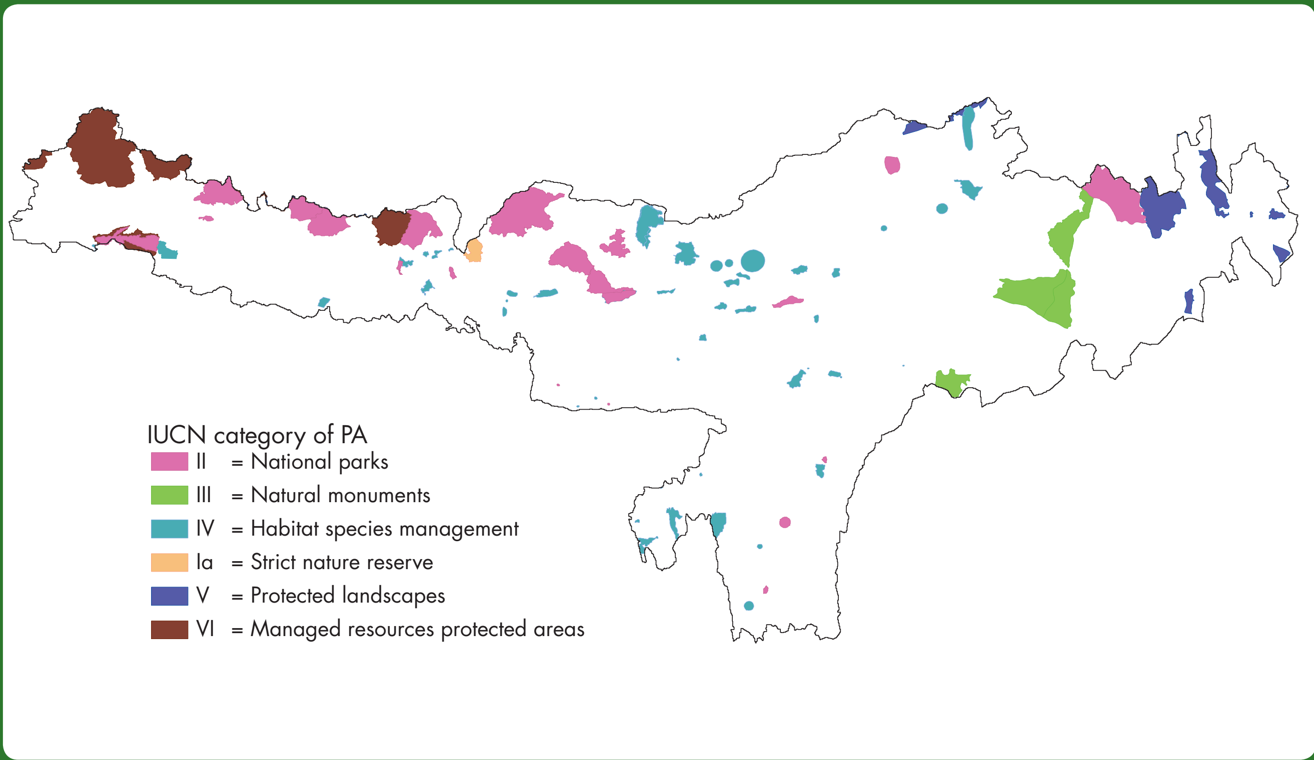
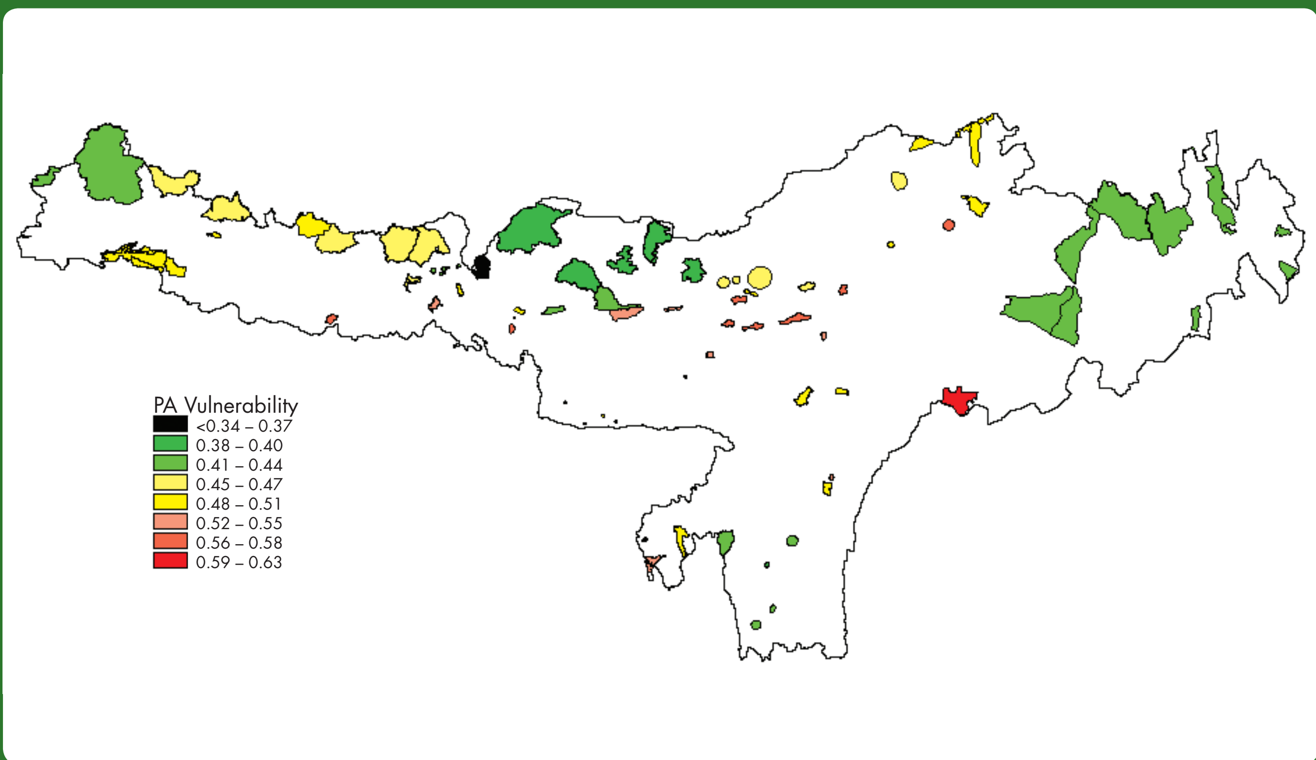


