# PREPARING FOR CHANGE

## Climate Vulnerability Assessment of the Chitwan-Annapurna Landscape

**Hariyo Ban Program**

USAID FROM THE AMERICAN PEOPLE WWF care

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In WWF a technical team worked long hours to undertake initial analyses, organize the workshop, synthesize results and prepare the report. The organizing team comprised Ramesh Adhikari, Ryan Bartlett, Sarah Freeman, Sunil Regmi and Eric Wikramanayake. Gokarna Thapa and Pankaj Bajracharya undertook GIS work.

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Judy Oglethorpe
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## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| AAPA | Aquatic Animal Protection Act |
| ACA | Annapurna Conservation Area |
| ADB | Asian Development Bank |
| CAPA | Community Adaptation Plan for Action |
| CARE | Cooperative for Assistance and Relief Everywhere |
| CHAL | Chitwan-Annapurna Landscape |
| CFUG | Community Forest User Group |
| CNP | Chitwan National Park |
| DDC | District Development Committee |
| DNPWC | Department of National Parks and Wildlife Conservation |
| DoF | Department of Forests |
| EIA | Environmental Impact Assessment |
| EPA | Environmental Protection Act |
| FECOFUN | Federation of Community Forest Users Nepal |
| GoN | Government of Nepal |
| Ha | Hectare |
| IPCC | Intergovernmental Panel on Climate Change |
| IUCN | International Union for Conservation of Nature |
| LAPA | Local Adaptation Plan for Action |
| LNP | Langtang National Park |
| MAPs | Medical and Aromatic Plants |
| MW | Megawatt |
| NAPA | National Adaptation Programme for Action |
| NCVST | Nepal Climate Vulnerability Study Team |
| NGO | Non-Government Organization |
| NTFP | Non-timber Forest Product |
| NTNC | National Trust for Nature Conservation |
| NWP | National Water Plan |
| TAL | Terai Arc Landscape |
| THR | Trans-Himalayan Region |
| USAID | United States Agency for International Development |
| VA | Vulnerability Assessment |
| VDC | Village Development Committee |
| WECS | Water and Energy Commission Secretariat |
| WWF | World Wildlife Fund |

# EXECUTIVE SUMMARY

The Himalayas are expected to experience many changes in temperature and precipitation due to climate change. Climate projections for Nepal suggest that monsoon (summer) precipitation will increase, especially in eastern and central Nepal, but actual rainfall patterns will be highly variable, both spatially and temporally. Extreme weather events are expected to become more frequent, with extended droughts interspersed between periods of intense precipitation. Winters are predicted to become warmer.

The Chitwan-Annapurna Landscape (CHAL) spans the geographically and biologically diverse Gandaki River basin in the central Nepal, extending from the tropical lowlands in Chitwan National Park (CNP) to the cold, high-altitude semi-desert of the Trans-Himalayan Region (THR) and the peaks of Annapurna, Manaslu and western Langtang. With an altitudinal range of nearly 8,000 m, highly dissected terrain, and complex seasonality, the landscape has a wide array of climates and microclimates that shape the habitats and environmental conditions for its rich biodiversity and ecosystem services. These support a human population of over 4.5 million and diverse economic activities. The ecological, socio-cultural and economic systems in the landscape are closely intertwined, with people's livelihoods dependent on sustained ecological integrity.

We used the *Flowing Forward* approach to determine the vulnerability of several key socio-ecological systems in the CHAL to climate change. The *Flowing Forward* process is organized around the three components of vulnerability as defined by the Intergovernmental Panel on Climate Change (IPCC); i.e., exposure, sensitivity, and adaptive capacity. The approach divides the landscape or river basin into Units and Subunits whose individual vulnerabilities combine to indicate the vulnerability of the larger basin or ecosystem. The Units, representing land use and land cover, biodiversity, and infrastructure in the landscape were stratified within five physiographic zones: Trans-Himalayan Region, High Himalaya, High Mountain, Middle Mountain, and Churia.

The analysis Units were further subdivided into several Subunits, reflecting forest types, freshwater sources and systems, agriculture types and practices, infrastructure, and key species that could be affected by climate change. These were considered to be key socio-ecological features that could become affected by climate change, which could, in turn, affect the survival and sustainability of biodiversity, human livelihoods and lives, and economies, or be early indicators of change. Strategic adaptation interventions could then be developed at spatial scales that can address change in ecological processes and links in a meaningful way.

The results of the analysis indicated the following Units to be most vulnerable to climate change: the subtropical broadleaf forests of the Churia hills and the semi-desert coniferous forests of the Trans-Himalayan region; spring sources in the Churia

range and all floodplains in the Gandaki basin; migratory birds in the Gandaki Basin and the Gharial in the lowlands of the Terai; *Pakho* agriculture in the Middle Mountains and Irrigated *Tar* in the Middle Mountains and Churia; the Seti and Rapti rivers; and the rural settlements and local roads across the basin.

As a general trend, the most vulnerable systems are in the lower region of the CHAL, especially in the Churia and Middle Mountains. Several interventions to enhance resilience in these systems were proposed, from promoting alternative energy sources and improved cooking stoves to reduce the demand for fuelwood and build forest resilience, and promoting climate-smart community-based forest management, to reforestation of denuded slopes vulnerable to natural disasters, regulating use of chemical fertilizers and pesticides in climate-smart farming, and conserving climate-resilient natural forests. Detailed recommendations and workshop outputs are presented in the following section.

# INTRODUCTION

The Hariyo Ban Program is a USAID-funded program that started in 2011 with the goal of reducing adverse impacts of climate change and threats to biodiversity in Nepal. It is implemented by four non-government organizations: World Wildlife Fund (WWF) (lead agency), Cooperative for Assistance and Relief Everywhere (CARE), the Federation of Community Forest Users Nepal (FECOFUN), and the National Trust for Nature Conservation (NTNC). The Program focuses on biodiversity conservation, payments for ecosystem services including climate change mitigation, and climate adaptation. Cross-cutting themes are livelihoods, governance, and gender and social inclusion. The Program works in two large landscapes in Nepal – the Chitwan-Annapurna Landscape (CHAL) which covers the Gandaki river basin in Nepal; and the low-lying Terai Arc Landscape (TAL) in the south.

CHAL covers 32,057 square kilometers with a varied topography from lowland Terai in the south, through the mid-hills, to the snowcapped high mountains and Trans-Himalayan desert in the north. The basin has important water resources, with several major perennial rivers. Its biodiversity includes parts of four WWF Global 200 Ecoregions, and includes many endangered and protected flora and fauna species (WWF Nepal, 2013a). CHAL is home to over 4.5 million people of diverse ethnicities, cultures and religions. Major income sources are remittances, followed by agriculture, tourism, services and wage labor. People are still heavily dependent upon forests and ecosystem services for their livelihoods and wellbeing.

Climate change impacts are already apparent in the landscape and these are projected to increase and intensify in the future. As part of its climate adaptation component the Hariyo Ban Program is supporting climate vulnerability assessments (VAs) at multiple levels as a first step to understanding current and potential future impacts, on which to base strategies for resilience building and adaptation, and their implementation.

The primary aim of this assessment is to assist with climate change-integrated conservation and development planning at landscape scale in the Gandaki basin. In addition, results will be used to inform smaller scale VAs that Hariyo Ban and others are supporting (e.g. at community and local (village development committee) level).

This report presents results on the vulnerability of important natural ecosystems, agricultural systems and man-made infrastructure—including the impact links—in CHAL. The exercise focuses on several key socio-ecological Units in the basin. It relies on the synthesis of outputs of a participatory experts' workshop, information from the existing literature and other VAs at different scales, and studies commissioned for the Hariyo Ban Program.

The report consists of an **Executive Summary** and this **Introduction,** followed by four parts. Part One provides the **recommendations for climate adaptation** from the climate vulnerability analysis of key natural and human systems in the CHAL. The Executive Summary and Part One represent a 'stand-alone' section for readers and implementers who can then refer to the subsequent sections for more detail on background, process, methodology, and analysis.

Part Two provides a brief **introduction to the Flowing Forward approach and methodology**, and its logic.

Part Three provides **an overview of the CHAL**, including its key natural and anthropogenic systems. It then summarizes the projected impacts of climate change in the CHAL and how these impacts will affect the ecological and human communities, including economic development plans for the landscape. This information was also provided to the workshop participants as background resource material to inform workshop deliberations.

Part Four provides the **workshop outputs and analysis** that were used to formulate and rationalize the recommendations for addressing climate vulnerabilities.

# PART 1. RECOMMENDATIONS

## Unit and Subunit-specific Recommendations

### Forests

- Promote alternative energy sources and improved cooking stoves to reduce fuel wood demand and deforestation/degradation, especially in the lower temperate broadleaf forests in the Middle Mountains and Churia, hence reducing non-climate pressures and building forest resilience.
- Promote "climate-smart" community-based forest management, with institutions and protocols for fire prevention and control. Reforest denuded areas in the Subtropical Broadleaf Forests of the Churia.

### Freshwater

- Protect and where possible restore climate-vulnerable spring sources through reforestation of watersheds and control of damaging land uses such as grazing, over-harvesting of forest products, poorly constructed roads, and inappropriate agriculture.
- Enhance monitoring of freshwater systems, focusing on glacial extent, snow line, and snow-water equivalent in higher altitudes; and the water quality and quantity in lower lying areas of the Middle Mountains and Churia.

### Species

- Identify and conserve important winter/nesting areas, summer habitats, and the intervening staging habitats for altitudinal migrant birds. Use the results of the climate scenario models to identify suitable resilient habitats and corridors along gradients in the Gandaki Basin.
- Work with upstream watershed communities to reduce fertilizer and pesticide use and develop soil management practices to reduce runoff and siltation during intense rainfall to conserve habitat and maintain water quality and quantity for gharial and their prey species in the lower reaches of the river system.

### Agriculture

- Increase funding and capacitate government extension services to provide climate-smart agriculture extension services, including climate adaptive farming techniques, crops, and climate change awareness programs. This is especially necessary for Pakho, Tar, Khet, and Tar systems in the Middle Mountains and Siwaliks.
- Improve access to seasonal climate information for farmers, including suggested planting dates and weather forecasts. This is especially necessary for Pakho, Tar, Khet, and Tar systems in the Middle Mountains and Siwaliks.

### Infrastructure

- Ensure climate vulnerability assessments are undertaken for all proposed and existing large infrastructure developments in CHAL including national and

local roads and hydropower developments, and incorporate results into design/operation.
- Eliminate unplanned road construction in all districts and at local levels, and promote "green road" construction with proper drainage and gradation that allow for more extreme weather events in the future, to reduce the risk of soil erosion and landslides.

## Sub-basin Recommendations

Specific recommendations were made for the following three sub-basins of the Gandaki (the ones where Hariyo Ban Program is focusing its CHAL work):

### Seti

The Seti River was given the highest vulnerability scores and therefore deserves particular attention. Important issues in the Seti included flooding and general destruction in downstream areas, but more specifically, losses in agricultural productivity resulting from increased glacial melt and more variability in rainfall. Unreliable flows make sedimentation issues more acute and reliable hydropower generation difficult.

The following were recommended to address these issues:

- Establish climate monitoring stations and an early warning system, including a mechanism for upstream-downstream communication for disaster preparedness.
- Promote alternative energy with an emphasis on biofuels, solar, and other sources to address issues related to increased energy demand and the unreliability of hydropower.
- To ensure long-term resilience:
    - Conserve headwater and riparian areas to prevent soil erosion and sedimentation. Areas that are sensitive to increased rainfall intensity and those which may provide refugia to aquatic species during extreme weather events should be prioritized for protection.
    - Assess the feasibility and benefits of providing more flow regulation (e.g. reservoirs), as they will likely be required for irrigation and flood control purposes, especially as flows become less predictable and less regular. It is critical that good information on ecosystem requirements are known prior to developments so mitigation measures and adaptation actions can be integrated with ecosystem conservation and adaptation efforts along the river.
    - Ensure land use planning that limits development in floodplains and allows the river to flood and change course in order to maintain natural ecological resilience of the system. Since the river has a reputation for rapid, devastating flooding events that are expected to worsen with the impacts of climate change, limiting development in the floodplain is prudent. It is likely that more information will need to be generated on the river's floodplain, including more detailed GIS mapping efforts, in order to do this.

### Marsyangdi

The workshop outputs indicated that the Marsyangdi has a relatively high natural resilience. Some of the important issues in the Marsyangdi are: increasingly unreliable hydropower production due to greater flow variability; damage to irrigation infrastructure due to greater flow variability and increased sedimentation; and increased flood risk and loss of agricultural productivity due to increased glacial melt and sedimentation.

The major recommendation for the Marsyangdi is:

- Engage hydropower operators to manage outflows to account for both upstream and downstream demands for water. The principal issue affecting the resilience of this sub-basin is the lack of connectivity in the river due to hydropower development. Ensuring that environmental flows are maintained will be an important way to safeguard the long-term resilience of this river system, especially as the need for multiple uses for water increases (irrigation, hydropower, flood control).

### Daraudi

The major issues in the Daraudi sub-basin are: conflict over limited water supplies due to more erratic rainfall; greater flow variability and increased sedimentation; increased flood risk and loss in agricultural productivity due to increased glacial melt and sedimentation; and risk of losing connectivity with hydropower development in critical parts of the river.

The recommendations for the Daraudi sub-basin are:

- Protect key source areas of the river that are becoming more threatened by increasing temperatures and changing precipitation patterns. Areas should be prioritized in a way that spreads risk: i.e. by making sure that multiple areas of the upper tributaries with different rainfall patterns are protected to ensure supply even if the rains decrease greatly in one area of the upper sub-basin. Studies on rainfall frequency and trends in the basin should be used to do this, and freshwater connectivity should be maintained to enable adaptation.
- Complementary to the above action, a study should be conducted to determine water demands (including planned hydropower) and sustainable water supply solutions to ensure reliable supply for users while not jeopardizing the ecological integrity and resilience of the system.

## Recommendations for Cross-Cutting Issues

Implementing specific, targeted interventions to reduce vulnerability in the CHAL requires addressing a number of larger, cross-cutting challenges that either currently limit adaptive capacity or are likely to in the future.

### Integrating Ecosystems into Official Adaptation Planning Across Scales

With simultaneous adaptation planning efforts at so many scales in Nepal, integrating across them will be somewhat challenging, especially without regional governing bodies that could be supported to integrate local and national planning. Nevertheless, to avoid maladaptation, it is particularly critical that in designing and implementing adaptation interventions at the village level the ecological, social, development, and administration links with surrounding communities and ecosystems be considered.

The following are recommended for better coordination across scales and sectors:

- Regular meetings or similar mechanisms to increase cooperation between neighboring district development committees (DDCs) and village development committees (VDCs) in priority areas around future development projects and adaptation interventions are necessary. This would ensure that, at a minimum, information is shared to reduce the chances of any one development unintentionally increasing vulnerability of nearby or downstream communities or districts, for example through the installation of an unplanned road that might temporarily increase access to markets, but in fact increases landslide risk downstream (maladaptation). Further discussions could focus on synergies between nearby or upstream/downstream communities who have undertaken community adaptation plans for action (CAPAs) and local adaptation plans for action (LAPA) VDCs.
- Adopt a simple check list for all proposed community adaptation interventions that outlines any potential negative impacts on surrounding ecosystems or neighboring communities, its degree of reliance on ecosystem services from areas well outside its boundaries, and synergies with other neighboring CAPAs or LAPAs, and conservation plans for enhancing connectivity in key wildlife corridors.
- Climate-smart all DDC and VDC development plans by building capacity to address climate change issues through trainings. Sessions could focus on key aspects of this report, highlighting the importance of considering larger ecosystem level vulnerabilities, their role in enhancing resilience at a larger scale, and avoiding adaptation options that enhance vulnerability for neighboring communities or those farther downstream (maladaptation).
- Undertake adaptation planning based on natural units as much as possible, e.g. subwatersheds and sub-basins.

### Climate-smart Infrastructure Development

With current infrastructure development in the CHAL largely uncoordinated and somewhat ad-hoc, a more deliberate planning process around current and future impacts of climate change is critical to reduce vulnerability of ecosystems, local communities and economic developments. Both existing and proposed developments fail to address the impacts of climate change, with neither recent trends in climate variability nor climate projections a part of planning or design.

This problem has to be addressed through holistic approaches to watershed management, while building key ministry capacity and mandate to stop or pause infrastructure development that fails to account for climate risk. The following are recommended:

- Work to empower the Water and Energy Commission Secretariat (WECS) to screen proposals for major water infrastructure developments that fail to account for climate change trends and projections in design, operations, or EIAs, beginning with the numerous hydropower projects already proposed for critical rivers in the landscape. If projects are well into the implementation phase, key stakeholders should engage to change operating rules to reduce impacts of increased hazards on downstream communities and ecosystems, particularly during peak drought and flood season.
- Work with DDCs, the Ministries of Local Development and Public Works to change local perceptions around the eventual consequences of rapid unplanned road development, emphasizing how such roads increase landslide risk and downstream sedimentation, which is increasing with climate change. A proven solution with numerous co-benefits exists in rural Nepal in “green roads” supported by the UK Department for International Development. This model provides additional employment opportunities for community members and roads are properly engineered for drainage, and are thus far more resilient to climate change impacts than poorly planned roads that are opened by bulldozer with no engineering or drainage.

### Building Ecosystem Resilience

Resilience is a function of six criteria that determine a system’s ability to absorb and then recover from impacts. Given the challenges of managing ecosystems along the steep slopes and extremely diverse microclimates of the Himalaya, building resilience is largely limited to maintaining blocks of intact natural vegetation, restoring or maintaining connectivity along climate gradients, identifying and protecting refugia, and reducing exposure to direct non-climate pressures like deforestation, forest degradation and pollution. In the longer term climate-induced changes will be inevitable, and these should be facilitated, for example through enhancing ecosystem connectivity and corridors along climate gradients, so that species can move in response to climate change.