Figure 19: **Protected area (PA) coverage and vulnerability in the Eastern Himalayas**

**a) Protected areas**




**b) Vulnerability of protected areas**



ranking scheme. Some characteristics of protected areas that predispose them to climate change vulnerability have been summarised by Malcolm and Markham (1997) as follows:

- Presence of sensitive ecosystem types and species near the edges of their historical, geographically limited distributions
- Topographic and geomorphological feature like size and perimeter to area ratio
- Presence of natural communities that depend on one or a few key processes or species, isolation from other examples of component communities
- Human-induced fragmentation of populations and ecosystems, and other existing anthropogenic pressures within and close to borders

There are 91 protected area systems in the EH listed in the World Database on Protected Areas ranging from areas as small as 2 hectares (Baghmara Pitcher Plant Sanctuary) to as large as 3,400,000 hectares (Qomolangma Nature Preserve) (Figure 20a). They cover the full range of IUCN categories, but only one has been designated as a Strict Nature Reserve (Toorsa, Bhutan, Category Ia). Htamanthi Wildlife Sanctuary in Myanmar is assessed to be the most vulnerable, while other big national parks like Kaziranga, Manas, and Koshi Tappu Wildlife Reserve are potentially vulnerable to climate change (Figure 19b). These conservation areas and other smaller ones are considered to be vulnerable as they are located within the most vulnerable parts of the EH. Increasing pressure for land and other natural resources from a burgeoning population make these areas susceptible to habitat fragmentation and species extirpation through illegal poaching, hunting, and overexploitation. Furthermore, they are isolated islands of wild habitats with no prospect for habitat expansion or corridor links to extend range or for genetic enrichment. Many of them are too small to remain viable and withstand the pervasive effects of climate change. Three sites in India, one in Bangladesh, and three in China could not be ranked for their vulnerability, as the index could not be computed.

## Vulnerability of ecosystems

Mountains exhibit high biodiversity, often with sharp transitions in vegetation sequences, subsequently ascending into barren land, snow, and ice. In addition, mountain ecosystems are often endemic, because many species remain isolated at high elevations compared to lowland vegetation communities that can occupy climatic niches spread over wider latitudinal belts. The response of ecosystems in mountain regions will be most important at ecoclines (gradual ecosystem boundaries), or ecotones (where step-like changes in vegetation types occur). Guisan et al. (1995) noted that ecological changes at ecoclines or ecotones will be amplified because changes within adjacent ecosystems are juxtaposed. In steep and rugged topography, ecotones and ecoclines increase in quantity but decrease in area, and tend to become more fragmented as local site conditions determine the nature of individual ecosystems. McNeely (1990) suggested that the most vulnerable species at the interface between two ecosystems will be those that are genetically poorly adapted to rapid climate change. Those that reproduce slowly and disperse poorly and those that are isolated or highly specialised will, therefore, be highly sensitive to seemingly minor stresses.

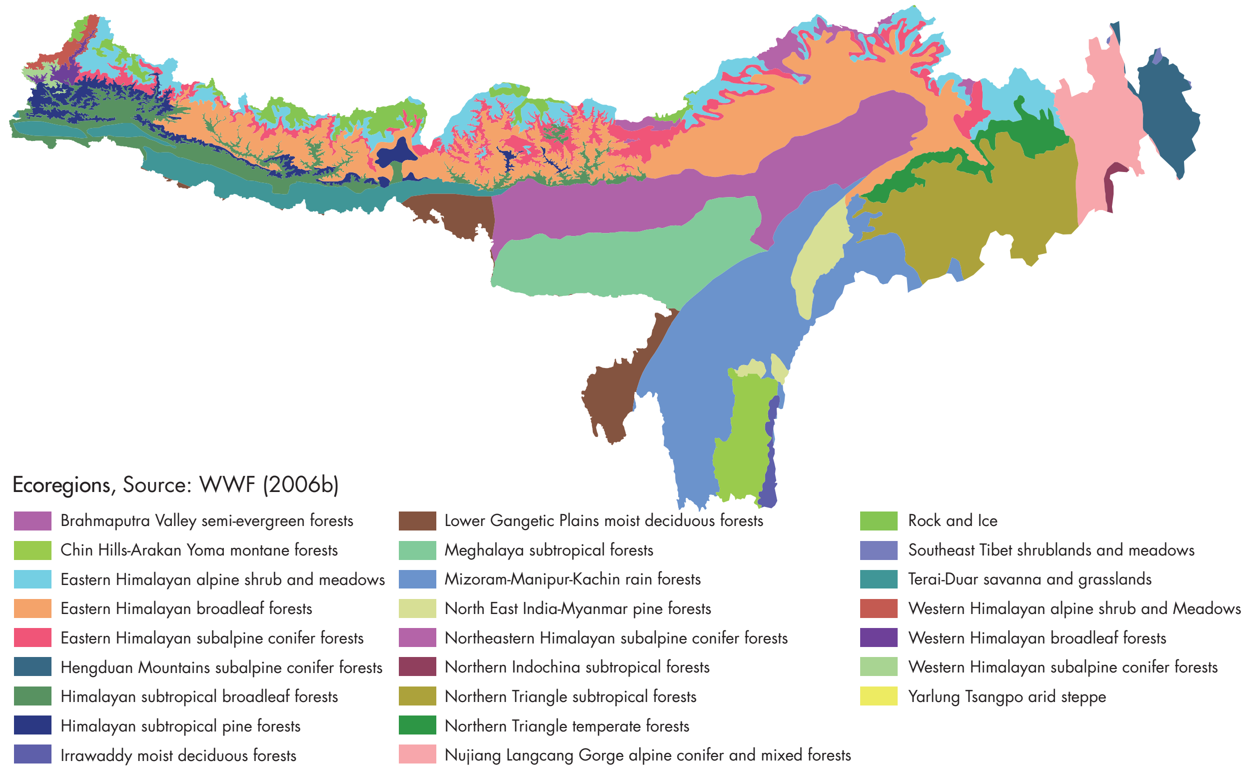
The Terrestrial Ecoregions of the World Version 2.0 (WWF 2004; Olson et al. 2001) map depicts 825 terrestrial ecoregions worldwide. Ecoregions are relatively large units of land containing distinct assemblages of natural communities and species, with boundaries that approximate the original extent of natural communities prior to major land use change. This comprehensive global map provides a useful framework and units for biological analysis and for conservation planning and action, like comparison among units and the identification of representative habitats and species assemblages, identification of areas of outstanding biodiversity and conservation priority, assessment of gaps in conservation efforts worldwide, and for communicating the global distribution of natural communities on Earth. These units are nested within two higher-order classifications: biomes (14) and biogeographic realms (8). Ecoregions have increasingly been adopted by research scientists, conservation organisations, and donors as a framework for analysing biodiversity patterns, assessing conservation priorities, and directing effort and support.