The following are recommended to build ecosystem resilience:

- Develop climate change integrated management plans for protected areas that address changes in habitat and ecological communities and species shifts.
- Identify climate-resilient forest ecosystems and habitats which are likely to be climate refugia and climate corridors, and protect them from degradation and clearing, using projected shifts in forest habitat in the landscape as a guide for identification (see Thapa et al., 2015).
- In anticipation of future development that might sever habitat connectivity, work with communities and developers to limit existing direct pressures and enhance connectivity through corridor management.
- Undertake vulnerability assessments for individual focal species where these do not yet exist and integrate them into species action plans and protected area management plans; begin monitoring existing wildlife populations in protected areas and in climate corridors to determine and track demographic and ecological changes for adaptive management.

- Work with communities to improve water security, for example by restoring watersheds, harvesting rainwater, and promoting water efficiency and multiple-use water systems
- Promote other “climate-smart” agriculture approaches; e.g., providing access to extreme weather tolerant crop species through seed banks and promoting integrated pest management, to help improve agricultural livelihoods and reduce climate risk.
- Promote alternative livelihoods to increase income diversity and shift households from heavy reliance on forest resources or slash and burn agriculture. This will also enhance connectivity by reducing deforestation and providing access to wildlife refugia.

### Stakeholder Engagement

- Build relationships and trust between upstream and downstream users in the watershed or basin to ensure cooperation and maintain for as long as possible the ecological integrity of sub-basins in the CHAL. The increase in unpredictable flows will require greater information flow and sharing, and more transparency and coordination amongst stakeholders. The information and uncertainty in future projections will have to be processed and provided in ways that can be distilled, communicated, and understood by many different groups of stakeholders.
- Bring together diverse groups to communicate that maintaining resilience of river systems—particularly efforts to conserve key headwater areas and maintain ecological flows in the rivers—is key to sustaining development and livelihoods, and disaster risk management.

# PART 2. METHODOLOGY

*Flowing Forward* is a landscape or river basin level, participatory approach to assess climate vulnerability of socio-ecological systems based on principles of ecosystem and hydrological connectivity. *Flowing Forward* systematically considers the factors that determine climate change vulnerability of key man-made and natural systems in a systematic way to: a) analyze the relationships between key man-made systems (e.g., infrastructure and population centers) and the ecosystems that sustain them through critical ecological services, and b) assess the vulnerability of natural systems that sustain biodiversity in the landscape or river basin to climate change. The outputs from the assessment provide a better understanding of the larger drivers of vulnerability and help to develop adaptation strategies and interventions to reduce vulnerability.

The *Flowing Forward* methodology builds upon local-level vulnerability assessments conducted at community level, which are usually more focused on developing Community Adaptation Plans of Action (CAPAs) and tend to lack the landscape context necessary to see and make the links with larger scale ecosystem services. The *Flowing Forward* approach thus better assesses system-level vulnerabilities.

## The Flowing Forward Workshop

The core of the *Flowing Forward* process is a participatory workshop during which invited stakeholders and experts (especially community members, resource managers, academics, and technical experts) convene to determine the vulnerability of key systems in the landscape. The workshop is informed by an evaluation of trends in climate (temperature and precipitation), biodiversity, economic development and assets, information on ecosystems and infrastructure in the landscape, and trends in socioeconomics and demographics that serve as resources to guide the workshop and to inform the post-workshop assessment and analysis to prioritize vulnerabilities and develop adaptation measures. Thus, *Flowing Forward* follows the principle of "triangulation," where multiple information sources are synthesized to manage the uncertainty and bias, especially in a data-scarce environment, to provide the most robust analysis possible.

The workshop process has four key steps:

1. The target landscape is divided into **Units and Subunits** for assessment. These are typically key ecosystems or ecosystem components whose individual vulnerabilities combine to determine the total vulnerability of the larger basin or ecosystem. Units and Subunits are provisionally pre-determined by a team of experts with good knowledge of the landscape, and presented at the workshop. But these Units and Subunits are subject to modification based on feedback from the workshop participants.

2. When the Units and Subunits are accepted by the participants, they are scored and ranked according to the three IPCC components of vulnerability: i.e.,

exposure, sensitivity, and adaptive capacity. Guidelines for assessing, scoring, and ranking are provided to the participants.

3. Vulnerability scores are then computed to determine the most vulnerable Subunits to prioritize adaptation options.

4. Finally, participants discuss optimal adaptation strategies and interventions for specific Units and Subunits and discuss larger regional adaptation strategies, including key next-steps and priorities for the coming years of the program.

The process and outputs are subsequently summarized in a technical report that is circulated to the participants for final review and validation.

In Nepal, *Flowing Forward* has already been applied in the Indrawati sub-basin (2011) and in the Terai Arc Landscape (2014). For this assessment of the CHAL the community inputs were obtained through smaller scale vulnerability assessments previously undertaken by the Hariyo Ban Program, using the Climate Vulnerability and Capacity Assessment approach which was adapted by the Program to integrate ecosystem aspects. Several community adaptation plans of action (CAPAs) had been prepared using this approach in accordance with Nepal's Local Adaptation Plan of Action (LAPA) process,[1] working with local groups such as community forest user groups (CFUGs). However, because of the local-scaled focus of these plans they often lack an understanding of the larger landscape context of key trends in climate and development that directly and indirectly affect the vulnerabilities they identify. *Flowing Forward* was thus chosen in part to help provide this large ecosystem-scaled context for better, more integrated adaptation planning efforts at the landscape scale of the CHAL.

Other resource material used in the CHAL vulnerability assessment included:

- a desktop review of peer-reviewed climate science
- commissioned studies on broad trends in natural resource use, environment and biodiversity, socio-economic development and infrastructure development
- WWF modeling of projected shifts in forest types, and an assessment of climate change vulnerable and resilient forest vegetation
- a rough analysis of rainfall and temperature data collected from the Government of Nepal (GoN) Department of Hydrology and Meteorology stations in the landscape

All this research material was provided to participants in the three-day participatory workshop held in April 2013 in the landscape, and is synthesized in Part 3 of this report.

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[1] Nepal is one of the first countries to operationalize its NAPA at the local level. Developing community adaptation plans is part of Nepal's Ministry of Environment requirements for the LAPA framework.

The workshop was attended by local and regional stakeholders, including government decision makers, non-governmental organizations (NGOs), the private sector, and community leaders.

## Conceptual Framework of Vulnerability

*Flowing Forward* measures vulnerability according to its IPCC definition; i.e., as a function of exposure, sensitivity, and adaptive capacity. However, though this formula seems relatively simple, it can be challenging to measure these three components in practice, especially during a rapid three-day, stakeholder-based assessment. The *Flowing Forward* approach therefore modifies this formula to bring greater clarity to the ranking process, where vulnerability is calculated as a function of exposure and *resilience*, rather than sensitivity (Figure 1).

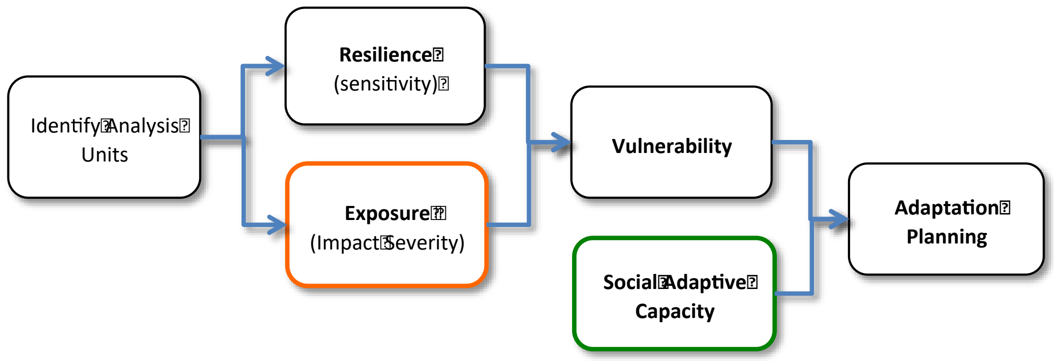


**Figure 1. The Flowing Forward workshop framework.**
Moving from left to right, Units of analysis in the landscape are first determined, followed by assessments of their resilience and exposure to determine vulnerability. Finally, Social Adaptive Capacity is assessed in developing adaptation interventions to address vulnerability. The colored boxes, Exposure and Social Adaptive Capacity, indicate components with additional steps not included here for simplicity.

*Flowing Forward* uses resilience because it focuses on the inherent qualities of systems in measuring vulnerability, rather than human response to climate change—which is typically how adaptive capacity is defined. Resilience of a system is defined by the qualities that allow it to absorb climate change impacts (sensitivity), and then recover from them (adaptive capacity). The human ability to respond—the more typical understanding of adaptive capacity—is also measured, but separately from the calculations of vulnerability for each system, and informs the development of adaptation interventions rather than ratings for vulnerability (Figure 1).[2]

To assess exposure and resilience, each system is rated on scales of 1-5 for a set of pre-defined measurement criteria for exposure and resilience, with 1 representing the most vulnerable and 5 the least. These are then averaged and calculated

[2] This is in part because the Units of analysis for social adaptive capacity are different than those systems rated according to their resilience and exposure capacity: information sources, policies, and institutions.

automatically in Microsoft Excel to produce final ratings of vulnerability for each Subunit. [3]

The final result is a set of rankings for all systems in the landscape, from most to least exposed, resilient, and vulnerable.[4] Participants then discuss the factors limiting or enabling adaptive capacity in the landscape to reduce vulnerability, focusing on policies, institutions, and information; i.e., the Social Adaptive Capacity.

With these results, participants then develop proposed adaptation interventions to address the most vulnerable Subunits and capacity constraints. These final rankings and proposed adaptation solutions are summarized in Part 4 of this document.

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[3] For more information on the *Flowing Forward* vulnerability function, see Annex 4.

[4] However, these scores are only indicators of qualitative discussions and not stand-alone, statistically rigorous data; they are intended to provide a simple means of prioritization.

# PART 3. BACKGROUND INFORMATION

## Overview of the Chitwan Annapurna Landscape

The CHAL spans the biogeographically diverse Gandaki River basin in central Nepal, extending from the tropical lowlands in Chitwan National Park to the tall Himalayan peaks in Annapurna Conservation Area, Manaslu Conservation Area and Langtang National Park. It is home to a wide range of climates and an array of microclimates that create extremely diverse ecosystems and habitats, from the cold, high-altitude semi-desert of the Trans-Himalayan Region to the seasonal, warm subtropics of the Churia hills and Terai floodplains. The consistent and predictable seasonal monsoon-driven climates help to create habitat for globally renowned biodiversity and the numerous ecosystem services—from live-giving water to medicinal plants—that support people within the landscape and thousands of kilometers beyond the CHAL boundary.

The CHAL (Figure 2) sits at the intersection between the wetter area of eastern Nepal and the drier western edge of the country (WWF Nepal 2013a). The divide is the Kali Gandaki River Gorge, the deepest gorge in the world, which acts as a biogeographic barrier for many species. Across these diverse areas, the CHAL has the same four major seasons typical to Nepal: the pre-monsoon (March-May), monsoon (June-September), post-monsoon (October-November), and winter (December-February).

The CHAL boundaries follow those of the Gandaki Basin in Nepal. The Gandaki is one of three major river basins that drain from Nepal into the Ganga River in India. It can easily be divided along the standard physiographic zones traversing east-west across the entire country: i.e., the High Himalaya, High Mountains, Middle Mountains, and Churia (or Siwalik) Range (Figure 2). The substantial climatic variation among these four elevation-based physiographic zones contributes to the existence of very different ecosystems (Table 1).

### Table 1. Climates of the Physiographic Zones of the CHAL

| Physiographic Zone | Climate | Mean Annual Precipitation (mm) | Mean Annual Temperature (°C) |
|---|---|---|---|
| High Himalaya and High Mountains | Arctic, Alpine, Sub-alpine | 150-200 | <3-10 |
| Middle Mountains | Sub-Alpine, Sub-tropical | 275-2,300 | 10-20 |
| Churia | Tropical/Subtropical | 1,100-3,000 | 20-25 |

Adapted from WWF Nepal (2013a)

Due to its unique climate, ecosystems, and culture the Trans-Himalayan Region is treated as an additional fifth zone for the purposes of this assessment. The Units for this assessment are nested within these physiographic zones.

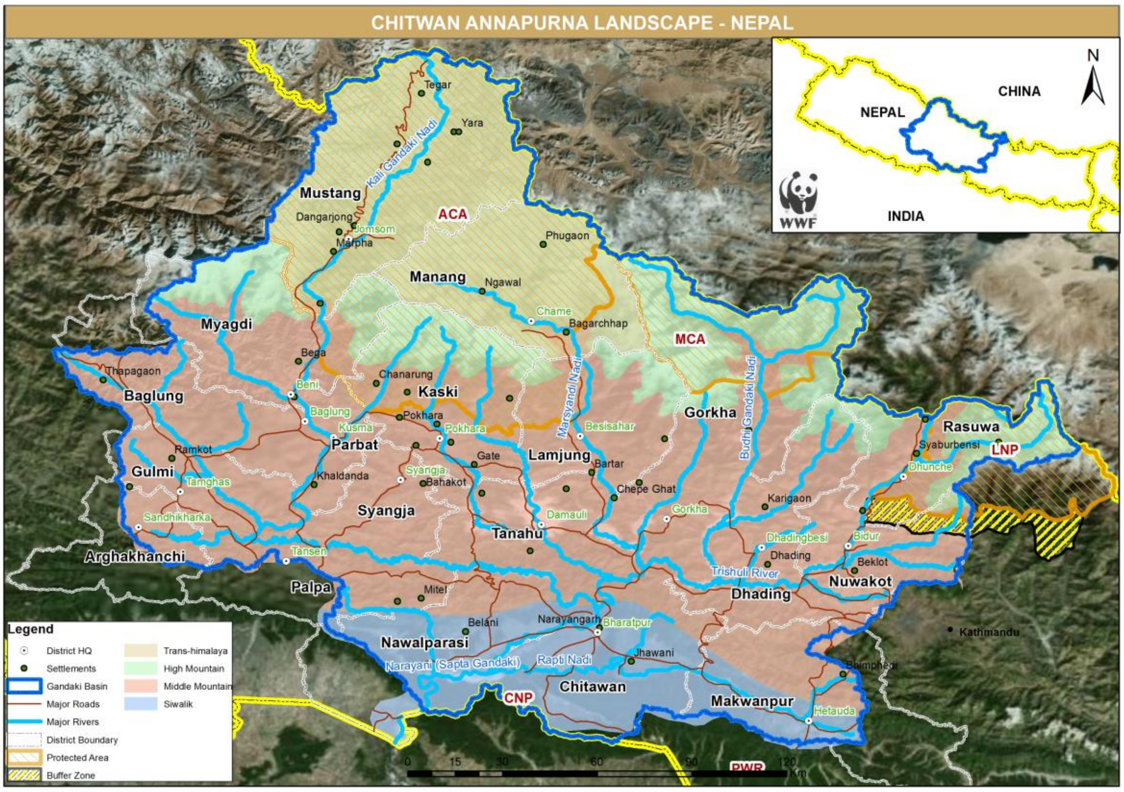


**Figure 2. Physiographic zones of the Chitwan Annapurna Landscape (CHAL).**
From north to south, the major physiographic zones are the Trans-Himalayan Region, High Mountains, Middle Mountains, and Siwalik.

## Development Trends in the CHAL: A 20-year Outlook

The CHAL is going through a period of rapid change, with much infrastructure planned or under construction, primarily new roads and hydropower facilities. The basin has substantial per-capita water resources, steep gradients, and proximity to national grid infrastructure that make hydropower an attractive renewable energy investment. Access is opening up to many remote areas as new roads are constructed. The tourism sector associated with world-renowned destinations is expanding, and manufacturing industries are growing, particularly in the Terai and near urban centers. At the same time, out-migration from rural areas in the hills and mountains continues as people move to urban centers and as migrant workers (especially men) seek employment opportunities elsewhere in Nepal, and outside the country.

While development is contributing to the national economy and improving the lives of the landscape's inhabitants, it is also creating enormous pressures on the ecosystems and biodiversity that attract tourists and provide the ecosystem services that support livelihoods and development and reduce disaster risk. And these pressures are increasing the exposure and sensitivity of many ecosystems to the impacts of climate change, in large part due to a lack of strategic planning at appropriate scales. Projects are largely being built to satisfy service needs on an ad-hoc basis without concern for larger potential negative impacts to surrounding communities, ecosystems, or climate considerations beyond their immediate locations or future conditions. Local communities in many parts of the landscape are already experiencing combined impacts of climate change and land use changes.

This section outlines the most important of these likely development trends in the CHAL in the next 20 years and their impacts on ecosystems and ecosystem services in the basin, both positive and negative.

### Livelihoods and Demographics

As is the case throughout Nepal, people in the CHAL are increasingly migrating out of distant rural mountain farming communities to urban and peri-urban areas of Pokhara and Kathmandu. This is evidenced by negative population growth in 14 of the 19 districts in the landscape, with districts in the lower-lying urban and peri-urban areas experiencing positive growth trends (WWF Nepal 2013a). This is accompanied by an ongoing shift away from typical subsistence-based farming livelihoods to income sources more often located in urban and peri-urban areas.

Livelihoods in the CHAL are generated by three primary sources: agriculture, tourism, and remittances. While agriculture had long been the dominant source of income for Nepalese nationwide, the latter two are increasing, with the expanding tourism sector increasingly supplementing the typical reliance on agriculture, and remittances—largely from male workers who labor abroad for months at a time—providing an even larger source of income to their families back home. In 2011 remittances contributed an average of 31% to household income nationally, and the population receiving remittances had more than doubled between 1996 and 2011, increasing from 23% to 56% (Central Bureau of Statistics, 2011).

Manang and Mustang Districts in particular have seen growing tourism rates since the 1970s, due to the world renowned trekking destination of the Annapurna Circuit, as well as their cultural significance including some famous and ancient Buddhist temples and holy sites (Aase et al., 2009). Tourism to the upper reaches of Mustang is facilitated in part by a new national road through the Annapurna Conservation Area, connecting the town of Jomsom to Pokhara (WWF Nepal, 2013a). Pokhara itself has greatly expanded as a tourism hub for the region.