Using this map, we identified 25 ecoregions within 2 realms and 7 biomes in the EH as shown in Figure 20a. Six of these are entirely located in the region, while one ecoregional unit specific to the HKH region has less than 1% representation in the EH (the Yarlung Tsangpo arid steppe).

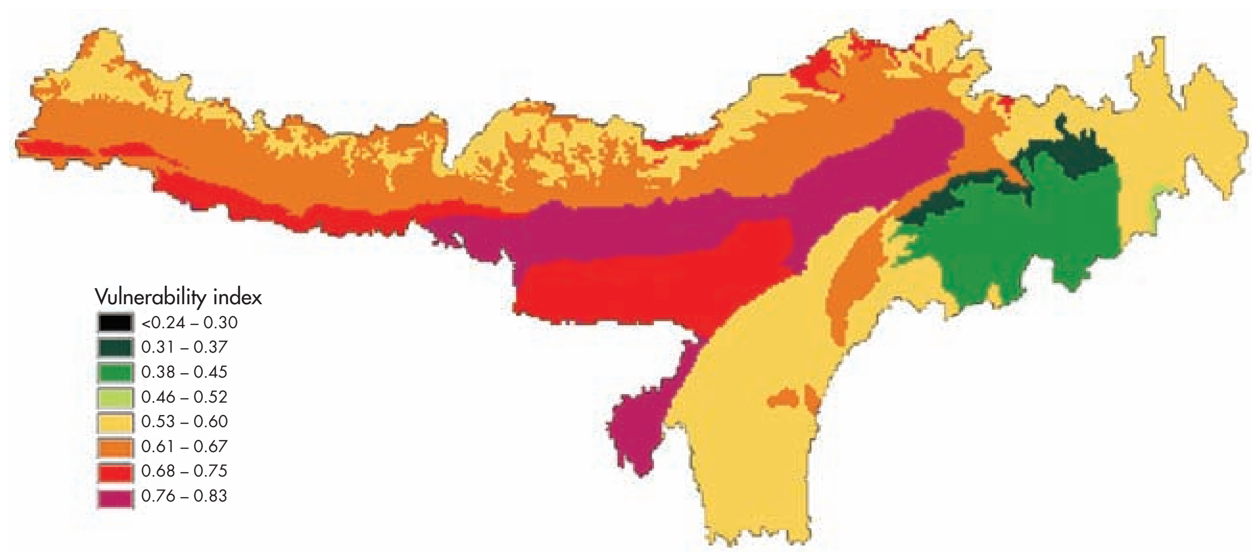
Mountain ecosystems are being continuously threatened by global change, including climate change. Management practices and the underlying socioeconomic changes have pushed the ecological resilience of mountains to their limits. Land use is the major driving force that could result in near complete loss of alpine vegetation by the end of the current century. Natural ecosystems are being continuously replaced or modified

Figure 20: **Ecoregions of the Eastern Himalayas and their relative vulnerability to climate change**

**a) Ecoregions**




**b) Vulnerability of individual ecoregions**



by agricultural systems. Thus it is important that ecosystem vulnerability is assessed within this context.

A modest attempt was made to characterise ecosystem vulnerability by implementing a quantitative approach anchored in the conceptual framework put forward by the IPCC. There are several other schools of thought in advancing the theoretical construct of vulnerability, but the most compelling ones are those that understand vulnerability as being the start-point characteristic of an ecosystem that predisposes it to future threats arising out of changes in the factors that influence the ecosystem condition. The approach taken in this assessment was essentially a compromise, drawing on the functional aspects of these perspectives. While hypothesising the process of quantification, it is almost impossible to think of vulnerability exclusively in the context of climate change and disregard other drivers of change that may impose stresses, directly or in concert with it.

The vulnerability level of ecoregions was assessed in the context of climate exposure, the sensitivity of their component ecosystems, habitats, and species, and their natural resilience, coupled with the coping capacity of the human population dependent on their goods and services for wellbeing. Appropriate variables and indicators were used to develop metrics for climate exposure, system sensitivity, and adaptive capacity which were calculated as dimension indices and then integrated into a vulnerability index. The map of the ecoregions was superimposed on the raster interpretation of vulnerability, and the pixel-level values enclosed within each ecoregion were averaged to obtain the mean index of vulnerability. The index values were then ranked to understand the relative fitness of ecoregions to withstand the adverse impacts of climate change. The results are given in Annex 2 and displayed visually in Figure 20b.

The Brahmaputra valley semi-evergreen forests were identified as the most vulnerable of the 25 ecoregions in the EH. The least vulnerable are the Northern triangle and Indochinese forests. The vulnerability index for the Yarlung Tsangpo arid steppe could not be assessed as <1% of its area is in the EH and probably below sub-pixel level. Other vulnerable areas are the lower Gangetic plains moist deciduous forests, Meghalaya subtropical forests, Terai-Duar savanna and grasslands, and Northeastern Himalayan sub-alpine conifer forests.

The overarching threats to the vulnerable ecoregions' natural habitats stem from forest clearing and livestock grazing. But settlements and agriculture go back thousands of years and have already taken a heavy toll on the natural habitat and biodiversity. Vast areas of original habitat were taken over by large tea plantations. The Naxalite insurgency in the Brahmaputra valley prevents effective government administration of conservation areas (protected areas and reserve forests). The movement is also funded to some extent by poaching and wildlife and timber trade. The dense human population is still growing rapidly. The urbanisation, industrialisation, and agriculture associated with this population growth and its resource and economic needs pose serious threats to the remaining forest fragments. The small, protected areas are vulnerable to this tidal wave of human growth and are inadequate to conserve biodiversity. Finding additional habitats for protection will be challenging. Therefore, existing protected areas should be effectively managed and protected, and restoring critical habitats should be considered where necessary. Deforestation is a huge factor, especially when it results from jhum (shifting cultivation) in and around the remaining blocks of forests. However, when allowed to be carried out in traditional fashion, jhum maintains forests and does not lead to deforestation (Kerkhoff and Sharma 2006). Hunting for tigers and elephants is rife. Mining for coal and limestone along the migratory routes of elephants threatens their traditional movement, resulting in the escalation of human-elephant conflicts, which are already intense. Many of these lands have been leased by tribal landholders to private mining companies.