These changes have implications for natural resource management. Farming is increasingly dominated by women as men seek employment abroad. But considerable amounts of rural agricultural lands are also being left fallow and abandoned, as larger segments of the population move into urban areas seeking economic opportunities in the tourism and services sectors. In the high mountains of Manang district as much as 60% of the land under cultivation in 1970 has been abandoned (Aase et al., 2009). Land tenure inequality—where poorer migrant farmers have limited ownership and small (less than 1 hectare) plots are inadequate to meet subsistence needs in many cases—is also driving the rural farming community toward alternative livelihoods in urban areas and abroad (WWF Nepal, 2013a).

At the same time, farming remains a primary source of livelihood, albeit challenged to provide food security for the large section of the population that continues to depend on it for subsistence and income generation. In a survey of rural farmers in 2012, only 24% produced sufficient food for one year, and only 33% for six months. Agricultural productivity in the CHAL is notably low in many areas, with farmers consulted for the WWF Nepal (2013a) study producing 16%, 8%, and 12% less rice, maize, and wheat, respectively than the national average. This can be attributed to a number of different climate and non-climate factors, including bad weather, uncertain monsoon rainfall, climate variability, inadequate and poorly maintained irrigation systems, low availability of good farmland, lack of a young labor force, low soil fertility, frequent livestock disease, and unscientific practices.

### Energy

Energy use in the CHAL—and throughout the country—continues to be dominated by biomass (including fuelwood and agricultural waste) and some imported fossil fuel. Though energy use data specific to the CHAL are limited, those at the national level are likely to reflect patterns in CHAL: 87% of total energy consumption in 2008/09 was derived from traditional biomass sources, 12% from commercial sources like grid electricity, coal, and petroleum, and only 1% from alternative sources like wind, solar, biogas, and micro-hydropower. Nearly all fuelwood consumption is for domestic purposes (99% of the total consumed in 2008/09). Given overall poverty rates and rural, subsistence-based, agriculture-dominated livelihoods throughout the country, continued reliance on fuelwood in the residential sector is not surprising (WECS, 2010).

Trends indicate growing energy use nationwide, with annual average consumption increasing by 2.4% during 2000-2009, which roughly tracks the GDP trend. Fuelwood consumption is increasing at the same rate, but the nation is also beginning to transition toward more sustainable sources, mostly solar which is growing at more than 200% annually. Still, growing fuelwood consumption is contributing to deforestation in the CHAL, which has become substantial enough to reduce wood availability, leading to localized fuelwood scarcity and subsequent energy demand crises (WWF Nepal, 2013a).

Nepal has for many years been unable to meet electricity demand nationally, with a large gap between supply and demand. Peak demand was projected at almost 900 megawatts (MW) for 2010, but with an installed supply capacity of only 689 MW there are blackouts and load shedding periods of up to 20 hours a day during the dry season, when flows for hydroelectric generation are significantly lower. This deficit has led to a national priority in developing the country's enormous hydropower potential (more than 42,000 MW are economically and technically feasible, according to a study by Soovacol et al., 2011), with a number of projects either planned or under development for the sub-basins in the Gandaki (WECS, 2010). These projects are discussed in much greater detail in subsequent sections on water use.

### Land and Resource Use

Land use in the CHAL is dominated by forests and agriculture that account for more than 50% of the total area, with the remaining area divided between high altitude exposed rock (classified as sand/bare soil), snow and ice cover, and grasslands and alpine meadows (Table 2).

### Table 2. Land Use in the CHAL

| Land Cover | Area (Ha) 2010 | Percent | % Change 1990-2000 | % Change 2000-2010 | % Change 1990-2010 |
|---|---|---|---|---|---|
| Forest | 1,136,709 | 35.5 | 0.4 | -0.1 | **0.3** |
| Agriculture | 677,456 | 21.1 | 1.8 | 0.3 | **2.1** |
| Sand/Bare Soil | 517,110 | 16.1 | -37.2 | 70.2 | **6.8** |
| Snow/Ice | 304,150 | 9.5 | 64.0 | -35.3 | **6.2** |
| Grasslands | 276,634 | 8.6 | 1.3 | -17.2 | **-16.1** |
| Alpine Meadow/Shrub | 260,682 | 8.1 | -8.6 | 3.5 | **-5.4** |
| Water | 32,969 | 1.0 | 0.0 | 0.4 | **0.4** |
| Total | 3,205,710 | | | | |

Source: WWF Nepal (2013a). Data are based on satellite imagery from 2010, and previous decades.

Trends in these major land uses over the last 20 years based on remote sensing indicate only small changes to the extents of forest and agricultural lands, but there have been fairly large reductions in grasslands (Table 2). But, because these are total area sums based on satellite data, they mask the reality of significant forest land conversion, with gains in national parks and protected areas offsetting otherwise substantial forest losses in lowland unprotected areas in the Churia and Middle Mountains due to infrastructure development, resettlement, and agriculture expansion (WWF Nepal, 2013a). It is also important to note the enormous fluctuations in sand/bare soil and snow/ice, again pointing to the challenges in accurately estimating land use change solely based on remote sensing, particularly in the complex topography of the CHAL. The substantial growth in high altitude exposed rock and reductions in snow and ice between 2000 and 2010 could, if correct, also be an indication of recent warming trends associated with climate change. More detailed research, based on higher resolution imagery and more accurate classifications is necessary to depict a clearer picture of current land cover in the landscape and determine if this is true.

### Mining

The current land use and development trends in the landscape are driving an increase in natural resource extraction, especially stone, sand and gravel mining, the primary source of building materials throughout Nepal. Mining is extensive in the alluvial plains of the major rivers in the basin, where naturally high sediment deposits provide rich sand, boulder and gravel resources. Though clearly necessary to provide building materials to support economic growth, current extraction methods are poorly regulated, resulting in numerous unintended negative environmental and social impacts that will only worsen as climate variability in the basin increases (WWF Nepal, 2014).

These impacts of large-scale sand and gravel mining include upstream channel degradation from “head cutting,” whereby the river progressively cuts away the streambed upstream from the mining site, which can change instream flow patterns, increase bank erosion; decrease vegetation cover due to increased flow rates; and destroy aquatic and riparian habitat due to riverbed degradation, lowered water tables, and general channel instability. Impacts also occur downstream: for example, mining can result in scouring of the riverbed due to increased water velocity and reduced sediment load. In some cases, the upstream and downstream channel degradation is so significant it has eroded roads and destroyed bridges, causing much economic losses and social hardships. Sediment scoured from upstream, downstream and the mine site itself is deposited downstream, and may result in “river cutting” where rivers change course. Agricultural and forest land may be lost through sediment deposit and river cutting. Rivers may cease to flow on the surface because of the thick layer of sediment. Though mining is prevalent throughout the Gandaki basin, the impacts are most severe in the lower reaches of the Seti River in Kaski and Tanahun districts and the Manohara River in Makwanpur near the Parsa Wildlife Reserve (WWF Nepal, 2014). More extreme weather events due to increasing climate variability (e.g. extreme rainfall and drought) will intensify these impacts.

### Water Resources and Hydropower

Agriculture remains the primary livelihood for most small land-holder inhabitants in the CHAL. As a result, it is also the dominant water use in the basin, followed by some localized higher municipal and industrial users. As is the case throughout Nepal, most farmers rely on rain-fed production due to the challenges associated with irrigation infrastructure development in the steep topography of the Himalayas. Irrigation is, however, used in the lower elevation areas (Middle Mountains, Churia, and Terai), where farmers practice *khet* and floodplain agricultural systems.

Water availability is also governed by huge seasonal fluctuations, because most of the annual precipitation falls in the summer monsoon months, forcing farmers and rural households to rely on snow and glacier melt, spring sources, and perennial streams for the remainder of the year. But many rural households do not have access to irrigation for crops or consistent spring water supplies for household uses.

Observations in the landscape indicate increasing scarcity, with decreased stream flows, drying of springs, and increased periods of drought during the dry season in the Middle Mountains and Churia. Though the exact cause of such declines is due in part to direct anthropogenic impacts from unsustainable and increasing agricultural water use, mining, loss of forest cover and infrastructure development, especially in these lower altitudes where development and migration are increasing, some communities in the Trans-Himalayan Region have observed major declines in snowfall in the last 5-6 years and indicate they may also be driven by recent warming trends caused by climate change (WWF Nepal, 2013a).

Exploitable hydropower potential in Nepal has been estimated between 43,000 and 83,000 MW. However, due to a number of technical, social, and environmental barriers—from poor transmission infrastructure to complex hydrology, high sedimentation rates, and local opposition—the country has only been able to develop 650 MW to date; less than 1% of national energy consumption in 2010 (Sovacool et al., 2011). Even when operational, the naturally high sedimentation rates, in combination with large seasonal fluctuations in stream flows, significantly reduce generation capacity. With precipitation patterns already becoming more variable due to increasing frequency and intensity of extreme weather events (storms and drought periods), climate change will further limit capacity and degrade facilities in the future (WWF Nepal, 2013a; WWF Nepal, 2014). High sedimentation rates are already affecting the 144 MW Kali Gandaki A dam, the country's largest. Due to its design this hydro station must continue to operate through high sedimentation, putting its turbines at risk of permanent damage and corrosion and ultimately shortening the lifespan of the facility (Sovacool et al., 2011; Asian Development Bank (ADB), 2012).

Even with this cautionary example of the many challenges facing the hydropower sector, Nepal's political leaders continue to push for massive, nationwide investments in hydropower dam construction to close the large gap between current supply and demand, and lessen the enormous burden placed on the national economy by frequent load shedding blackouts. A number of these are in the CHAL due to its proximity to the national grid and to Kathmandu, including the 600 MW Budi Gandaki and 128 MW Upper Trishuli reservoir dams (WWF Nepal, 2013a). Most dams in various stages of proposal, construction, or operation in the landscape are run-of-the-river design, which due to limited storage, will be ineffective in mitigating the current reason for load shedding—i.e., peak-load electricity demand—further calling into question the overall benefits of their development (ADB, 2012; WWF Nepal, 2013a).

Though these dams can be argued as important for future energy security, the stations already operating have had substantial negative social and environmental impacts. Communities have been forced to relocate. Though these families have been compensated and have found employment during project construction, these benefits are often temporary and have failed to support sustained livelihoods, ultimately leading to the same status quo poverty. For example, mitigation measures at Kali Gandaki A have proven incapable of providing continued income generation to families that previously relied upon a fishery for livelihoods (ADB, 2012).

Aquatic ecosystems and services have been further impacted by erosion, water quality degradation, and sedimentation increases during construction, and continue to experience the eco-hydrological consequences of impounded and fragmented rivers. On site, hazardous and solid wastes have been improperly disposed of, contaminating nearby soils and water supplies. More significantly, these rivers now have permanently altered flows, affecting sedimentation rates, water chemistry (dissolved oxygen, temperature), and flow patterns downstream, and block fish migration routes, including those of the endangered golden mahseer (ADB, 2012; Shrestha, 2003; Sharma, 2008).

Particularly worrisome is non-compliance with social and environmental mitigation intended to reduce these negative impacts post-construction. A review of Kali Gandaki A by project financer ADB 10 years after its construction found that operators had failed to implement vegetation rehabilitation in construction zones and along transmission lines; were not trapping and moving fish around the dam; and most worryingly, for climate change impacts, were not maintaining minimum required flows during the dry season; and had failed to install an early warning system for downstream communities for sudden increases in flows (ADB, 2012).

Proposed new dams, particularly those on the Kali Gandaki, Seti, Marsyangdi, and Trishuli rivers that are already impounded will worsen these existing impacts without substantial mitigation measures, while those on the currently free flowing Budi Gandaki and Daraudi Rivers will severely affect existing river and stream connectivity. There could be greater social impacts, particularly because several proposed dams are reservoir, rather than run-of-the-river design, creating a much larger footprint of displaced communities and permanently altered geology and ecosystems. Unfortunately, the weak processes for mitigating or lessening the social and environmental impacts of such massive infrastructure developments—like requirements for EIAs and enforcement of recommended mitigation measures outlined therein—seem likely to worsen with future hydropower development (Sovacool et al., 2011). In addition, Nepal does not yet have strategic environmental assessment legislation to require more complex assessments of a series of developments, such as a set of dams in a basin, or mixed large-scale developments (WWF Nepal, 2013a).

## Climate Trends and Projections in the CHAL

Climate change is now accepted as a critical threat to the Himalayas. But due to the complex climate and lack of representative historic data records it has been difficult to draw specific conclusions about what future climate is likely to resemble. Despite this, and due to the significance of climate to the Himalayan context, the IPCC Fifth Assessment Report highlights what is known about the implications of climate change in the region in a specific case study (IPCC, 2014). The main conclusions point to changes in phenology (Panday and Ghimire, 2012; Shrestha et al., 2012) and confirmation of glacial loss both due to climate change and anthropogenic black carbon. In the section that follows, the specifics of what is known and unknown are highlighted in more detail, given the convergence of community perceptions, climate trends and projections.

### Temperature

There is general agreement between observations and projections that temperature is increasing in the landscape. Minimum, maximum and average temperatures have been found to be increasing with a rate of warming that is greater than the global average (Shrestha et al., 2012). This is particularly true at higher altitudes (Manandhar et al., 2012). These increases are corroborated both by community level observations noted during community adaptation surveys (CAPAs) conducted for this project, as well as other peer reviewed literature on community perception of change in the region (Chaudhary & Bawa, 2011; Manandhar et al., 2012).

### Rainfall

Projections and trend analyses of rainfall totals and averages in the CHAL are highly variable (Manandhar et al., 2012). Although overall trends are inconclusive, there is observed evidence of an increase in consecutive dry days and an increase in the length of longest dry spells in some areas of the landscape (Manandhar et al., 2012). Similarly, there is anecdotal evidence that even though the direction of change in precipitation is unknown, there are changes in its pattern (IPCC 2014; Nepal Climate Vulnerability Study Team (NCVST), 2009), particularly of the monsoon. This observation is backed by community perceptions from community assessments (CAPAs), where people reported drier winters. Additionally, with the rising temperatures in the region, there has been both an observed and perceived shift of snowfall to rainfall in shoulder seasons at higher altitudes, ultimately reducing non-monsoon melt water which is important for floodplain agriculture and hydropower generation (Chaudhary & Bawa, 2011; Paudel & Andersen, 2011).

## Projected Impacts and Other Effects of Climate Change

General consensus is that glaciers in the upper catchment of the Gandaki are losing mass (Bolch, et al., 2012; Shrestha & Aryal, 2011). Because of the linkage between glaciers and river discharge it is believed that this will affect the seasonality of flows in the rivers, particularly increasing discharges in the dry pre- and post-monsoon seasons and decreasing annual minimum discharges. This is likely to be more severe in areas which rely more heavily on glacial melt as opposed to monsoon rains (IPCC, 2014). To date these changes are only anecdotally observed (Bolch, et al., 2012; Manandhar et al., 2012). Local communities' perceptions and observations indicate a general drying of spring sources, which are commonly used for multiple household needs including drinking water (Chaudhary & Bawa, 2011; Manandhar et al., 2012).

Also important for local livelihoods, particularly for those dependent on agriculture, is the emergence of new pests and diseases in specific places. This has been reported widely in the CAPAs. Although there are no empirical studies specifically in the CHAL to verify these community observations, the findings correspond with those in two peer-reviewed studies of communities in the broader area (Chaudhary & Bawa, 2011; Manandhar et al, 2012).

As temperatures rise and precipitation patterns change, vegetation that is critical to conservation of important wildlife species in the landscape will also change, forcing many species to move north to higher altitudes. In a climate envelop model for the CHAL based on downscaled projections of Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report scenario A2A, Thapa et al. (2015) identify significant changes to forest vegetation over the coming decades and century due to climate change. The projections show there could be substantial changes in forest vegetation in the Middle Mountains and Churia, but the forest vegetation of the higher elevations is relatively resilient to climate change (Figure 3-and 4).

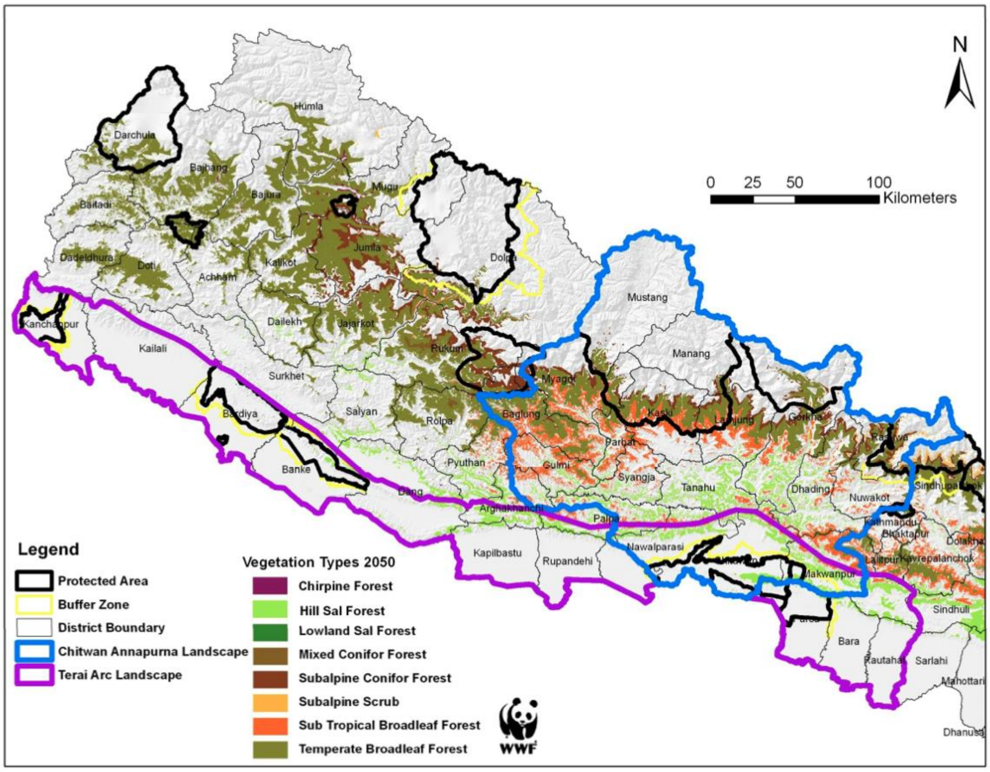


**Figure 3. Resilient Vegetation in 2050 under A2A Scenario.**

These patches represent the areas where the vegetation composition is not expected to change by 2050 under the A2A climate projection, and do not represent forest loss or fragmentation due to anthropogenic drivers. From Thapa et al. (2015). **Note**: this study used the IPCC A2A greenhouse gas scenario (IPCC 2007). The A2A scenario is the highest IPCC emissions scenario; it was chosen because recent assessments indicate that emissions during the 2000's exceeded the highest predictions by the IPCC. Because of uncertainties of climate projections, these maps can only serve as broad indicators of potential change in the long term, and should be considered as one tool among others to provide guidance in landscape conservation planning. They should be evaluated against other available knowledge.

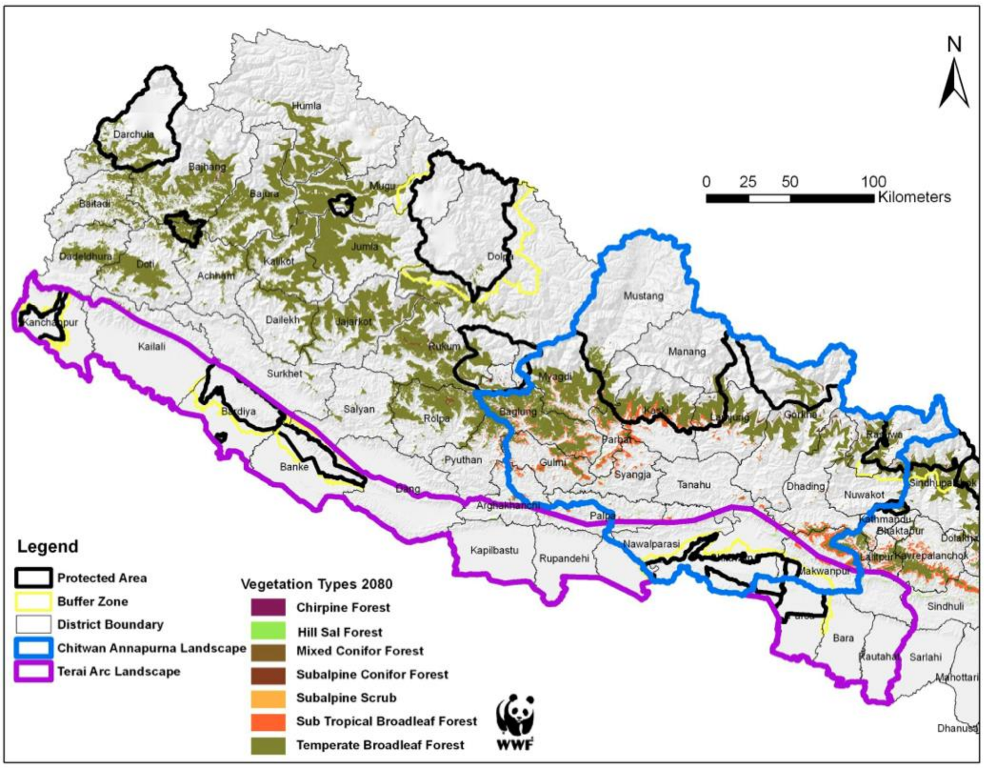


**Figure 4. Resilient Vegetation in 2080 under A2A Scenario.**

These patches represent the areas where the vegetation composition is not expected to change under the A2A climate projection by 2080, and do not represent forest loss or fragmentation due to anthropogenic drivers. From Thapa et al. (2015). **Note**: this study used the IPCC A2A greenhouse gas scenario (IPCC 2007). The A2A scenario is the highest IPCC emissions scenario; it was chosen because recent assessments indicate that emissions during the 2000's exceeded the highest predictions by the IPCC. Because of uncertainties of climate projections, these maps can only serve as broad indicators of potential change in the long term, and should be considered as one tool among others to provide guidance in landscape conservation planning. They should be evaluated against other available knowledge.

Major efforts to reduce current deforestation should focus on securing the resilient forests as climate refugia. Thapa et al. (2015) provide a broad, basin-scale spatial analysis of intact forests that will likely be resilient to climate change. Some of these include micro-refugia in river valleys and north and northwest facing slopes. The outputs from this analysis can be used as a guide to identify and conserve these refugia as part of the landscape or basin-scale conservation plan.

# PART 4. CLIMATE VULNERABILITY ANALYSIS

## Climate Vulnerability Workshop for the CHAL

With all the background information from previous sections as a guide, a participatory workshop was held in Pokhara in April 2013 to rank and prioritize key infrastructure, ecosystems, and species in the landscape for their vulnerability and to develop initial adaptation actions moving forward. Over 60 stakeholders participated in the three-day workshop.

### Workshop Objectives

The broad objectives of the workshops were to**:**

1. Develop an understanding of the potential climate change impacts facing the Chitwan Annapurna Landscape.
2. Prioritize adaptation interventions at the landscape level (which was roughly concordant with the Gandaki basin).
3. Assess the landscape-wide vulnerabilities viz-a-vis the National Adaptation Programme for Action (NAPA) and LAPAs to develop ecosystem-based adaptation strategies for 'climate-smart' landscape management.

### Units and Subunits used in the Flowing Forward Approach

Some man-made and natural system Units were nested within the five physiographic zones: Trans-Himalayan Region, High Himalaya, High Mountain, Middle Mountain, and Churia (Tables 3 to 7 below).[5]

### Trans-Himalayan Region (3,000-4,500 m)

Located in the northwestern region of the CHAL between the border with China and the Himalayan range, and in the rain shadow of the Himalayas, the Trans-Himalayan Region (Figure 5) has a cold, dry climate (Table 3). Though the elevation ranges from

[5] However, due to the composition of workshop participants and to provide greater efficiency in the workshop process, they were further divided into broad thematic categories, each representing one breakout group: that were identified are Forests, Freshwater systems (other than rivers), Rivers, Agriculture, Infrastructure, and Species.

approximately 1,800 m to higher than 8,000 m above sea level, 96% of the region lies above 3,000 m, and 43% of that above 5,000 m (Paudel & Andersen, 2011). Rangeland is the primary land use type (43%), followed by much smaller percentages of forest (4.5%) and cultivated land (1.3%) (Figure 5). Altitudes lower than 3,000 m are generally warmer and receive more mean annual rainfall (880 mm) in comparison with the coldest, driest reaches of upper Mustang, which only received an average of 164 mm per annum in the 35 years between 1973 and 2008—roughly 5,000 mm less than the wettest part of the country in the Middle Mountains near Pokhara (WWF Nepal, 2013a; Paudel and Andersen, 2011). The lower reaches of the Trans-Himalaya receive most of the precipitation as rainfall during the summer monsoon months of June to September and snow during winter from December to February. At higher altitudes, the only precipitation is snow, falling primarily during the monsoon months.

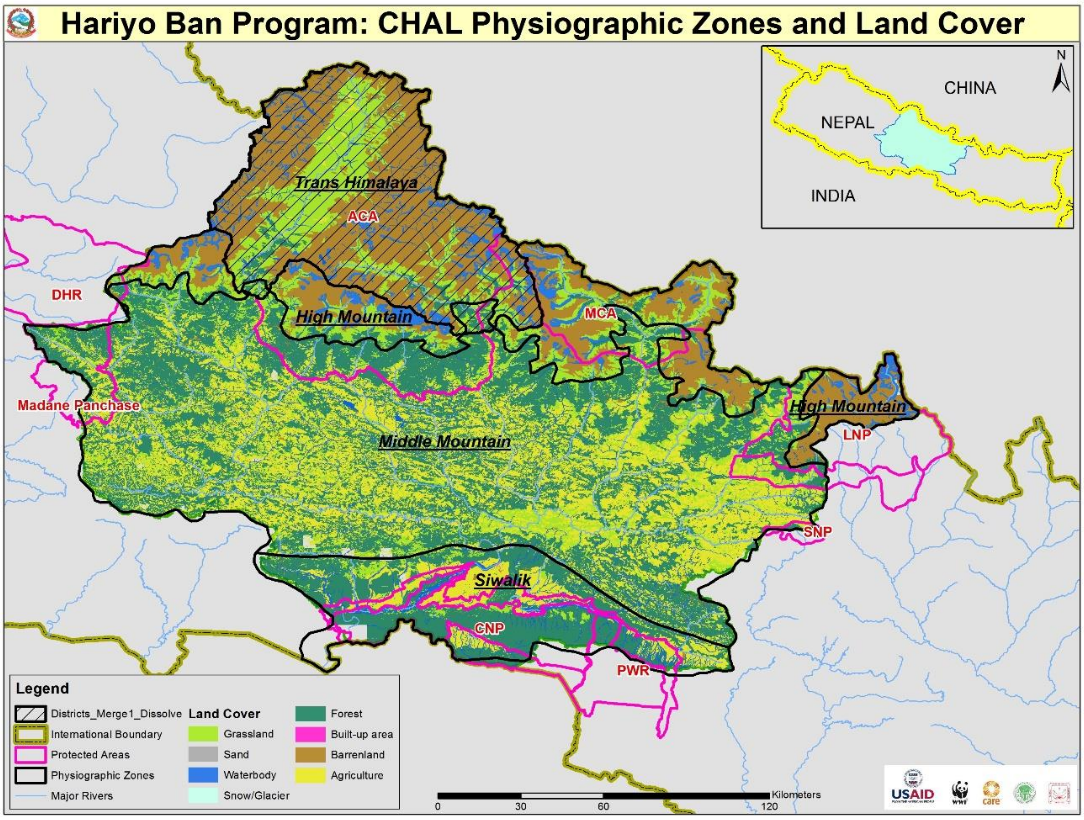


**Figure 5. Land Use and Physiographic Zones of the CHAL**
**Note**: 'High Mountain' in the figure combines High Mountain and High Himalaya

**Table 3. Average and Record Temperatures in the THR (Mustang and Manang Districts)**

| | Min (°C) | Max (°C) | |
|---|---|---|---|
| Pre-Monsoon (Mar-May) | 4.5 | 17.7 | |

| | | | |
|---|---|---|---|
| Monsoon (June-Sept) | 11.3 | 20.9 | |
| Post-Monsoon (Oct-Nov) | 4.3 | 15.9 | |
| Winter (Dec-Feb) | 1.2 | 11.2 | |
| Record | -12.4 | 25.9 | |

**Note**: All temperatures, excluding records, are mean annual averages. Adapted from Paudel and Andersen (2011).

The harsh, cold climate results in relatively slow-growing vegetation and low productivity ecosystems. Not surprisingly agricultural productivity is limited as well (Paudel & Andersen, 2011; Bhattarai et al., 2010). As a result, the region's inhabitants have for centuries relied on a nomadic pastoral lifestyle, unlike the farmers of the lower altitudes who can rely on longer growing seasons and a greater diversity of livelihood sources.

Table 4 defines and describes the man-made and natural system Subunits in the Trans-Himalayan region in greater detail. This information was used in the Flowing Forward vulnerability assessment.

**Table 4. Subunits of the Trans-Himalayan Region and their socio-ecological roles in the CHAL**

| **Trans-Himalaya Region (THR) (3,000-4,500m)** | | |
|---|---|---|
| **Subunit** | **Definition** | **Ecosystem Services and Importance** |
| *Semi-desert Coniferous Forest* | Dominated by hillside scrubby vegetation, with very low annual precipitation levels, this is a cold semi-desert forest with small patches of pine and juniper trees, but mostly bare sandy desert. | Source of Kali Gandaki River; home to musk deer and other important species of the snow leopard prey base; fuelwood for local communities; limited fodder for some livestock in grassier areas, and non-timber forest products (NTFPs) like the highly valuable yarsa gumba, or caterpillar fungus (Jolly, 2011) |
| *Floodplain Agriculture* | The normally dry river beds of rivers and streams in the lower altitude valleys of the THR; entirely dependent on river flows and flood pulses for water. | Used by farmers to plant hearty crops like apples, buckwheat, and oats. |
| *Bari Agriculture* | Small, imperfectly leveled outward-sloping hillside plots upslope from floodplains, these are entirely rainfed agricultural production areas. | Farmers typically follow rotational cropping patterns with fallow periods, growing maize, finger millet, wheat, barley, and potato. |

| | | |
|---|---|---|
| *National Roads* | Main highways that run east-west and north-south across the country, including roads connecting to regional district headquarters; typically engineered and designed for proper drainage and gradation. Recent construction has brought new connections between Mustang and Manang districts to larger urban areas of Pokhara and the Middle Mountains. | Benefits to local livelihoods and wellbeing through easier access to markets, education and health care. Negatively impacting the landscape in the construction process due to improper materials disposal (simply pushed over the side into rivers and floodplains, changing river morphology), and dynamiting loosening already unstable soils, increasing an already high risk of landslides for nearby communities (WWF Nepal, 2014; Paudel & Andersen, 2011). |

### High Himalaya (above 5,000 m)

Encompassing all of the high-altitude areas outside of the Trans-Himalayan Region, the High Himalaya comprises the cryosphere and rocky outcroppings above the alpine zone. It includes the glaciers and snowfields that are very important water sources to ecosystems and communities downstream, but these areas also support high-elevation species such as snow leopards and blue sheep and generate revenue from mountain tourism. The Annapurna Conservation Area is the most popular tourism destination in Nepal, with a large percentage of visits to more technical mountaineering destinations, as well as the more remote cultural and religious destinations in Mustang (WWF Nepal, 2013a).

At these relatively higher altitudes (above 5,000 m) where ecosystem services and human populations are limited, workshop participants chose to only assess the vulnerability of the cryosphere (Table 5) considering its importance as a critical water source during the dry season.

**Table 5. Subunits of the High Himalaya and their socio-ecological roles in the CHAL**

| Subunit | Definition | Ecosystem Services and Importance |
|---|---|---|
| *Cryosphere* | Glaciers, snowfields, and rocky outcroppings of the higher altitude areas of the High Himalaya. | Downstream water supplies, particularly during pre- and post- summer monsoon when rainfall is considerably reduced.<br><br>Especially important for communities in THR that receive less rainfall. |

### High Mountains (3,000-5,000 m)

Below the cryosphere, but still home to a colder, drier climate where precipitation typically falls as snow in the winter months, the High Mountain zone (Figure 5) is generally limited to alpine and rangeland ecosystems, with some sub-alpine forests in the lower altitudes, along the southern margins. Total annual precipitation levels at altitudes as high as 4,500 m have been measured as high as 5,000 mm (Kansakar et al., 2004).

In this more hospitable lower altitude climate, a greater diversity of ecosystems provides several critical services to relatively sparse, but not insignificant human populations. The Subunits selected for analysis in the High Mountain zone are in Table 6.

### Table 6. Subunits of the High Mountains and their socio-ecological roles in the CHAL

| Subunit | Definition | Services and Importance |
|---|---|---|
| *Alpine Scrub and Meadows; Rangelands* | A large percentage of the High Mountains; mix of open pastures, meadows (locally referred to as *karka*), and high alpine scrub vegetation like combined juniper-rhododendron scrub, home to a high diversity of medicinal and aromatic plants (MAPs). | MAPs supporting local livelihoods, including various caragana species and the conflict-prone caterpillar fungus (*Cordyceps sinensis);* grazing lands for herding communities; source waters for several rivers; tourism for thousands of trekkers in the Annapurna Conservation Area (ACA), and habitat for charismatic species like the snow leopard and its prey species like the blue sheep. |
| *Alpine Coniferous Forest* | Dominated by fir (*Abies spectabilis*), birch (*Betula utilis*), spruce, pine, and juniper, and some *Rhododendron* in the lower reaches closer to the Middle Mountains. | Habitat for red panda, musk deer, and black bear; water supplies from spring sources; NTFPs and MAPs like *Swertia* (chiraito), kutki (medicinal Himalayan bitter root), *Bergenia* (locally known as pakhanbet) for domestic use and sale; and tourism in the ACA and Langtang. |
| *High Altitude Lakes* | Numerous high altitude lakes and wetland habitats with mostly clear, nutrient-poor waters, including the 15 lake and pond Gosaikunda complex, a Ramsar site in Langtang National Park. | Migratory bird habitat; river and stream source for multiple watersheds and sub-basins; livestock and community drinking water.<br><br>Gosaikunda is source for the Trishuli River, home to a number of International Union for Conservation of Nature (IUCN) Red-listed endangered flora and fauna, and is an important Buddhist and Hindu religious pilgrimage site. |
| *Spring sources* | Small ground sources throughout the region, originating from rainfall, snow and glacial melt higher in the catchment. | Drinking water supplies critical to local populations, wildlife, and livestock; hot springs (Marjung) serve as tourist destinations. |

### Middle Mountains (1,200-3,000 m)

The more temperate, lower elevation Middle Mountain areas (Figure 5) of the CHAL experience the highest amounts of precipitation in the basin, creating rich biodiversity and numerous ecosystem services. Due to this more favorable climate, agricultural production and human populations are much denser, resulting in land use dominated by large swaths of agriculture (Figure 5), including all four types of production typical to Nepal; i.e., from higher elevation *bari* terraced agricultural lands to the much larger tracts of the floodplains. Land cover in this zone include large areas of temperate, sub-alpine forests in the higher latitudes, including intact forests protected within the Annapurna Conservation Area. The largest urban area in the landscape, Pokhara, is also found in the Middle Mountains zone.

Not surprisingly, because of this richer natural and agricultural productivity associated with the more hospitable climate, more man-made and natural systems were selected for the vulnerability assessment process than in the High Mountains. The Subunits representing the natural systems include the Temperate Coniferous Forest, Upper Temperate Broadleaf Forest, Lower Temperate Broadleaf Forest, Spring Sources, and Middle Mountain lakes, while the man-made Subunit systems include *bari, khet, pakho, tar* (irrigated and non-irrigated) and Floodplain Agriculture, and National Roads (Table 7).