The Terai is Nepal's main area for logging and wood industries. Sawmilling is the largest wood-based industry, with private sawmills spread over most of the Terai districts. Fuelwood production is also important, most consumed within the country and the rest exported to India. In addition to recorded log production, some unauthorised cutting for export also takes place. Growing population pressure in the hills has led to migration to, and settlement in, the Terai, both spontaneously and through government-sponsored resettlement programmes. The southern parts of the Terai are, therefore, densely populated, and most of the area is under cultivation, although northern regions have a lower population density. Water diversion, especially for irrigation, poses another significant threat. Poaching and overgrazing are also a problem. Much of the savanna grassland may have been created by burning by pastoralists and other human intervention.

### Vulnerability of administrative areas

To assess the relative vulnerability of countries in the region, the vulnerability outcome was projected on to an administrative map to produce area-averaged vulnerability index figures for every sub-national unit. This offers a glimpse into the socio-political contours of vulnerability and the forces that are in effect to impact some units more than others. Once again, units were ranked according to their vulnerability scores focusing on the assessment of potential entry points for adaptation activities and the identification of institutional partners for implementation. These units are listed in the Annex 3 along with a few important characteristics and the scaled dimensions of vulnerability with scores and ranks.

### Implications of the vulnerability analysis

There were significant inverse spatial correlations between many of the indicators used to describe ecosystem sensitivity and resilience, and human adaptive capacity in the demographic and socioeconomic aspects, which suggest that sensitivity or susceptibility and adaptive capacity or resilience describe one basic attribute of an ecosystem and in essence mean one and the same. Therefore, the relevance of defining sensitivity as one of the dimensions of vulnerability is questionable, while exposure is often indistinguishable from impact. Instead, it is proposed to redefine these dimensions as stress, potential impact, adaptive capacity, and threat. Further, there is sufficient justification to conclude that a social vulnerability-based approach within a social constructivist framework is the preferred strategy for vulnerability assessment, bearing in mind the key objective of addressing the needs of adaptation policies and actions.

The vulnerability profile described for the mountain ecosystems of the EH illustrates the inequality that pervades the human ecology and political economy of the region. There are contradictions as well as conformity with the mainstream perception that poverty leads to ecological vandalism and resource degradation. Evidence accumulated through this study also suggests otherwise: that the poor understand the need to safeguard the ecosystem structure and functions as a proximate source of wellbeing. Resilient ecosystems are often found overlapping with places where the poor live. Equally, the most vulnerable areas are those where the poor are concentrated, like the Brahmaputra valley, the Terai-Duar belt, and the lower Gangetic plain of West Bengal. High population density and insufficient attention to the enhancement of human social capital are major factors that magnify vulnerability of not only the human adaptive capacity, but also the ecosystem's ability to sustain the flow of goods and services. Equally, some of the metrics selected as proxy indicators for quantifying ecosystem attributes might have introduced unanticipated skews in the estimation process and confounded the results, especially if a particular measure has a greater value range compared to others. The indicators associated with the evaluation of biodiversity, ecosystems, and environment components may have caused such results, and are most likely the reason for the low vulnerability index for Bhutan, Zhongdian in China, and Kachin in Myanmar. Discrete indication of somewhat higher vulnerability in the high mountain areas was most likely due to high exposure levels to climate variability and change.

The vulnerability analysis was linked to existing natural and human wellbeing strategies, ecosystem services, and biodiversity endowments to identify points of intervention where the ability of ecosystems and people to adapt and build resilience could be strengthened through a process of autonomous and planned adjustment. The work on climate change vulnerability assessment was conducted in the context of mountain ecosystems of the EH to inform adaptations for sustained ecosystem services in biodiversity conservation, protected area management, water resources security, and human wellbeing. It directly addresses the information needs of adaptation decision-makers and contributes to policy-making by providing specific recommendations to planners and policy-makers on the enhancement of adaptive capacity and the implementation of adaptation policies. This entails integrating risk reduction measures into the development of plans, programmes, and policies. Such understanding helps to prioritise the allocation of resources for adaptation measures. The identification of limits to adaptation for valued systems provides important information for the determination of critical levels of climate change. The diverse groups of stakeholders with interests and concerns in mountain ecosystem services in the EH are expected to make use of the information on vulnerability for prioritising adaptation measures and research areas.

## Response, Adaptation and Mitigation

Sometimes climate change adaptation is seen as competing with the human and economic development needs of the world's poor. Climate change can be perceived as a problem distant in time, uncertain in its effects, and of less consequence than present-day poverty. Adaptation and mitigation may, therefore, seem less urgent and less compelling than increasing development efforts for the world's poor. But climate hazards are immediate, they are growing, they threaten the quality of life and life itself, and they directly impact on the goals of development. In this assessment, the direct link between climate stresses and human poverty is reconfirmed through intense exploration of transmission mechanisms and channels of human vulnerability in the face of interacting and reinforcing multiple stresses.

The foregoing sections on sensitivity and impact establish a credible basis for concrete action in response to the effects of climate change. The components of mountain ecosystems that are the focus of this assessment were found to be the sources of key transmission mechanisms through which climate change could negatively affect human wellbeing. Climate change can also act in concert with other stresses to undermine human wellbeing by modulating livelihood strategies and decisions. Agricultural production and food security are contingent on climate-sensitive resources; without these resources people could be faced with malnutrition and starvation. Subsistence farming is inclined to be risk averse and to prefer risk-proofing over profitability to consolidate household food security. Coping with successive adverse climatic impacts locks people into a poverty trap, as not many resources remain with which to accrue income-generating assets and build up economic safety nets. Selling assets to protect consumption depresses market prices creating conditions for increases in inequalities in income, gender, nutrition, education, and health. Receding glaciers and erratic precipitation shape the facets of water stress and water insecurity in the EH. The fragile mountain ecosystems and precarious biophysical and socioeconomic conditions are prone to hydrometeorological disasters, and 20 to 30% of land species could face extinction under 1.5 to 2.5°C of warming, with serious consequences for the ecosystem services that they provide. Higher temperatures in tandem with variable and extreme conditions of humidity and precipitation could expand the reach of diseases like malaria, dengue, and so forth.