**Table 7. Subunits of the Middle Mountains and their socio-ecological roles in the CHAL**

| **Natural Systems** | | |
|---|---|---|
| **Subunit** | **Definition** | **Ecosystem Services and Importance** |
| *Temperate Coniferous Forest* | Dominated by Himalayan blue pine (*Pinus wallichiana*), deodar cedar (*Cedrus dodara*), Himalayan cypress (*Cupressus torulosa*), Himalayan hemlock (*Tsuga dumosa*), west Himalayan fir, and red pine. | Habitat for red panda, musk deer, and black bear; water supplies from drinking water springs; erosion control; groundwater recharge; fuel wood; NTFPs; and tourism revenue in the ACA. |
| *Upper Temperate Broadleaf Forest* | Dominated by brown oak (*Quercus semicarpifolia*), especially on southern-facing slopes, bamboo (locally called *nigalo*), laurel (*lokta* in Nepali) used for hand-made Nepali paper, and *Rhododendron* spp. | Spring sources, slope stabilization and erosion control, notable biodiversity habitat, tourism in the ACA, and NTFPs and MAPs, including kutki, medicinal early marsh orchid (*panch aaunle*), stinging nettle (*chalne sisnu*), *nirmasi*, *Aconitum* (*bish* in Nepali), bay-berry (*kafal*), wild mushrooms and wild garlic. |
| *Lower Temperate Broadleaf Forest* | Occurring between 2000-2700 m in the west and 1700-2400 m in the east, these forests are dominated by alder (*Alnus nitida*), *Castanopsis (C. tribuloides* and *C. hystrix*), multiple species of oak, and bamboo. | Notable NTFPs and MAPs include *sabai* grass, found on cliffs and used for making rope, paper and brooms; cinnamon (*dalchini* in Nepali), asparagus, and soap-nut (*ritha*). Located at lower altitudes, these forests are relied upon heavily by local populations for fuelwood and NTFPs. |
| *Spring Sources* | Small ground sources originating from snow-melt, rainfall, or glaciers. | Drinking water supplies critical to wildlife, local populations and their livestock, particularly in rural areas. Hot springs attract tourism, particularly in Tatopani in the ACA, but are numerous throughout the landscape as well. |
| *Middle Mountain Lakes* | Similar to High Mountain lakes, but with lower clarity and more nutrients; they include Phewa lake and Kamal Pokhari in Pokhara; the seven lakes of Lekhnath in the Pokhara valley (Khaste, Rupa, Begnas, Maidi, Dipang, Neurani and Gundi); Buchharto tal and Titi lake. | Habitat for migratory birds, source waters for rivers and streams in various watersheds, drinking water for local populations and their livestock, and fish stocks, including substantial populations of trout in Phewa lake that feed locals and tourists in Pokhara. |
| **Man-made Systems** | | |
| **Subunit** | **Definition** | **Ecosystem Services and Importance** |

| | | |
|---|---|---|
| *Bari Agriculture* | Small, imperfectly leveled outward-sloping plots on hillsides upslope from floodplains, entirely rainfed. | Farmers typically grow maize, finger millet, barley, wheat, mustard, or potatoes on rotations with fallow periods. |
| *Pakho Agriculture* | Slopes terraced to roughly 30-35 degrees on the steeper grades of the hillsides of less intensive agriculture, with Nepali khoria (slash and burn) practiced widely. | Typical crops are potato, maize, black lentil, horse lentil, beans, millet and colocasia. |
| *Khet Agriculture* | Usually lowland, relatively flat, small terraces irrigated during the dry season (smaller plots, alluvial soil and high water retention make irrigation feasible). | Cropping patterns of rice to wheat to fallow, or rice to wheat to maize, alongside some mustard, potato, and vegetable production; higher intensity agriculture practiced for a short season where water is available on river banks, at altitudes 1,200 m or below. |
| *Floodplain Agriculture* | River and stream beds in the lower altitude valleys that flood every year during the monsoon, providing rich nutrients and sufficient water for agricultural production. | |
| *Tar Agriculture (irrigated)* | Large, flat highland areas near floodplains. | Rice, wheat, mustard, potato, and vegetables. When irrigated and water is available, there is a short season of intensive agriculture. |
| *Tar Agriculture (rainfed)* | Same lands as the irrigated Tar, but different crops are grown due to reliance on rainfall. | Maize, finger millet, wheat, barley, and mustard on rotations with fallow periods. |
| *National Roads* | Multiple national roads cut through the Middle Mountains, both east-west and north-south, including the two recently completed roads into the THR, and the east-west highway between Pokhara and Kathmandu. | Critical to the CHAL economy, reducing cost of goods and easing transportation throughout the basin. |

### Churia (Siwalik) Range (below 1,200 m)

The hills of the Churia (or Siwalik) range (Figure 5) and the plains of the Terai below have warmer subtropical and tropical climates with high rainfall. This region supports a rich biodiversity, including notable wildlife species such as tiger, rhino, elephant, and gharial. The much warmer tropical to subtropical climate allows for greater natural productivity in both ecosystems and agricultural production areas. As a result, and in part due to its easier access to national infrastructure, it is the most heavily populated of the four zones, creating increasing pressures on the region's aquatic and forest ecosystems through expanding agricultural production and land conversion and increasing infrastructure development (WWF Nepal, 2013a; WWF Nepal, 2014).

Reflecting these trends in a region where man-made and natural systems are increasingly intertwined, participants prioritized the following Subunit systems for vulnerability assessment during the workshop: Subtropical Broadleaf Forests, Oxbow Lakes, Ramsar Sites, and Spring Sources for natural systems and *Bari, Khet, Pakho, Tar* (irrigated and non-irrigated) and Floodplain Agriculture, and National Roads for man-made systems (Table 8).

**Table 8. Subunits of the Churia and their socio-ecological roles in the CHAL**

| **Natural Systems** | | |
|---|---|---|
| **Subunit** | **Definition** | **Ecosystem Services and Importance** |
| *Subtropical Broadleaf Forests* | Typical species include: tea (*Schima wallichii*) and beech (*Castanopsis indica*); riverine forests of mahogany (*Cedrela*) and silk trees (*Albizzia*) along large rivers in foothills; Nepalese Alder (*Alnus nepalensis*) widespread along streams and moist places. Additional species include kyamun (*Cleistocalyx operculatus*), jamun (*Syzygium cumini*), sal (*Shorea robusta*), *Terminalia, Mellotus*, bamboo, chiuri (used for ghee), and soapnut | Flow regulation and rainfall recharge; river bank stabilization and erosion control; biomass for cooking; and numerous NTFP and MAP species including snakeroot (*Rauvolfia serpentina*), harro, barro, amala, and nim. |
| *Oxbow Lakes* | Old river curves or meanders that eventually become isolated wetlands as river courses gradually change over time. | Nutrient cycling and water quality; unique, high productivity habitat for important and endangered bird, plant, and aquatic species. |
| *Ramsar Sites* | Wetlands of international importance that contain a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate bio-geographic region; the largest is Beeshhazar Tal, a 3,200-hectare oxbow lake system in the buffer zone of Chitwan National Park. | Wildlife corridors (Barandabhar) and watering holes for notable species like the Bengal tiger, gharial, rhino, otter and numerous bird species, which are substantial draws for the local tourism industry and locally dependent livelihoods. |
| *Spring Sources* | Small ground sources of water, originating primarily from rainwater. | Important drinking water supplies for wildlife, and local communities and their livestock; and irrigation. |
| **Man-made Systems** | | |
| **Subunit** | **Definition** | **Ecosystem Services and Importance** |
| *Bari Agriculture* | Small, imperfectly leveled outward-sloping plots on hillsides upslope from floodplains, entirely rainfed | Maize, finger millet, soybeans, upland rice, and black gram (lentils) on rotations with fallow periods |

| | | |
|---|---|---|
| *Pakho Agriculture* | Slopes terraced to roughly 30-35 degrees on the steeper grades of the hillsides of less intensive agriculture, with Nepali khoria (slash and burn) practiced widely. | Typical crops are potato, maize, black lentil, horse lentil, beans, millet and colocasia. |
| *Khet Agriculture* | Usually lowland, relatively flat, small terraces irrigated during the dry season (smaller plots, alluvial soil and high water retention make irrigation feasible) | Cropping patterns of rice to wheat to fallow, or rice to wheat to maize, alongside some mustard, potato, and vegetable production; higher intensity agriculture practiced for a short season where water is available on river banks, at altitudes 1,200 m or below. |
| *Floodplain Agriculture* | River and stream beds in the lower altitude valleys that flood every year during the monsoon, providing rich nutrients and sufficient water for agricultural production. | |
| *National Roads* | | Critical to the CHAL economy, reducing cost of goods and easing transportation throughout the basin. |

In addition to these Subunits, some Units—the Rivers, Species, and Infrastructure—were also analyzed outside of any specific physiographic zone because they cut across multiple zones (e.g., rivers that span the entire CHAL) or have such universal aspects as to not warrant zone-specific assessment (e.g., rural settlements). Furthermore, in many cases, community level assessments already exist, and it was therefore important not to repeat that work, and instead try to integrate broader level implications of community level vulnerability into this larger landscape assessment.

### Rivers

The major sub-basins of the Gandaki basin were assessed to prioritize future adaptation work at that scale and to provide a more holistic assessment of entire rivers, from source to confluence. These rivers provide multiple critical services to people and ecological communities throughout the landscape, but are already under pressure from rapid, uncoordinated and unplanned roads and hydropower infrastructure development. This pressure will only increase with the impacts of climate change.

River valleys and the rivers currently provide migration routes for fish and birds; as climate change advances they will become important routes for large numbers of plant and animal species seeking cooler, damper conditions at higher altitudes and in climate refugia in response to climate change. Many narrow river valleys are themselves likely to be climate refugia because of their steep slopes, limited sunshine and cooler temperatures.

The rivers in Table 9 represent the nine major sub-basins of the landscape which feed into the Gandaki River, which eventually flows into the Ganga in India. Those with multiple existing and planned hydropower dams are at greatest risk to permanent changes in their ability to provide key ecosystem services in the landscape.

### Table 9. Major sub-basins of the CHAL

| River | Overall Importance |
|---|---|
| Seti | Numerous critical ecosystem services, including sediment transport for sand and gravel mining operations that provide construction materials throughout the landscape; important corridor between Chitwan and ACA |
| Marsyangdi | Ganga Purna and Tilicho lake as a source, flows down to Mugling |
| Kali Gandaki | Damodar Kunda, Chunup Khola as sources, 3000-5000 m, alpine to subtropical, deepest gorge in the world |
| Trishuli | Gosaikunda to Mugling (part of the upper basin is in China), alpine to tropical, represents coniferous to sal and riverine forest, significant corridor from upstream to downstream |
| Narayani | Inflows from 7 sub-basins; sub/tropical forest and riverine forest; crocodile and dolphin; flows along Chitwan NP |
| Madi | Sub-catchment of Seti; important for biodiversity and intact forests; part of CNP-ACA corridor |
| Daraudi | Sub-catchment of Marsyangdi; important for connectivity as it is still free flowing |
| Rapti | Low-lying sub-basin in Siwaliks and Terai; important for irrigation and for maintaining grasslands and wetlands in CNP and Parsa Wildlife Reserve |
| Budhi Gandaki | Sub-catchment of the Trishuli, draining through Manaslu Conservation Area; important for connectivity |

## Species

There are several notable important endangered species of conservation importance in the landscape. Some plant species with medicinal and other values and charismatic animals with tourism appeal are important to support livelihoods of the people, while other species (from plants and insects to birds and mammals) are important to sustain ecosystem functions. Several species are also indicators of overall ecosystem health because of their sensitivity to ecological change. The species selected for this analysis were gharial, snow leopard, red panda, rhino, tiger, golden mahseer, wild dog, hornbill, migratory birds, and orchids (Table 10). While the habitats for some species are limited to a single physiographic zone, other species extend across multiple zones. But the habitats of the former are affected by upstream impacts. Therefore, the species were assessed at the landscape scale.

### Table 10. Species chosen as Subunits for climate vulnerability analysis in the CHAL

| Species |
|---|

| Subunit | Definition | Ecosystem Services and Importance |
|---|---|---|
| *Gharial* | *Gavialis gangeticus*; a crocodilian native to the Indian subcontinent; has undergone both chronic long-term and rapid short-term decline due to fishing impacts and malicious killing; currently listed as critically endangered by the IUCN (Choudhury et al., 2007). | Tourism in CNP and its buffer area; serves as an indicator species of freshwater quality and overall aquatic ecosystem health in the wetlands of the Siwaliks and CNP. |
| *Snow leopard* | *Panthera uncia*; native to the mountain ranges of Central Asia, occupying alpine and subalpine areas generally 3,350 and 6,700 meters; IUCN Red List of Threatened Species as Endangered; population estimates are somewhat uncertain, their estimated decline due to retaliatory killing and poaching (WWF, 2013b; Jackson et al., 2008). | Cultural and religious significance for locals and mountain tourists that track it in hopes of a sighting, and is also an important indicator of overall ecosystem health; declining numbers indicate declining health. |
| *Red panda* | *Ailurus fulgens*; small arboreal mammal native to the eastern Himalayas and southwestern China; feeds mainly on bamboo, but is omnivorous; IUCN listed as vulnerable; threatened by habitat loss and fragmentation due to deforestation and poaching (Wang et al., 2008). Found in the ACA, Langtang National Park (LNP), and Manaslu protected areas; majority of its habitat is outside protected areas in the Middle and High Mountains (WWF Nepal, 2013c). | Important for tourism and cultural reasons, and indicates overall health of temperate, broadleaf, and sub alpine forests. |
| *Rhino* | Greater one-horned rhinoceros: one of the three Asian rhino species; currently classified as vulnerable on the IUCN Red List (Talukdar et al., 2008); its numbers have been growing due to recent conservation successes, particularly in Nepal; faces threats from poaching driven by the global black market for rhino horn. | The second largest single population in the world is found in CNP, attracting substantial tourism income to the area, but also indicating the overall health of grassland ecosystems in the CHAL (WWF Nepal, 2013d). |
| *Tiger* | Classified as endangered by the IUCN due to continuous poaching threats—with only approximately 2,000 estimated left in the wild—the Bengal tiger's numbers have grown in Nepal in recent years, with a 63% increase since 2009 due to conservation successes in and around the country's national parks in the Terai, including CNP (Chundawat et al., 2011; WWF, 2013e). | The population is a similar draw for tourism income in the landscape, but even more importantly indicates the overall health of multiple ecosystems, including lowland tropical and subtropical forests and alluvial floodplain grasslands. |

| | | |
|---|---|---|
| *Golden mahseer* | Freshwater migratory fish species found in cold and snow fed water of the Nepali Middle Mountains and Siwaliks; classified endangered, it faces overfishing, habitat encroachment, significant chemical and physical alteration of habitat caused by urbanization and development (Jha & Rayamajhi, 2013); hydropower expansion is threatening viability through blocking upstream migration. | Important to sport-fishing tourism; is a highly regarded local protein source; indicates overall health and connectivity of the river systems in the landscape. |
| *Wild dog* | Asiatic wild dog (*Cuon alpinus*); currently under severe decline, remaining numbers estimated at less than 2,500 individuals; photographed using camera traps in 2011 in both the eastern and western reaches of the Siwaliks in CNP and sightings reported in LNP in 2000 (Thapa et al., 2013). | Like the other prey species analyzed for their vulnerability, they serve an important role in the ecosystems of the Siwaliks as indicators of healthy, intact forests and prey base. |
| *Hornbill* | Currently listed as Near Threatened by the IUCN, the great hornbill (*Buceros bicornis*) is mostly limited to protected areas in Nepal; populations are suspected to be under rapid decline due to deforestation, forest degradation, and land conversion, all of which are significant threats in the Siwaliks of the CHAL (Birdlife International, 2013; WWF Nepal, 2013f). | Its preference for forests with higher densities of large trees make it a good indicator of forest health. |
| *Migratory birds* | Both altitudinal and transboundary outside Nepal; notable species include: Demoiselle crane which for example migrates from Mongolia to India; vultures, common greenshank, common teal, Eurasian curlew, cormorant, geese, spotted eagle, and imperial eagle, among others (Bhandari, 2009). | Due to their reliance on wetland areas for resting stops between long migrations, they serve as important indicators of overall wetland health. Certain species like ibis is also an indicator species for climate change due to its preference for specific habitat in the Himalaya. |
| *Orchids* | Forests in the Siwaliks and Middle Mountains are known for diverse orchid populations, including 113 species (two of which are endemic: *Eria pokhrensis* and *Panisea panchanesis*) in the protected Panchase region near Pokhara (WWF, 2013f). | Supporting some tourism income in the region, indicates overall health of the larger ecosystem, in this case the tropical and subtropical broadleaf forests. |

## Infrastructure

With current trends of rapid infrastructure development in the CHAL, a priority was to explicitly assess the vulnerability of key infrastructure to climate change and consequent environmental impacts. The analysis was based on the critical importance of infrastructure in supporting community livelihoods and potential “knock-on” effects in enhancing the vulnerability of those livelihoods and key ecosystem services that are themselves vulnerable to climate change.[6] The Subunits selected are presented in Table 11.