Instead of focusing on one-off extreme events, the governments in the region and the donor agencies must realise the threat that climate change poses to development and ensure that adaptation and mitigation measures are formulated and integrated into the wider development agenda. Climate change could jeopardise the priority targets of enhancing sustainable wellbeing enshrined in the Poverty Reduction Strategy Papers and Millennium Development Goals (MDG). Invariably, socio-political approaches encompassing governance, institutional policies, and legal frameworks are the proven way to weather the adverse impacts of global change, including climate change.

Globally, two broad policy responses have been identified to address climate change. The first is 'mitigation', which refers to actions aimed at slowing down climate change by reducing net greenhouse gas (GHG) emissions. The second is 'adaptation', which refers to actions taken in response to, or in anticipation of, projected or actual changes in climate.

## Adaptation

There is general agreement that humans have already had an overwhelming impact on natural ecosystems and that this interferes with the functioning of ecosystems in ways that are detrimental to our wellbeing. Ecosystem services are essential to human civilisation, but human activities are already impairing the flow of ecosystem services on a large scale. If current trends continue, humanity will dramatically alter virtually all of the Earth's remaining natural ecosystems within a few decades. The primary threats are: land use changes that cause loss of biodiversity; disruption of carbon, nitrogen, and other biogeochemical cycles; human-caused non-native species invasions; releases of toxic substances; possible rapid climate change; and depletion of stratospheric ozone. Fortunately, the functioning of many ecosystems could be restored if appropriate action is taken in time. However, attempts to take timely action to minimise climate-related risks are often hampered by the following:

1. The perception by some decision makers that the impacts of climate change are distant and speculative and, therefore, do not warrant immediate action
2. The difficulty in making site-specific predictions about future climate at a scale relevant to ecological processes
3. The global nature of climate change requiring large-scale efforts to integrate local, regional, and national activities

Expectations in terms of adaptation within the region have enriched available options and established a context for evaluating the relevance of such options with a specific focus on the EH. Three rounds of stakeholder consultations provided a proper forum for close interaction to identify issues, impacts, and trends, and to make recommendations on adaptation strategies and governance issues for the conservation and management of vulnerable mountain ecosystems under changing climatic scenarios. The outputs from the discussions and recommendations synthesised much of what we already know, and have applied to the real world situation with varying degrees of success. These dialogues contributed to the process of identifying the promising alternatives that could strengthen current practices and help in replicating emerging approaches in addressing climate change issues. The highlights of these workshops in relation to adaptive capacity in the EH include the following:

1. The initial symptoms of climate change are sufficiently apparent to necessitate proactive and anticipatory adaptation measures.
2. High priority areas for adaptation are ecosystem resources conservation and management, poverty alleviation, human health, hazard mitigation, and climate risk reduction.
3. Early action towards adaptation to climate change is imperative in tackling the vulnerabilities associated with climate change. In particular, action should be taken to strengthen the instruments for protected area management; mainstream climate adaptation policies into national poverty reduction programmes and plans; empower communities in natural resources management; and create an enabling environment for equal partnerships and inclusive participation. A promising entry point with a quick payoff is to integrate traditional knowledge of land use with sustainable production systems. With the predominantly poor socioeconomic context and near absolute reliance on climate-sensitive resources, the coping capacities of people are somewhat limited, making them highly vulnerable to the loss of particular ecosystem services.
4. Adaption strategies cannot be developed in isolation from wider policies for socioeconomic development in the region. Across the EH, climate change is merely one among many important stresses including environmental pollution, land use change, and the development pathway embraced within each nation's vision of progress and prosperity. Resources available for adaptation to climate are limited and adaptive responses are closely linked to human capacity and development activities, which should be considered in evaluating adaptation options.
5. Large numbers of adaptation and mitigation measures are being proposed to address climate change issues across and along sectors, systems, and themes, and over various time horizons considered important for mountain ecosystems and the people dependent on their services. Some of these are local, micro-scale response actions to cope with short-term extremes, some merely anecdotal, but most are long-term strategies to strengthen resilience and reduce the vulnerability of ecosystems and humans. These options include policy harmonisation and adjustment; support for traditional ingenuity with science and technology; community empowerment and capacity building; applying existing and generating new information; development of physical infrastructure like check dams, water-harvesting, afforestation, and river embankments; putting forecasting and early warning systems in place; awareness building; and expanding the insurance industry. The only shortcoming, and a defining one, is the disconnect between forward looking adaptation measures and those adopted autonomously by individuals.
6. Prerequisites for developing effective adaptation strategies include an understanding of current perceptions and coping strategies at local levels to deal with emerging climate change challenges, and of ecological knowledge systems and ecosystems conditions; recognition of the existence of multiple stresses on the sustainable management of resources; and collaboration between locals and scientists.
7. Climate change vulnerability varies across space and among groups depending on policies, services, and governance; levels of human wellbeing and livelihoods; and the gravity of environmental disruptions. Accountable and responsive government and the empowerment of people to improve their lives are also necessary conditions for successful adaptation.
8. The potential for successful adaptation to climate change in the EH lies in sustainable natural resources management, poverty reduction, ecosystems and biodiversity conservation, integrated watershed management, human development, and disaster risk reduction.
9. Adaptation strategies need to be treated as an integral part of national programmes, not as isolated projects outside the planning system. Adaptation will also benefit from taking a more systems-oriented approach, emphasising multiple interactive stresses, horizontally coordinated and vertically integrated.

Table 23 presents a list of the adaptation efforts related to climate change and mountain ecosystems identified through the stakeholders' workshops. The list is not intended to be comprehensive, but rather to present an overview of actions that have been identified in the EH. The list has been compiled based on regional consultations and supplemented by an overview keyword search of the primary literature. It must be emphasised that this list is limited to actions either being currently implemented or recommended for implementation that are specific to coupled human-environment system management in response to climate change. Many other adjustment and management activities are undoubtedly underway that are supportive of climate change adaptation, but not yet explicitly linked to it.