### Table 11. Infrastructure chosen as Subunits for climate vulnerability analysis in the CHAL

| **Infrastructure** | | |
|---|---|---|
| **Subunit** | **Definition** | **Services and Importance** |
| *Hydropower Dams* | Numerous, mostly run-of-the-river dams in the CHAL in various phases of planning, construction, and operation; largest dam in the country is the 144 MW Kali Gandaki A; two storage dams are currently in planning and construction phases: Upper Trishuli (128 MW) and Budhi Gandaki (600 MW). | They provide critical electricity to local communities and the national grid; have considerable negative effects on local livelihoods and ecosystem services, from changing river morphology and reducing flows downstream, to blocking fish migration routes. |
| *District Roads* | These join a VDC HQ office or nearest economic center to the district headquarters, via either a neighboring district headquarters or the Strategic Road Network (Nepal Rural Roads Standard - 2055). | Provide important connections between villages and national roads, increasing local access to markets and decreasing the cost of goods; often also contribute to a number of problems in the landscape due to improper engineering in construction and insufficient maintenance that often increase landslide risk, especially at higher altitudes (WWF Nepal, 2014; WWF Nepal, 2013a). |
| *Urban Settlements* | Found mostly in the lower altitude areas of the Siwaliks and Middle Mountains and directly connected to national electricity and transportation infrastructure; currently experiencing rapid growth due to greater income opportunities. | Provide markets for buying and selling goods, access to healthcare, diverse income generating activities, and most typical government services; increasingly pressuring surrounding ecosystems and ecosystem services through rapid infrastructure development, land conversion and deforestation, increasing water use, sand and gravel mining for construction materials, and siltation of rivers and wetlands (WWF Nepal, 2013a). |

[6] For example, through unplanned district roads causing increased landslides due to increasing frequency and intensity of extreme storms

| | | |
|---|---|---|
| *Rural Settlements* | Small settlements ranging from 5-7 clustered households in the High Himalaya to 100-150 in the lower Middle Mountains and Siwaliks; some rely on local energy generation through micro-hydropower; have few options for transporting goods, and often limited livelihood diversification options. Generally cut off from central markets for exchanging goods and access to adequate health care. | Home to most inhabitants in the CHAL, these provide numerous basic government services including health posts, some ministerial department outposts, markets for trading agricultural products and basic goods and services. In and around national parks, tourism provides critical supplemental income to local populations. |
| *Riverbed Mining* | Substantial private mining operations, both mechanical and manual labor; occurs in riverbeds throughout the Middle Mountains and Siwaliks, but is most concentrated in the floodplains of the lower Seti, Trishuli, and East Rapti. | Though a critical source of materials, it has extreme impacts on rivers: changes in morphology, scouring, channelization, stream bank erosion, and hardening of floodplains, reducing recharge and water tables for nearby farmers, destruction of bridges, and declining water quality, among others; also exacerbates existing problems associated with naturally high flow variability in the landscape (WWF Nepal, 2013a; WWF Nepal, 2014). |

## Workshop Results

### Resilience of Subunits

#### Forests

Across all forest Units the Upper Temperate Broadleaf Forest Subunit was ranked as the most resilient (Figure 6). This is due to relatively high scores across the five factors as scored by the participants: i.e., they are adapted to an existing wide range of climates (natural variability); have available areas at higher elevations (refugia) to shift in response to increasing temperatures; and there are multiple species performing the same key functions (high functional redundancy).

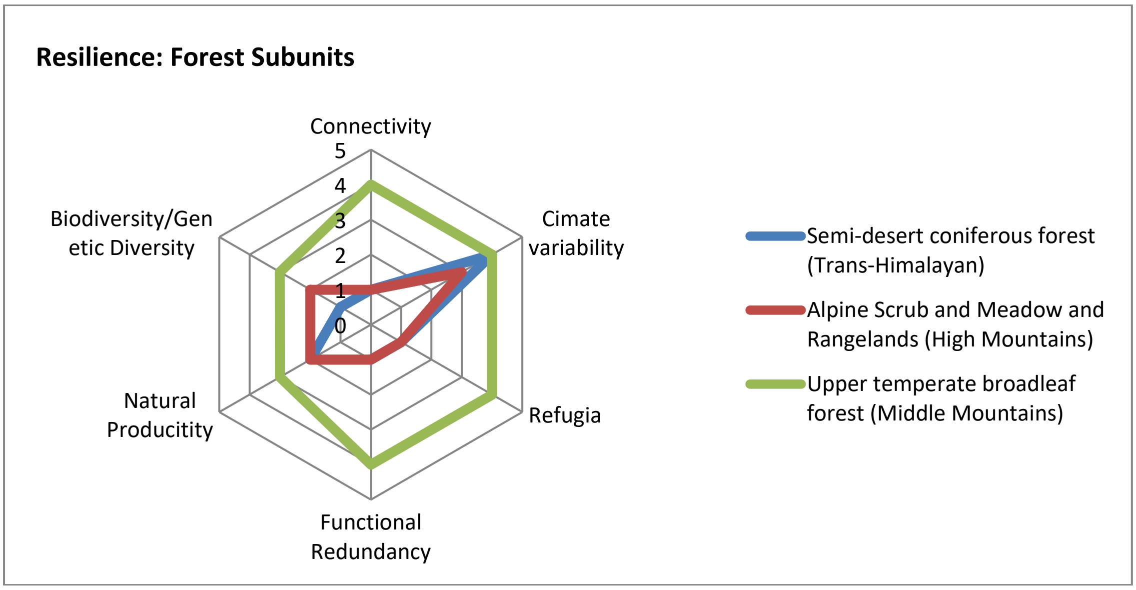


**Figure 6. Forest Subunits Resilience. This radar diagram shows the distribution of rating scores for the most and two least resilient systems: Upper Temperate Broadleaf Forests shown in green and Alpine Scrub and Semi-Desert Coniferous forests shown in red and blue, respectively.**

In contrast, Semi-desert Coniferous Forests in the Trans-Himalayan Region and Alpine Meadows and Rangelands in the High Mountain zone were found to be the least resilient for the opposite reasons: i.e., there is greater fragmentation and limited connectivity between forest patches; low biodiversity and natural productivity in the colder, drier systems; limited species that provide similar services (functional redundancy); and limited options to shift upslope in response to warming (lacking refugia).

#### Agriculture

The Khet systems[7] in the Churia were ranked as most resilient among the agriculture Subunits due to average scores (3) for connectivity to surrounding agricultural areas, ability to respond to natural climate fluctuations (natural variability), available substitutes

[7] Alluvial terraces in the flat lowlands, below 1,200 m

for key inputs like water and fertilizer (functional redundancy), and high scores (4) for yield/productivity and genetic crop diversity (Figure 7).

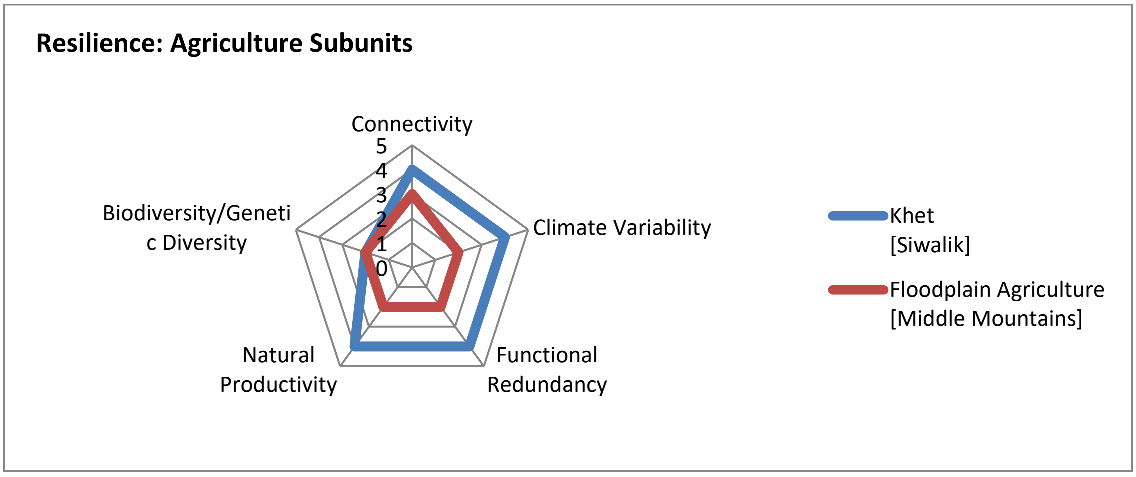


**Figure 7. Agriculture Subunits Resilience. This radar diagram shows the distribution of rating scores for the most and least resilient systems: Khet Agriculture Systems in the Siwaliks shown in blue and Floodplain Agriculture shown in red, respectively. Note: the refugia criteria was not relevant for this case, so agriculture Subunit resilience was only assessed by five criteria.**

In contrast, the Floodplain Agriculture in the Middle Mountains was rated least resilient for similar reasons: i.e., low connectivity to other agriculture systems; a high dependency on very specific climates (low natural variability); minimal duplicate sources for key inputs like fertilizer or water (functional redundancy); and low crop productivity. For both systems, crop genetic diversity was rated very low due to reliance on a limited number of varieties.

### Freshwater

The most resilient Freshwater Subunits were the Ramsar Sites (Figure 8), which had relatively high scores for the five resiliency criteria: strong connectivity to other wetlands spread over a large area; regular exposure to a high range of climate extremes (natural variability); presence of high quality areas less exposed and more resilient to change (refugia); access to multiple important sources of water (functional redundancy); and very high levels of productivity and biodiversity.

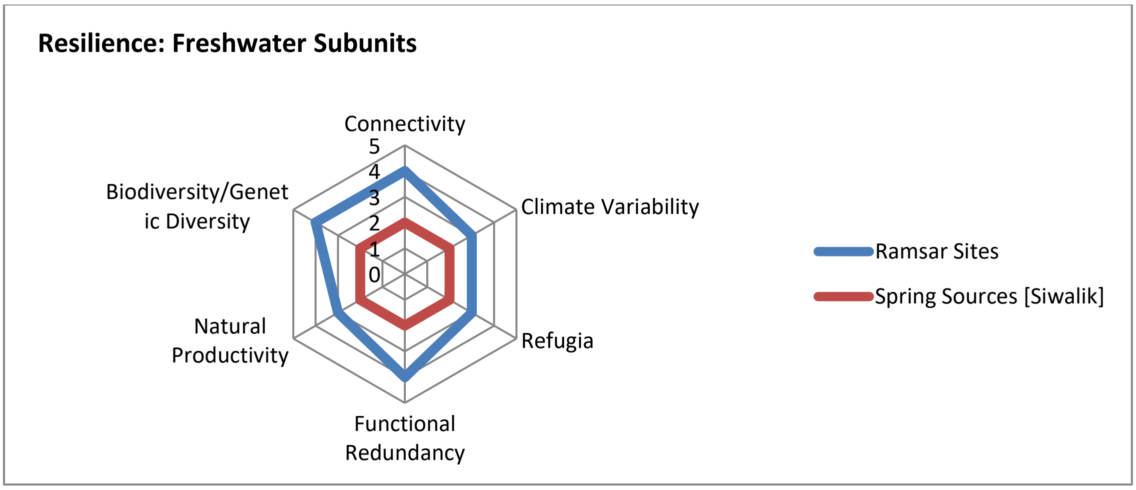


**Figure 8. Freshwater System Resilience. This radar diagram shows the distribution of rating scores for the most and least resilient Freshwater systems: Ramsar Sites throughout the basin shown in blue and Spring Sources in the Siwalik shown in red, respectively.**

The spring sources in the Churia were considered the least resilient due to low ratings across all criteria: i.e., decreased connectivity due to dropping water tables; very limited tolerance to extreme climates like droughts and heat waves, with sources frequently drying up during dry periods; very few sources that are not affected by climate change (i.e., none or limited refugia); limited alternative water sources (functional redundancy); poor water quality due to development, landslides and floods, and limiting natural production and recharge; and deforestation reducing biodiversity in and around spring sources.

### Rivers/Sub-basins

The resilience ratings for the Seti River are the lowest of all the rivers considered due to universally low scores for all factors except connectivity, which was rated higher because the river is currently unimpeded by dams (which will change if currently proposed dams are constructed). Participants considered the Seti to be exposed to natural climate extremes (natural variability), particularly due to channelization and slope instability from sand and gravel mining; have limited watersheds that could act as refugia; have fewer inflows and source waters (less functional redundancy); and have overall lower productivity and biodiversity due to poor water quality (Figure 9).

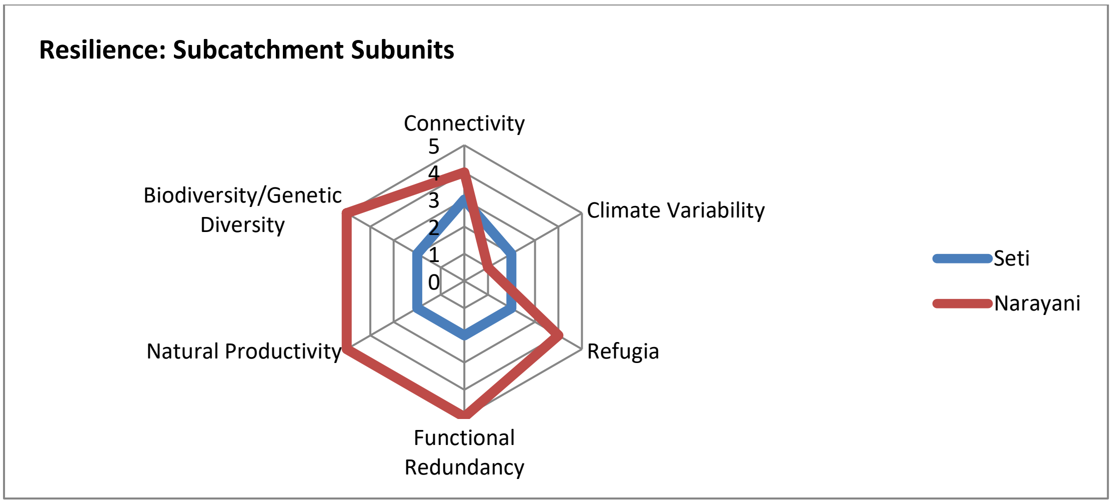


**Figure 9. Resilience of sub-basins in the Gandaki. This radar diagram shows the distribution of rating scores for the most and least resilient sub-basins of the Gandaki. The Seti river is shown in blue and Narayani in red.**

Participants rated the Narayani sub-basin high due to its multiple inflows and source waters, unimpeded connectivity, large size, and high water quality and overall biodiversity. Notably, it was rated the most resilient of all the sub-basins in the landscape, and received some of the highest resilience scores of all Subunits across all major Unit groups.

### Species

Within the species analyzed by the species group, wild dog (Figure 10) was found to be the most resilient due to relatively high scores for resilience factors: i.e., average to high habitat connectivity; access to habitats that will be more resilient to climate change impacts (refugia); adaptability to different habitat types (functional redundancy); and high reproduction rates. A lack of knowledge about the genetic diversity of the populations in the CHAL resulted in a much lower score for that criteria.

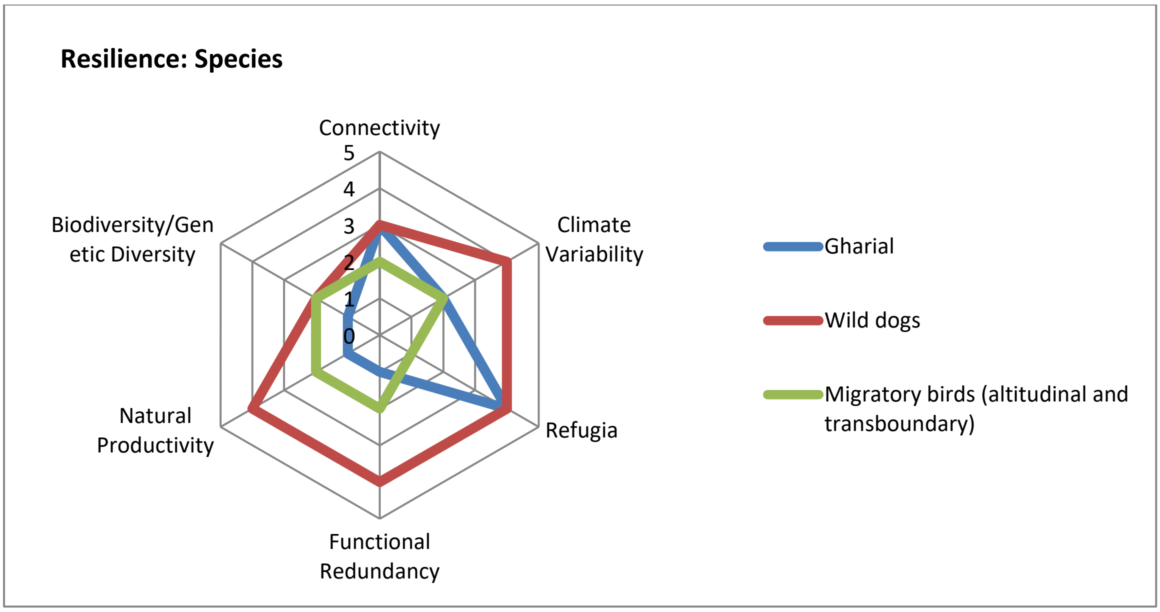

**Figure 10. Resilience of focal species in CHAL. This radar diagram shows the distribution of scores for the most and least resilient species in CHAL according to the five criteria. Wild dog is represented in red, gharial in blue, and migratory birds in green.**

The two least resilient species, gharial and migratory birds, received much lower scores for their resilience criteria: i.e., limited exposure to existing natural climate variability; fragmented habitats, particularly for migratory birds that are facing increasingly fragmented forests (with the gharial habitat somewhat more connected); low reproduction and survival rates; limited substitute habitats and food sources; and low genetic diversity with limited populations.

### Infrastructure

Infrastructure, due to its differences from the other Subunit categories, was rated for three criteria specific to man-made systems (Figure 11): connectivity (in this case to other key infrastructure that it relies upon); inclusion of climate variability in planning, design and construction; and inclusion of climate variability in operations and maintenance.

The most resilient systems in the infrastructure group were determined to be national roads (Figure 11) due to relatively high ratings for all three resilience criteria; they were determined to be well connected to other roads systems and account for at least some climate variability in design and regular maintenance.

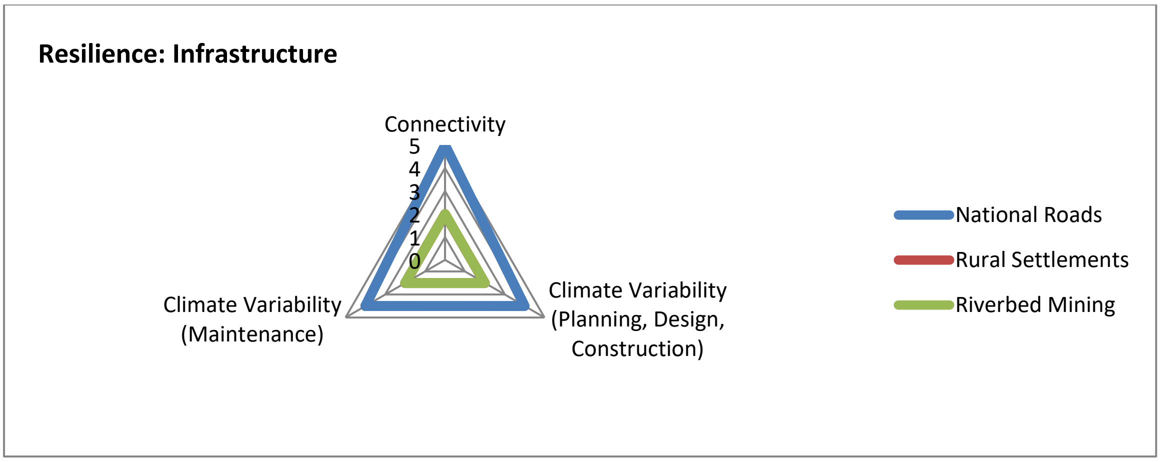


**Figure 11. Resilience of infrastructure systems. This radar diagram shows the distribution of rating scores for the most and least resilient infrastructure systems in the CHAL. National Rivers in blue, and Rural Settlements and Riverbed Mining in red and green, respectively (Rural Settlements and Mining have identical scores for each, so are represented by only one color in the graphic).**

Riverbed mining and rural settlements, on the other hand, were both rated very low (Figure 11) due to universally low scores for all three criteria: i.e., they are isolated from national infrastructure; and climate variability is rarely accounted for in planning, construction, design or maintenance.

## Exposure of Subunits

### Forests

Subtropical Broadleaf Forests were rated most exposed of all forest Subunits because impacts were often determined to be immediate (manifestation), highly damaging (severity), and covering a large area (extension) (Table 12). Participants rated them most exposed to two potential impacts in particular: increased deforestation from agricultural expansion; and natural productivity and biodiversity losses due to temperature increases and increasingly frequent, intense extreme precipitation events leading to hazards like droughts, floods and landslides.

### Table12. Potential Climate-Development Impacts Rated by the Forests Breakout Group

| Impact | Affected Forest Subunits | | | | | | |
|---|---|---|---|---|---|---|---|
| | Semi-desert coniferous | Range-lands | Alpine coniferous | Upper temperate broadleaf | Lower temperate broadleaf | Temperate coniferous | Subtropical Broadleaf |
| Increased deforestation and degradation (fuel wood demand) | 3.7 | | 2.7 | 3.3 | 3.3 | 3.3 | 4.0 |
| Higher intensity forest fires (more frequent and intense drought) | 4.3 | | 3.0 | 2.3 | 2.3 | 3.3 | 4.0 |
| Increased deforestation (agriculture) | | | | | 2.0 | 2.3 | 4.3 |
| Increased deforestation (poor infrastructure planning) | 1.3 | | | | 3.3 | 3.0 | 4.0 |
| Increased deforestation (energy development) | | | | 2.7 | 3.3 | 2.7 | 2.7 |
| Increased deforestation (migrating communities) | | | | | 1.3 | 1.3 | 4 |
| Productivity, species loss (climate variability and extreme events) | 1.7 | 1.3 | 2.0 | | 3.0 | 3.0 | 4.7 |
| | | | | | | | |
| **Average Subunit Exposure** | 2.7 | 1.3 | 2.6 | 2.8 | 2.7 | 2.7 | 4.0 |

**Note:** Average Subunit Exposure is the mean of all impact exposure scores for each Subunit. Color shading indicates lowest (lighter) to highest exposure scores (darker) by impact. Grey areas indicate Subunits not affected by each impact.

After Subtropical Broadleaf Forests, the Semi-desert Coniferous Forests in the Trans-Himalayan Region and the Upper Temperate Broadleaf Forests in the Middle Mountains were rated next most exposed overall, though upper and lower temperate and coniferous broadleaf forests all received very similar ratings. The Semi-desert Coniferous Forests were rated particularly exposed to higher intensity forest fires, but were rated based on far fewer impacts than forests at lower altitudes. Interestingly, Alpine Meadows, Scrub, and Rangelands were rated least exposed (Table 12), which is not surprising given their isolation at higher altitudes, away from population and economic development centers where most potential climate-development impacts are likely to occur.[8]

## Agriculture

Participants rated Pakho systems in the Middle Mountains most exposed (Table 13), with high scores for both of its impacts: i.e., due to the impacts of increasing food insecurity and feminization on the land and its uses, which affect livelihoods (severity), the immediate impact (manifestation), and coverage of a large percentage of Pakho farming systems in the Middle Mountains. Bari and Khet systems in the Siwaliks were also rated somewhat high, especially due to the increasing use and reliance on fertilizer and pesticides.

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[8] This result should, however, also be considered with some skepticism, as their most significant direct human pressure—overgrazing—was not rated.

### Table 13. Potential Climate-Development Impacts Rated by the Agriculture Breakout Group

| Impact | Affected Agriculture Subunits | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Bari (MM) | Khet (MM) | Pakho (MM) | Bari (Siwalik) | Khet (Siwalik) | Pakho (Siwalik) | Tar (Irr) | Tar (Rainfed) |
| Food insecurity due to outmigration (multiple impacts of climate change: infrastructure instability, access to markets, extreme hazards) | | 2.7 | 3.7 | | | 2.3 | | 3.3 |
| Feminization of agriculture areas due to outmigration (enhanced by greater climate variability) | | | 3.7 | | | 3.3 | | 3.0 |
| Unsustainable reliance on costly imported fertilizer and pesticide inputs (increased pest incidence) | 3.0 | 3.3 | | 3.3 | 3.3 | | 2.7 | |
| | | | | | | | | |
| **Average Subunit Exposure** | **3.0** | **3.0** | **3.7** | **3.3** | **3.3** | **2.8** | **2.7** | **3.2** |

**Note:** Average Subunit Exposure is the mean of all impact exposure scores for each Subunit. Color shading indicates lowest (lighter) to highest exposure scores (darker) by impact and overall (Average). Grey areas indicate Subunits not affected by each impact. MM stands for Middle Mountains and Irr for irrigated.

The only irrigated agriculture Subunit analyzed (Irrigated Tar) was found least exposed, and to only one impact—unsustainable reliance on and use of fertilizer and pesticides.

### Freshwater

Participants rated the Middle Mountain lakes as highly exposed due to already occurring and increasing extraction rates (manifestation) associated with population growth and multiple uses (severity) (Table 14).

### Table 14. Potential Climate-Development Impacts Rated by the Freshwater Breakout Group

| Impact | | Affected Freshwater Subunits | | | | |
|---|---|---|---|---|---|---|
| | Cryosphere | Floodplain | Middle Mountain Lakes | Ramsar Sites | Spring Sources (Middle Mountains) | Spring Sources (Siwalik) |
| Increased conflict over limited water supplies (migration, unreliable rainfall, over extraction) | | | 3.7 | | | |
| Reduced water availability (poorly planned hydro, roads infrastructure) | | | 3.0 | | 2.3 | 4.0 |
| Reduced agricultural productivity and biodiversity loss (reduced water quality from erosion/siltation) | | 4.0 | 2.3 | | | |
| Reduced water quality and soil moisture degradation (fertilize/pesticide use, temperature increases) | | | 3.3 | 1.3 | | |
| Rapid reductions in snow fed rivers (rapid high altitude snow/ice melt) | 2.7 | | | | | |
| | | | | | | |
| **Average Subunit Exposure** | 2.7 | 4.0 | 3.1 | 1.3 | 2.3 | 4.0 |

**Note:** Average Subunit Exposure is the mean of all impact exposure scores for each Subunit. Color shading indicates lowest (lighter) to highest exposure scores (darker) by impact and overall (Average). Grey areas indicate Subunits not affected by each impact.

Spring sources in the Siwaliks were rated highly exposed to potential reduced water availability associated with unplanned or poorly planned hydropower and road development that causes deforestation and, in conjunction with decreased rainfall reliability, ultimately leads to poor groundwater recharge. Participants determined the impact was already being felt (manifestation), is damaging to most spring sources (extension), and is highly damaging due to high current depletion rates (severity).

Interestingly, Ramsar sites in the landscape (including the large Beeshazari Tal complex in the lowlands of the Churia) were found least exposed, largely due to their protection from the impacts of current and future unplanned infrastructure development, relative to other freshwater systems in the CHAL.

#### Rivers and Sub-basins

Participants rated the Seti, Trishuli, Narayani, and Rapti sub-basins the most exposed (Table 15) due to relatively high scores for degree of damage (severity), area of the sub-basin affected (extension), and when the impact is expected to occur (manifestation). For all four sub-basins and their impacts, manifestation was rated 4 or higher due to the impact having an immediate effect or at least within the next year. Extension was also rated high across all four rivers, with impacts already affecting or expected to affect 60-90% of the sub-basin. Severity was also rated high for most of these rivers due to human settlement vulnerability, existing degradation due to development impacts from sand mining, or road or hydropower development.

### Table 15. Potential Climate-Development Impacts Rated by the Species Breakout Group

| Impact | Affected Sub-basin Subunits | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Kali Gandaki | Madi | Seti | Daraudi | Mars-yangdi | Budhi Gandaki | Trishuli | Narayani | Rapti |
| Increased flood risk, sedimentation, and lower agricultural productivity (increased glacial melt) | 3.7 | 3.3 | 4.0 | 2.0 | 2.3 | 1.7 | 3.7 | 4.0 | |
| Reduced hydropower production, infrastructure damage (increased sedimentation) | 3.0 | 3.0 | 4.0 | 2.3 | 3.0 | 1.7 | 4.3 | 3.7 | 4.3 |
| Increased sedimentation from landslides on rural roads (rainfall variability) | 2.7 | | | | | | | | |
| Increased incidence of water-borne disease, flooding | | | | | | | | 4.3 | 4.3 |
| Increased conflict over declining water supply (lowering water tables, rainfall variability) | | | | 3.3 | | | | | |
| Aquatic species loss (increased river temperatures, rainfall variability) | | | | | | | | | 2.7 |
| | | | | | | | | | |
| **Average Subunit Exposure** | 3.1 | 3.2 | 4.0 | 2.6 | 2.7 | 1.7 | 4.0 | 4.0 | 3.8 |

**Note:** Average Subunit Exposure is the mean of all impact exposure scores for each Subunit. Color shading indicates lowest (lighter) to highest exposure scores (darker) by impact and overall (Average). Grey areas indicate Subunits not affected by each impact.

Participants rated the Budi Gandaki the least exposed, mostly due to lower scores for manifestation, with expected impacts occurring more than 10 years in the future, and extension, with impacts only occurring in less than 50% of the sub-basin.

### Infrastructure

Participants in the infrastructure group rated local roads the most exposed (Table 16) due to relatively high scores for the key criteria for all three impacts to which they were exposed. Local roads received the highest scores for damage caused by increased heavy storm events and subsequent state of disrepair. Severity was rated high due to poor planning and design. Extension was moderate due to localized, but significant effects, and manifestation also high due to an immediate effect. District roads, while slightly better engineered, still received similarly high exposure scores.

## Table 16. Potential Climate-Development Impacts Rated by the Infrastructure Breakout Group

| Impact | Affected infrastructure Subunits | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | District Roads | Local Roads | Nat'l Roads | Micro, Small Hydro | Large Hydro | Urban Settlements | Rural Settlements | Riverbed Mining | Irrigation |
| Increased soil erosion (climate variability, extreme storm intensity, frequency) | 3.0 | 3.0 | | | | | | | |
| Rapid infrastructure wear and tear (increased runoff intensity to poor design) | 2.7 | | | | | | | | |
| Rapid surface deterioration of roads (channeling due to increased soil erosion) | 3.7 | | 3.0 | | | | | | |
| Increased disrepair due to loss of drainage structures (increased flow variability) | 2.7 | 3.7 | 1.7 | | | | | | |
| Increased disrepair (poor planning and extreme events) | 2.7 | | 2.3 | 2.0 | 2.0 | 2.3 | 2.7 | 2.0 | 2.0 |
| Rapid wear and tear (lack of design for climate change) | | 3.7 | 1.7 | | 2.0 | 2.3 | 2.7 | | |
| Higher siltation, reduced water quality (extreme rainfall, extreme discharge) | | | | 3.0 | 3.0 | | | | |
| Increased pressure on urban infrastructure from climate refugees | | | | | | 2.3 | 2.7 | | |
| | | | | | | | | | |
| **Average Subunit Exposure** | 2.9 | 3.4 | 2.2 | 2.5 | 2.3 | 2.3 | 2.7 | 2.0 | 2.0 |

**Note:** Average Subunit Exposure is the mean of all impact exposure scores for each Subunit. Color shading indicates lowest (lighter) to highest exposure scores (darker) by impact and overall (Average). Grey areas indicate Subunits not affected by each impact.

National roads, however, were rated lowest for their exposure, due to better engineering and drainage structures that limit overall severity, extension, and manifestation of potential impacts. While still exposed for all three criteria, participants noted reduced severity, minimal area of impact, and occurrence further into the future than local and district roads that are already experiencing significant impacts.

### Species

Gharial was rated most exposed (Table 17) due to high scores both for reduced survival rates associated with temperature increases causing skewed sexes in the population (affecting reproduction and demographics), and for water and habitat quality degradation due to increased erosion and siltation from road development. Participants noted that Gharial habitats in the Narayani and Rapti rivers are already experiencing increasing siltation and pollution (manifestation), to which Gharial are extremely sensitive (severity). Increased road construction around both rivers affect a large percentage of its habitat (extension).

Migratory birds and wild dogs were also rated highly exposed, due to impacts of habitat degradation, irregular downstream flows, and increasingly uneven spatial distribution of drinking water.

### Table 17. Potential Climate-Development Impacts Rated by the Species Breakout Group

| **Impact** | **Affected Sub Unit** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Tiger** | **M'seer** | **Migratory Birds** | **Wild Dogs** | **Rhino** | **Gharial** | **Red Panda** | **Snow Leopard** | **Hornbill** | **Orchids** |
| Increased forest degradation, human wildlife conflict (fuel wood demand) | 3.0 | | 4.0 | | 2.3 | | | | 2.0 | |
| Water quality degradation (increased erosion, siltation) | | 2.7 | | | | 4.0 | | | | 3.0 |
| Habitat destruction, increased human-wildlife conflict (vulnerable communities) | 3.7 | | | | | | | | | |
| Irregular downstream flows (hydropower outflows uncertainty) | | | 3.3 | | | | | | | |
| Uneven spatial distribution of drinking water (increasingly erratic rainfall patterns) | | | | 3.7 | | | | | | |
| Range shifts and population reductions (habitat changes; food source loss; human encroachment) | | | | | 4.0 | | | | | |
| Reduced survival rate, population reductions (longer cold spells, impacts on vegetation/food source phenology) | | | | | | 3.7 | | | | |
| Habitat encroachment, degradation in low lying areas (loss of drinking water sources) | | | | | | | 2.3 | | | |
| Greater human wildlife conflict and degradation in alpine meadows (overgrazing) | | | | | | | | 3.0 | | |
| | | | | | | | | | | |
| **Average Subunit Exposure** | **3.3** | **2.7** | **3.7** | **3.7** | **3.2** | **3.8** | **2.3** | **3.0** | **2.0** | **3.0** |

**Note:** Average Subunit exposure is the mean of all impact exposure scores for each Subunit. Color shading indicates lowest (lighter) to highest exposure scores (darker) by impact and overall (Average). Grey areas indicate Subunits not affected by each impact.

### Vulnerability

The vulnerability of a Subunit is calculated based on its ratings for the six resilience criteria and severity rating of each impact to which it is exposed.[9]

[9] Microsoft Excel spreadsheets where all ratings and notes are entered throughout the process are designed to calculate these final scores automatically. Facilitators checked these calculations between the second and third days of the workshop to remove errors and portray results to each group in a more easily understood format.

### Forests

Seven forest Subunits were assessed in the landscape (Table 18). The Subtropical Broadleaf forests in the Churia Zone were considered to be most vulnerable, followed by the Semi-desert Coniferous Forests in the Trans-Himalayan Region, based on the resilience and exposure scores assigned by the participants. The Upper Temperate Broadleaf Forests in the middle mountains were the least vulnerable forest type to climate change.

**Table 18. Forest Unit Group Vulnerability Ratings. Red to green color scale indicates most to least vulnerable.**

| Subunit | Zone | Vulnerability |
|---|---|---|
| Subtropical Broadleaf forest | Churia | 3.5 |
| Semi-desert coniferous forest | Trans-Himalayan Region | 2.7 |
| Lower temperate broadleaf forest | Middle Mountains | 2.6 |
| Temperate coniferous forest | Middle Mountains | 2.6 |
| Alpine coniferous Forest | High Mountains | 2.5 |
| Upper temperate broadleaf forest | Middle Mountains | 2.3 |
| Alpine Scrub/Meadow, Rangelands | High Mountains | 1.9 |

**Note:** Final vulnerability ratings are a function of averaged exposure ratings for all impacts affecting each Subunit and averaged resilience criteria.

### Agriculture

Five different agricultural practice Subunits nested within two physiographic zones were assessed for vulnerability (Table 19). Pakho, irrigated Tar in the Middle Mountains followed by Bari in the Churia and rainfed Tar in the Middle Mountains were rated as the most vulnerable agricultural systems in the CHAL. Pakho in the Churia and Khet and Bari in the Middle Mountains were the least vulnerable systems.

**Table 19. Agriculture Unit Group Vulnerability Ratings.**

| Subunit | Zone | Vulnerability |
|---|---|---|
| Pakho | Middle Mountains | 3.3 |
| Tar (irrigated) | Middle Mountains | 3.0 |
| Bari | Churia | 2.9 |
| Tar (rainfed) | Middle Mountains | 2.9 |
| Khet | Churia | 2.8 |
| Pakho | Churia | 2.7 |
| Khet | Middle Mountains | 2.7 |
| Bari | Middle Mountains | 2.5 |

**Note:** Red to green color scale indicates most to least vulnerable. Final vulnerability ratings are a function of averaged exposure ratings for all impacts affecting each Subunit and averaged resilience criteria.

### Freshwater

Six different non-lotic freshwater systems and sources were assessed for vulnerability (Table 20). Spring sources in the Churia and the flood plains in all zones were considered to be most vulnerable to climate change. The spring sources of the Middle Mountain zones and all Ramsar sites were thought to be least vulnerable to climate change impacts.

**Table 20. Freshwater (non-lotic) Unit Group Vulnerability Ratings.**

| Subunits | Zone | Vulnerability |
|---|---|---|
| Spring Sources | Siwalik | 3.7 |
| Floodplain | Multi-Zone | 3.3 |
| Cryosphere | High Himalaya | 2.7 |
| Lakes | Middle Mountains | 2.7 |
| Spring Sources | Middle Mountains | 2.3 |
| Ramsar Sites | Multi-Zone | 1.3 |

**Note:** Red to green color scale indicates most to least vulnerable. Final vulnerability ratings are a function of averaged exposure ratings for all impacts affecting each Subunit and averaged resilience criteria.