Table 23: **Climate adaptation management actions currently being implemented or recommended for implementation in the Eastern Himalayas**

| **Adaptation action** | **Capacity building** | | | | **Biodiversity target** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **System** | | **Level** | | | **Range** | |
| **Description** | **Research/monitoring/ assessment** | **Education/extension** | **Plans/policies** | **Implementation** | **Terrestrial** | **Freshwater** | **Ecosystem** | **Species** | **Genetic** | **Local** | **Widespread** |
| **Livelihood and human wellbeing** | | | | | | | | | | | |
| Capacity development (human, institutional, financial, political, social) | ● | ● | | ● | ■ | □ | ■ | ■ | □ | ■ | □ |
| Enhance information and access, education and training, and awareness | ○ | ○ | ○ | ○ | ■ | □ | ■ | □ | □ | ■ | □ |
| Agroecological approach based on agricultural productivity potential | ○ | ○ | ● | ○ | □ | | ■ | | □ | ■ | □ |
| Community empowerment and participation | | ● | ○ | ● | ■ | □ | □ | □ | | □ | ■ |
| Population control and regulation of pressure | | | ● | ● | □ | | | | | □ | |
| Enabling policy instruments | | | ○ | ○ | ■ | □ | ■ | □ | | ■ | |
| Increase or diversify livelihood options | ● | ● | ● | ● | ■ | □ | ■ | □ | | ■ | |
| Insurance for social risk management and poverty reduction | | | ○ | ○ | □ | | □ | | | □ | ■ |
| **Water, wetlands and hazards** | | | | | | | | | | | |
| Water control and conservation infrastructure | ● | ● | ● | ● | | ■ | □ | | | □ | ■ |
| Monitoring, forecasting and early warning systems | ○ | ○ | | ○ | ■ | | ■ | | | □ | ■ |
| Scientific management of water/wetland bodies to enhance aquatic resource productivity (fisheries, medicinal plants, reeds, etc.) | ○ | | ○ | ○ | | ■ | | □ | | ■ | □ |
| GLOF mitigation | ● | ○ | ○ | ● | □ | □ | □ | □ | | ■ | |
| Disaster risk reduction | ○ | ○ | ○ | ○ | □ | □ | □ | □ | | ■ | □ |
| Integrated watershed management integrating traditional techniques | ○ | ○ | | ○ | ■ | □ | | | | ■ | □ |
| **Ecosystems and biodiversity** | | | | | | | | | | | |
| Landscape ecosystem approach to biodiversity conservation | ○ | | ● | | ■ | □ | ■ | □ | □ | | |
| Forest fire management | ● | ● | ● | ● | ■ | | □ | □ | | | □ |
| Sustainable management and use of forest resources | ● | ● | ● | ● | ■ | | □ | □ | | | □ |
| Shift to green, environmentally friendly technologies | ○ | | ○ | | □ | | □ | □ | | | □ |
| Enhance sinks and reduce sources of GHG emissions | ○ | | ○ | | □ | □ | □ | | | | □ |
| Conserve natural habitats in climatic transition zones | ○ | | ○ | | □ | | ■ | □ | | ■ | |
| Restoration of degraded ecosystems | ○ | | ○ | ○ | ■ | □ | ■ | □ | | | □ |
| Formalise traditional knowledge systems | | | ○ | ○ | | | □ | □ | | ■ | |
| Promote community-based ecotourism | | | ● | | ■ | | ■ | □ | | ■ | |
| Shift in social habits in the consumption and use of ecosystem services | | ○ | | ○ | ■ | ■ | ■ | □ | | □ | □ |
| Improve shifting cultivation practices | ● | ● | | | ■ | | ■ | | | □ | |
| **Human health** | | | | | | | | | | | |
| Measures to reduce air and water pollution | | | ○ | ○ | □ | ■ | □ | □ | | | □ |
| Adapt solutions to prevent vector-borne diseases/epidemics | ● | ● | ○ | ● | □ | □ | □ | □ | | | □ |
| Improve health care system, including surveillance, monitoring, and information dissemination | ● | ● | ● | ● | | | | | | | ■ |
| Improve public education and literacy rate in various communities | ○ | ● | ● | ● | | | | | | | ■ |
| Increase infrastructure for waste disposal | | | ● | ○ | □ | □ | □ | | | | ■ |
| Improve sanitation facilities in RMCs | | ● | | ● | | | | | | | ■ |

**Note:** blank cell = not applicable

● Being practiced
○ Recommended for future

■ Primary target
□ Secondary benefits

Highlights of some of the highest priority options for adaptation to climate change in the EH are summarised in Table 24. The information compiled was sourced from various national reports, which were then reconciled with the practices and prospects shared during the three rounds of stakeholder consultations.

## Ecosystems and biodiversity

Mountain ecosystems warrant protection, not only to maintain ecosystem integrity and adaptability, but also to secure their protective role against slope erosion and as a component of mountain hydrology and water quality. There is general agreement that humans have already had an overwhelming impact on natural ecosystems and that this interferes with the functioning of ecosystems in ways that are detrimental to our wellbeing. On the other hand, adaptation of natural ecosystems to climate change cannot be achieved without some kind of human intervention.

Effective conservation and the sustainable use of natural resources are the overarching precepts of sound biodiversity management. Humans are integral parts of the ecosystems that are now being increasingly exposed to climate change stress. Without addressing the socioeconomic wellbeing of people, there is very little incentive for them not to overexploit or to protect biodiversity resources. Adaptation strategies must be people-oriented within the framework of protecting landscapes, ecosystems, habitats, and species so that anthropogenic interferences are kept to a minimum for natural resilience to take over and sustain the ecosystem

Table 24: **A sector-wise summary of potential adaptation options generally identified for the region**

| Sector | Adaptation options |
|---|---|
| Agriculture | • Promote water use efficiency in agriculture through effective water storage (soil conservation, water harvesting) and optimising water use (drip, microjet, and sprinkler irrigation)<br>• Adjust agricultural production systems to production environment (short, early-maturing crops, short-duration, resistant and tolerant varieties, appropriate sowing and planting dates, proactive management)<br>• Improve land cultivation management<br>• Adopt agroecosystems approach to planning and production methods<br>• Weather and seasonal forecasting for climatic conditions, crop monitoring, and early warning systems<br>• Adjust cropping calendar and crop rotation to deal with climatic variability and extremes |
| Water Resources | • Ensure the economic and optimised use of water through rainwater harvesting and modern water conservation systems (groundwater supply, water impoundments), and strengthen the unified management and protection of water resources (efficient water resource systems)<br>• Flood regulation, protection, and mitigation; tapping water sources to increase water-supply capacity<br>• Adopt integrated watershed management and protect ecosystems (restore vegetation cover, prevent and control soil erosion and loss)<br>• Construct irrigation systems and reservoirs, and adjust the operation of water supply infrastructure<br>• Monitor water resources to readjust national and sectoral plans (reduce future developments in floodplains)<br>• Improve preparedness for water-related natural disasters |
| Ecosystems and biodiversity | • Prevent deforestation and conserve natural habitats in climatic transition zones inhabited by genetic biodiversity with potential for ecosystem restoration, and reintroduce endangered species<br>• Adopt integrated ecosystem planning, monitoring, and management of vulnerable ecosystems<br>• Reduce habitat fragmentation and promote development of migration corridors and buffer zones<br>• Enhance forest management policy for the protection of natural forests (control and stop deforestation and ecological damage), prevent desertification processes, and mixed-use strategies<br>• Plan to develop forestry planting and growth technology for fast growth species to increase share of forest (afforestation and reforestation), to conserve and rehabilitate soil and prevent slope failure and mass wasting, and for forest protection<br>• Undertake preventive measures for forest hazards<br>• Preserve gene material in seed banks |
| Human health | • Strengthen preventative medicinal activities and reinforce disease prevention measures<br>• Implement epidemic prediction programmes to cope with possible vector-borne diseases, both for humans and domestic animals<br>• Adopt technological/engineering solutions to prevent vector-borne diseases/epidemics; increase infrastructure for waste disposal; improve sanitation facilities; reduce air and water pollution; and track water quality, water treatment efficiency, and soil quality<br>• Improve healthcare systems, including surveillance, monitoring, and information dissemination<br>• Improve public education and literacy rates in various communities |
| Natural disasters | • Strengthen the early warning system within the national meteorological and hydrological service<br>• Undertake full assessment of wildfire-risk zones and increase public awareness |

Source: Stakeholder consultations; documents pertaining to the NAPA, NCSA and NCs of EH countries to UNFCCC structure and functions. Recently, there has been a strong drive to transition from contemporary conservation approaches to a new paradigm of landscape-level interconnectivity between protected area systems that are defined around the protectionist focus on species and habitats. The concept emphasises the shift from the mundane species-habitat dichotomy to a more inclusive perspective on expanding biogeographic range so that natural adjustments to climate change can proceed without restriction. However, the benefits of this approach have yet to be realised. Whatever the conservation approach, communities in a protected area system must be regarded as a medium of adaptation, rather than being perceived as the reason for environmental degradation and biodiversity loss. Local participation in conservation efforts should include decision-making prerogatives and a cooperative environment of shared ownership in the process.

On the other hand, biodiversity in natural ecosystems has also been adapting naturally or autonomously without much adjustment from the people and communities that benefit from their services. As the magnitude of climate change, and other global change stressors for that matter, increases with time, the need for planned adaptation will become more acute. Traditionally, communities that depend on biodiversity resources have informal institutions and customary regulations in place to ensure that external perturbations do not exceed natural resilience beyond a certain threshold. Judging by the rate of the changes taking place in the demographic, economic, and socio-political landscapes of human society, and their positive feedback to the climate system, these traditional approaches may need to be supplemented by formal adaptation measures to address the new threats to biodiversity.

Maintaining resilience in ecosystems is the primary objective of adaptation strategies for protecting wildlife and habitats (IPCC 2007 b,c). Activities that conserve biological diversity, reduce fragmentation and degradation of habitat, and increase functional connectivity among habitat fragments will increase the ability of ecosystems to resist anthropogenic environmental stresses, including climate change. An effective strategy for achieving this is to reduce or remove existing pressures. However, adaptation options for ecosystems are limited, and their effectiveness is uncertain. Measures directed at specific effects of climate change are unlikely to be applied widely enough to protect the range of ecosystem services upon which societies depend. Fortunately, reducing the impacts of non-climate stresses on ecosystems would also buffer ecosystems from the negative effects of climate change. The range of potential strategies given in Table 25 is broad enough to address most of the problems associated with mountain ecosystems in the EH.

Table 25: **Strategies to increase resilience of ecosystems to climate change and other stressors**

| Stressor | Strategy/human response | Examples |
|---|---|---|
| Physical habitat alteration | Conservation | • Establish protected areas, parks and refugia<br>• Protected landscapes |
| | Restoration | • Afforestation<br>• Reforestation<br>• Soil conservation |
| Pollution | Regulation of emissions | • Control $SO_2$, $CO_2$, NOx, and volatile organic carbon emissions<br>• Regulate emissions of CFCs (Montreal Protocol)<br>• Reduce point source water pollution |
| | Regulation of land use and non-point sources | • Protect riparian buffers<br>• Change urban and agricultural practices |
| Non-native invasive species | Prevention of introduction and establishment | • Monitor areas around ports of entry and eliminate new populations |
| | Management of established populations | • Release biological controls<br>• Eradicate invasive species |
| Global climate change | Reduction of greenhouse gas emissions | • Reduce fossil fuel combustion<br>• Conserve energy |
| | Reduction of climate impacts via reduction of other stressors | • Increase ecosystem resilience to climate impacts via habitat protection, reduced pollution, control of invasive species, sustainable resource use |
| | Direct reduction of climate change impacts | • Schedule dam releases to protect stream temperatures<br>• Transplant species<br>• Establish migration corridors |

A common approach to ecosystem conservation in mountains and uplands is the setting up of climate refugia, parks and protected areas, and migration corridors to allow ecosystems to adapt or migrate. National parks with restricted access and biosphere reserves are one form of refugium. A major problem in many parts of populated mountain regions is that ecosystems have been so fragmented and the population density is so high that many options may be impossible to implement. In addition, various assessment studies have shown that the designation of interconnected and comprehensive reserve networks and the development of ecologically benign production systems would result in increasing conflict between economic development and environmental concerns (Chapter 13 of Agenda 21).

Challenges remain to the adoption of an effective strategy to address climate and non-climate related risks to ecosystems. A significant challenge is to incorporate biodiversity thinking into adaptive responses to ensure that future development activities do not further jeopardise the world's biological resources. Setting priorities among strategies is difficult, partly because so little is known about the effectiveness of alternative actions intended to reduce ecosystem vulnerability. Caution is needed in developing adaptive measures, because lack of information and/or conflicting ecosystem goals can lead to mal-adaptation. For example, diverting hazardous pollutants from water to air or land may benefit aquatic ecosystems, but cause problems in terrestrial ecosystems. Likewise, corridors connecting habitat fragments may help some species disperse, but might also allow aggressive invasive species to enter fragile habitats.

Good practices in planned adaptation are premised on the availability of adequate information on the status of biodiversity, trends in environmental change, including climate change, and their potential impacts on biodiversity, human resources, expertise, institutional capacity, political commitment, and financial resources. Without being inclusive, some adaptation options in the EH are as follows:

1. Develop institutional arrangements that are responsive to addressing climate change issues and sensitive to the societal and economic priorities at the national and local levels.
2. Conduct research and development in agroforestry and community forestry to enhance carbon sequestration, reduce soil erosion, and improve water quality and livelihood options.
3. Operationalise a transboundary landscape approach in biodiversity conservation and protected area management.
4. Establish climate-monitoring stations to facilitate the generation of accurate, long-term climatological time-series data and associated infrastructure for operational networking and data sharing.
5. Identify and monitor climate sensitive organisms as indicators for early detection of climate change signals and facilitate proactive adaptation mediation.
6. Ensure the sustainable management of rangelands and formalise climate-conscious pastoralism, not only to enhance productivity, but also to protect the ecosystem, reduce $CO_2$ emissions, and increase storage above and below ground.

## Water and wetlands

Climate change will increase variability and uncertainty in the availability of water resources, while at the same time exposing people to altered frequency and intensity of water-related hazards (floods, droughts, water-borne diseases). Adaptation must focus on addressing these problems by enhancing the capability of people to deal with such situations. Water harvesting and water storage structures are some common measures used to manage the variability and uncertainty associated with water use systems and to prepare for droughts. Flood mitigation work and the construction of protective embankments along flood-prone rivers, as well as operationalising early warning systems, can diminish the risks posed by flooding, and protect people's lives, property, and productive assets. The demand and competition for water resources in the EH is likely to intensify as the resource base is eroded due to climate change and human interference. Appropriate institutional mechanisms of governance, policy changes, and a regulatory framework are necessary to ensure equitable resource access and distribution, as well as to safeguard the resilience of wetlands and curb overexploitation.

A key strategy for ensuring the future of wetlands and their services is to maintain the quantity and quality of the natural water regimes on which they depend, including the frequency and timing of flows. This means that an ecosystem-based integrated water resources management policy has to be developed and implemented. Integrated water resources management can rationalise supply and demand situations by maintaining adequate supply and improving water use efficiency. Tradeoffs may be required between competing water uses, but decisions on water management must consider the need to protect wetlands. Adaptation strategies must consider other major drivers of change alongside climate change, as climate change cannot be managed in isolation. The triangulation of the three environmentally relevant 'Rs' – reduce, recycle, and reuse – in relation to wastewater is emphasised as another adaptation method. Finally, the importance of education and awareness, as well as capacity building at all levels, cannot be underestimated.

### Hazards

In addition to short-term approaches such as response and recovery, there is a need to think about the long-term goal of awareness, preparedness, and risk reduction. From the natural hazards perspective, responding to climate change involves an iterative risk management process that includes both adaptation and mitigation, as neither on its own can address all potential climate change impacts. At the policy level, adaptation needs to be mainstreamed into the planning process and integrated into sectoral development programmes and activities. At the institutional level, capacity building is an obvious priority to enhance the knowledge and information base, strengthen networks across agencies and governments, and promote regional cooperation. Adaptation options include, among others, improvement of observation and forecasting, development of early warning systems, mapping of hazards and vulnerabilities, community awareness and participation, and forest and water conservation. Engineering works are alternative options for adaptation through risk mitigation.

### Human wellbeing

Human wellbeing in the EH is inextricably linked to natural resources, such as agriculture and hydropower, which are highly sensitive to climate change. People live under constant threat from natural hazards such as water stress and scarcity, food insecurity, food, water, and vector-borne diseases, GLOFs, landslides, floods, and droughts. The adaptation of populations to the spread of malaria and other vector-borne diseases is determined by the economic level of a given population, the quality and coverage of medical services, and the integrity of the environment. Good health is a good indicator of a population's adaptive capacity to climate change. Adaptation measures for livelihoods and human wellbeing include the following, among others:

1. Establish and strengthen infectious disease surveillance systems.
2. Build the capacity of the health sector through training, exposure, and networking of professionals to enhance their understanding of the threats posed by climate change to human health.
3. Conduct research to fill the knowledge gaps and reduce uncertainties in adaptation measures.
4. Facilitate community involvement and awareness in using water resources more sustainably.
5. Improve land use planning to promote afforestation in degraded water catchment areas.
6. Develop varieties of crops and livestock with greater resilience to climate change, variability, and extreme events.
7. Undertake community-based forest management and afforestation projects for conservation and development purposes; increase wood production to reduce the extractive pressure on natural forests and enhance carbon sequestration.

Adaptations are mostly aimed at eliminating projected climate change impacts. However, in some cases adaptations can be aimed at exploiting a climate change opportunity. Regardless of whether or not countries around the world succeed in achieving major reductions in GHG emissions, climate change models predict that excess greenhouse gases already in the atmosphere will drive climate change and its impacts for centuries to come. As a result, the need to implement activities aimed at adapting to the potential changes is imperative.

### Mitigation

Global reductions in GHG concentrations are expected to slow the rate and magnitude of climate change over the long term. To do this, both sources of and sinks for greenhouse gases must be managed. Examples are using fossil fuels more efficiently and expanding forests to sequester greater amounts of carbon dioxide from the atmosphere. Because the potential responses of natural systems to human-induced climate change are inherently limited, the best overall strategy is to minimise the amount of change.

Broadly speaking, any effort to reduce the rate or magnitude of climate change by reducing atmospheric GHG concentrations can be viewed as a long-term activity toward mitigating impacts on biodiversity at all levels. Therefore, developing strategies that reduce GHG emissions and maximise the carbon sequestration potential of living systems should be viewed as critical elements in stabilising climate and minimising the long-term impacts on biodiversity. Deforestation, peatland degradation, and forest fires account for about one-fifth of the global carbon footprint. Conservation of forests and soil offers triple benefits: climate mitigation, people, and biodiversity.

Mitigation actions that have complementary adaptation benefits, and vice versa, should be preferred. The restoration of degraded landscapes with vegetation and the implementation of agroforestry systems are two examples where carbon sequestration benefits can be achieved simultaneously with reduced soil erosion and improved water quality, both of which can provide biodiversity conservation benefits (Watson 2005). Freshwater biological systems can be assisted to help mitigate the impacts of climate change, particularly through the increase and protection of riparian vegetation, and by restoring river and stream channels to their natural morphologies.

GHG management is a global issue, and mitigation efforts in the EH can rightfully be placed in this context. According to National Communications (NC) of the regional countries to the UNFCCC, the region is assessed to be a net sink and GHG emissions are minimal compared to other regions of the world. The EH has low per capita GHG emissions, but could face considerable challenges in achieving further improvement in energy efficiency due to limited capability.