### Sub-basins

Of the nine sub-basins assessed for climate change, the Seti, Rapti, Trishuli, and Narayani were considered to be the most vulnerable (Table 21). The Budi Gandaki was rated the least vulnerable.

### Table 21. Sub-basin Unit Group Vulnerability Ratings.

| Subunits | Vulnerability |
|---|---|
| Seti | 3.7 |
| Rapti | 3.3 |
| Trishuli | 3.1 |
| Narayani | 3.1 |
| Madi | 2.8 |
| Daraudi | 2.6 |
| Marsyangdi | 2.5 |
| Kali Gandaki | 2.5 |
| Budhi Gandaki | 1.6 |

**Note:** Red to green color scale indicates most to least vulnerable. Final vulnerability ratings are a function of averaged exposure ratings for all impacts affecting each Subunit and averaged resilience criteria. All sub-basins cover multiple physiographic zones.

### Infrastructure

All local roads were rated as being highly vulnerable to climate change impacts, along with rural settlements (Table 22). Riverbed mining operations, district roads, dams and micro hydro projects were also considered vulnerable, but to a lesser extent. All national roads were rated as being the least vulnerable infrastructure, although the national roads in the mountains were considered relatively more vulnerable than those in the lowlands.

### Table 22. Infrastructure Unit Group Vulnerability Ratings

| Subunit | Zone | Vulnerability |
|---|---|---|
| Local Roads | Multi-zone | 3.0 |
| Rural Settlements | Multi-zone | 2.9 |
| Riverbed Mining | Multi-zone | 2.3 |
| District Roads | Multi-zone | 2.3 |
| Dams | Multi-zone | 2.3 |
| Micro and small hydro | Multi-zone | 2.3 |
| Urban Settlements | Multi-zone | 2.2 |
| Irrigation | Multi-zone | 2.0 |
| National Roads | High Mountains | 1.8 |
| National Roads | Trans-Himalaya | 1.8 |
| National Roads | Middle Mountains | 1.7 |
| National Roads | Churia | 1.6 |

**Note:** Red to green color scale indicates most to least vulnerable. Final vulnerability ratings are a function of averaged exposure ratings for all impacts affecting each Subunit and averaged resilience criteria.

### Species

Gharial and migratory birds were considered to be the most vulnerable species from among the 10 key species assessed (Table 23). Flagship species such as tiger, rhinoceros and snow leopard were thought to be relatively less vulnerable, while red panda, orchid species, mahseer, and hornbills were least vulnerable.

### Table 23. Species Unit Group Vulnerability Ratings

| Subunit | Vulnerability |
|---|---|
| Gharial | 3.6 |
| Migratory birds | 3.5 |
| Tiger | 3.0 |
| Rhino | 2.9 |
| Snow leopard | 2.9 |
| Wild dog | 2.8 |
| Red panda | 2.6 |
| Orchids | 2.6 |
| Mahseer | 2.5 |
| Hornbill | 2.3 |

**Note:** Red to green color scale indicates most to least vulnerable. Final vulnerability ratings are a function of averaged exposure ratings for all impacts affecting each Subunit and averaged resilience criteria. All species habitats cover multiple physiographic zones.

### Social Adaptive Capacity

A critical component of a vulnerability assessment is the human resource capacity and other enabling conditions such as institutional capacity and adequate policies necessary to address and mitigate the impacts of climate change; i.e., the social adaptive capacity. While the Resilience analysis assessed the innate capacity of Subunits to recover from impacts, this step measures the human factors that can either strengthen or weaken that response.

Therefore, the assessment of social adaptive capacity—measured by readiness of information, policies, and institutions (Figure 12)—develops a better understanding of these aspects, and is crucial for designing interventions to address the vulnerabilities outlined in the previous section.

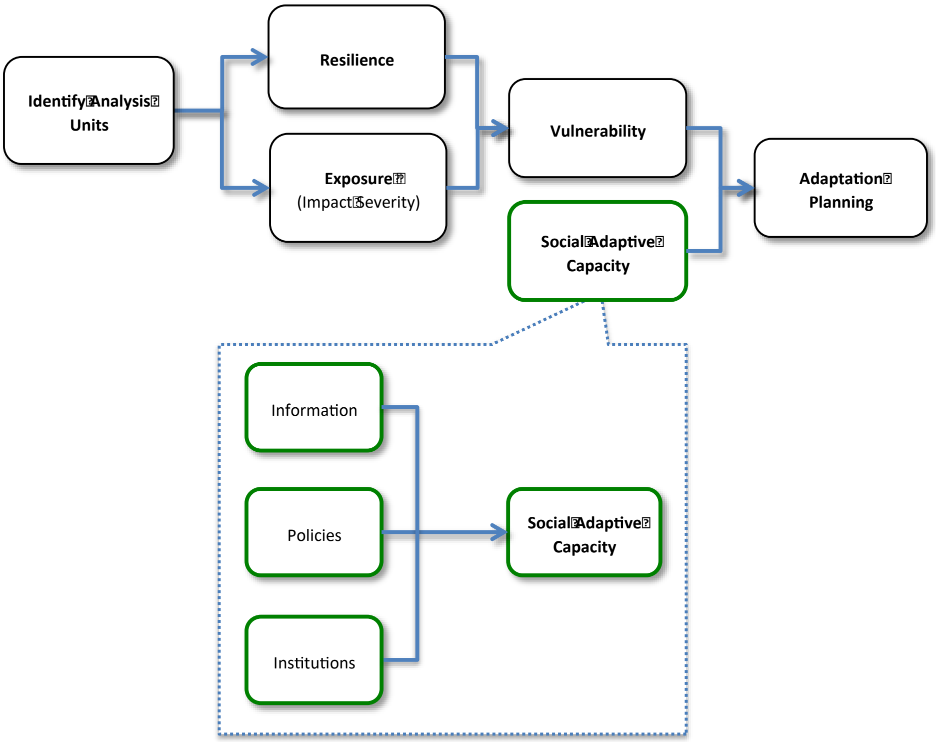



**Figure 12. Social adaptive capacity assessment in the Flowing Forward framework, measured as a function of three factors: information, policies, and institutions.**

As with the ranking process for sensitivity and exposure, each of the three key components of adaptive capacity is measured by its own relevant unique set of criteria. Using the criteria in Table 24, each breakout Unit group rated the policies, institutions, and information sources relevant to the management of their Subunits.

## Table 24. Factors and criteria for assessing social adaptive capacity

| | |
|---|---|
| **Policies** | |
| Forward Thinking | The extent to which the policy considers future conditions through flexible approaches and planning for multiple future scenarios. |
| Implementation and Enforcement | The degree to which the policy is implemented and enforced in such a way that it meets its goals. |
| Iterative | If the policy is new, the extent to which it has been designed to be regularly reviewed and revised; or if the policy is old, how often it has been reviewed since its initial implementation. |
| Resources | Degree to which the policy considers sufficient human, informational, technical, and financial capacity. |
| Coherency | The extent to which the policy acknowledges, and does not conflict with, other policies across multiple scales of governance (i.e. local, regional, national). |
| **Information** | |
| Frequency of Collection | The number of times the data is collected over time |
| Iterative Analysis | The extent to which the analysis of data is repeated |
| Quality | The degree to which the data is complete, meets appropriate standards, and is accurate |
| Accessibility | The difficulty or ease in accessing the data. |
| Communications | The degree to which the information is processed and packaged for intended audiences so that it can be operationalized. |
| **Institutions** | |
| Mandate & Authority | The degree to which the institution has a mandate and authority needed to meet its goals |
| Competence | The degree to which the institution carries out responsibilities efficiently and effectively |
| Resources | The degree to which the institution has the human, informational, and technical resources and capacity available to meet its goals |
| Transparency | The extent to which it consults with other stakeholders |
| Collaboration | Amount of coordination and/or collaboration with other relevant institutions |

## Results

As is the case with the vulnerability rankings, it is important to place these results in context. The ratings are only meant to provide guidance for program managers to focus on adaptive capacity to implement future adaptation actions in the landscape. Also, not all participants were sufficiently knowledgeable to explain some rankings, and in others, their relative biases obviously affected the results.[10] The results of brief breakout group assessments should also not be considered comprehensive. But, alongside additional sources of information and program manager expertise in policies, information management, and institutional capacity, the outputs provide reasonable guidance.

[10] Some groups, for example, had more representation from government ministries that were understandably less willing to accept criticism of their specific departments, or more willing to criticize others over their own.

Rather than comprehensively list out all rankings for all breakout groups, the following sections highlight notable results for each breakout group. Refer to Annex 1 for complete spreadsheet ratings for each group.

### Forests

The most notable results of the social adaptive capacity analysis for forest management in the CHAL are the extremely low scores for important information sources like fire occurrence and extent, and vegetation cover. Even though such information is very important for adaptation, it is never collected and processed (Table 25). On the other end of the spectrum, data collection is much better on human migration rates. However, for all information sources evaluated, quality, accessibility, communication, and iteration were all ranked low (Table 25).

**Table 25. Adaptive Capacity: Forests Information Sources**

| Type of Information | Importance for Adaptation | | Frequency of Collection | | Iterative | | Quality | | Accessibility | | Communications | | Avg. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| fire occurrence and extent | High importance | 5 | never | 1 | Never | 1 | NA | 1 | NA | 1 | NA | 1 | ***1.0*** |
| human migration rates | High importance | 5 | Every 10 years; population census | 5 | Good analysis | 4 | Fairly good | 3 | Fair | 2 | Poor | 1 | ***3.0*** |

**Note:** scores are ranked from 1-5, with 1 representing low and 5 high adaptive capacity. Scores in the final right-hand column are averages of the five factors.

Results from policy and institution ratings point to additional changes that would significantly improve social adaptive capacity in the forestry sector (Table 26). The 1999 Local Self Governance Act, one of the country's most important regulations for natural resource management that decentralized power to local governing authorities, for example, was rated relatively low due to conflicts with other important regulations like the Forest and Environmental Protection Acts, as well as a lack of regular review and revision. This law, along with many others in Nepal, is poorly implemented at the local level due to a lack of locally elected officials in VDCs and DDCs; capacity at this level is significantly reduced as a result (which explains why they are the lowest rated of all institutions for forestry). Amending these regulations to remove conflicts and holding elections at the local level—obviously not easy tasks in either case—are potential courses of action to raise social adaptive capacity in the forestry sector.

### Table 26. Adaptive Capacity: Forestry Policies and Institutions

| Forests Breakout Group Adaptive Capacity Assessment: Policies | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Policy and Year** | **Takes forward-thinking and** | | **Implemented and enforced effectively?** | | **Reviewed and revised** | | **Resources and capacity** | | **Consistent with other policies at** | | ***Avg.*** |
| **Local Self Governance Act 1999** | Good | 4 | Poorly implemented due to elected body at local level | 2 | not revised | 1 | Good resource and limited technical capacity | 3 | Conflicts with Forest Act 1991 and Environment protection Act | 2 | ***2.4*** |
| **Forest Act 1993** | Well elaborated participation and community management of foerst resources | 4 | Yes; good in community forestry implementation but other forest management regimes are poorly implemented | 3 | Not revised | 1 | Good resource and capacity | 4 | Conflicts with LSGA and Environment protection Act | 3 | ***3*** |
| **Institutions** | | | | | | | | | | | |
| **Institution** | **Mandate and** | | **Leadership** | | **Resources** | | **Transparancy** | | **Collaboration** | | ***Avg.*** |
| **VDCs and DDCs** | very limited | 1 | Poor; absence of elected body | 1 | Fairly good | 3 | No transparent | 1 | Collaborate with political parties | 2 | ***1.6*** |
| **CFUGs** | Full mandate for resource management and utilization | 4 | fairly good | 3 | Not adequate | 2 | Good transparency | 3 | Collaboraton with District line agencies | 3 | ***3*** |

**Note:** scores are ranked from 1-5, with 1 representing low and 5 high adaptive capacity. Scores in the final right-hand column are averages of the five factors.

## Agriculture

Compared to information sources for forests, those for agriculture received somewhat higher scores due to more regular collection. This is not surprising given its importance as a key livelihoods source in the CHAL. Almost all agriculture information sources, however, received low scores for communications and accessibility, indicating substantial need to improve access to information on livestock productivity, crop yields, market prices, important inputs, insurance, etc.

### Table 27. Adaptive Capacity: Agriculture Information Sources

| **Type of Information** | **Relevant Unit/SubUnits** | **Importance for CC Adaptation** | | **Frequency of Collection** | | **Iterative Processing & Analysis?** | | **Quality** (temporal gaps, spatial gaps) | | **Acessibility** (e.g. free to public, accessible for a fee, or never accessible) | | **Communications** (Across scales, packaging, Communication Networks) | | ***Avg.*** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| market price of crops/livestock | All | More important | 4 | daily | 5 | important | 4 | not very detail | 3 | free to public | 2 | weak | 2 | ***3.3*** |
| crop yields | All | More important | 4 | thrice a year | 3 | important | 4 | not very detail | 3 | free to public | 2 | weak | 2 | ***3.0*** |
| cropping variety/types (disease resistance, resilliency) | All | More important | 4 | twice a year | 2 | mid important | 3 | not very detail | 4 | free to public | 2 | weak | 2 | ***2.8*** |
| livestock productivity | All | More important | 4 | thrice a year | 3 | important | 3 | not very detail | 3 | free to public | 2 | weak | 2 | ***2.8*** |

**Note:** scores are ranked from 1-5, with 1 representing low and 5 high adaptive capacity. Scores in the final right-hand column are averages of the five factors.

Of all the major Unit groups, policies for agriculture were ranked the lowest, with only one of the major relevant policies, the Local Governance Act ranking higher than 3.0 (Table

28). This is generally due to low scores for the iteration and resources factors, and somewhat higher scores for coherence and forward-thinking. The Agribusiness Promotion Policy of 2006 and the Soil and Watershed Conservation Act of 1982 were ranked lowest due to weak implementation (as is the case across many natural resource management policies in Nepal), poor coherence and coordination with other national level policies, minimal resources for implementation, and infrequent review and revision.

### Table 28. Adaptive Capacity Rankings: Agricultural Policy

| Agriculture Breakout Group. Adaptive Capacity Assessment: Policies | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Policy and Year** | **Forward Thinking** | | **Implementation and Enforcement** | | **Iterative** | | **Resources** | | **Coherency** | | ***Avg.*** |
| **Agribusiness Promotion Policy 2006** | not very | 2 | weak implemetation | 1 | Not reviewed | 1 | less resources | 1 | mid coherrent | 2 | ***1.4*** |
| **Local Governance Act 1999** | integrated and forward looking | 4 | enforced well | 4 | Not reviewed | 2 | less human and financial resources | 3 | mid coherrent | 3 | ***3.2*** |

**Note:** scores are ranked from 1-5, with 1 representing low and 5 high adaptive capacity. Scores in the final right-hand column are averages of the five factors.

Given the numerous challenges Nepalese farmers already face, from low productivity to difficult access to markets, improving the Agribusiness Promotion Policy would be one potential way to increase the economic resilience of farmers to impacts of climate change. Improving implementation of the Soil and Watershed Conservation Act would also be highly beneficial to both farmers and ecosystems, through actions to reduce topsoil loss, sedimentation, and landslide risk.

### Table 29. Adaptive Capacity Rankings: Agricultural Institutions

| Agriculture Breakout Group Adaptive Capacity Assessment: Institutions | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Institution** | **Mandate and Authority** | | **Competence** | | **Resources** | | **Transparency** | | **Collaboration** | | ***Avg.*** |
| Farmers Organizations and Associations | Weak | 2 | Weak | 2 | Weak | 2 | Weak | 2 | Weak | 2 | ***2*** |
| Private Sector (dairy, poultry, agrovet) | Moderate | 3 | Good | 4 | Moderate | 3 | Good | 4 | good | 4 | ***3.6*** |

**Note:** scores are ranked from 1-5, with 1 representing low and 5 high adaptive capacity. Scores in the final right-hand column are averages of the five factors.

For agriculture institutions, the rankings show an interesting contrast between typical Nepalese farmers' organizations and associations, which were ranked lowest (2), while the more recently developed, larger scale private sector was ranked significantly higher (3.6) (Table 29).

### Freshwater

Rankings for the social adaptive capacity of freshwater systems were mixed, with both very low and high scores. The Environmental Protection Act (EPA) of 1997 was rated the highest (4.0), and the Aquatic Animal Protection Act (AAPA) of 1998 and the 2005 National Water Plan (NWP) the lowest (1.6) (Table 30).

### Table 30. Adaptive Capacity Rankings: Freshwater Policy.

| Freshwater Ecosystems and Subcatchments Breakout Groups | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Policy and Year** | **Takes forward-thinking and integrated approach?** | | **Implemented and enforced effectively?** | | **Reviewed and revised periodically?** | | **Resources and capacity available for implementation?** | | **Consistent with other policies at different scales of governance?** | | ***Avg.*** |
| Aquatic Animal Protection Act 1998 | the act has less scope and complete ignores cc issues | 1 | not much of implemention | 1 | old act, not reviewed yet | 1 | some research and initiatives, | 2 | supports national wetland policy however it is not inclusive | 3 | ***1.6*** |
| National Water Plan 2005 | climate change component is not included | 2 | not much done for implemenation. WESC is there but less functional | 1 | | 3 | internal funds very limited, most of the resouces are from outside. Human resources at intermediate/technical level is limited | 2 | other plans and polices are not favorable to water plan | 2 | ***2*** |
| Environmental Protection Act 1997 | IEE and EIA are included in the Act. It is more holistic however still room for improvement in term of cc | 3.5 | envrionment assessment are mandatory but still not proporely followed | 4 | periodic review and revision | 4 | presence of adequate human/technical resources. Financial resources present mainly in terai | 4 | well coherent with other sector such as road, hydropower, forest, mining, small and large industries, etc. | 4 | ***3.8*** |

**Note:** scores are ranked from 1-5, with 1 representing low and 5 high adaptive capacity. Scores in the final right-hand column are averages of the five factors. As policies for sub-basins and freshwater ecosystems are the same, this table represents the rankings of both groups.

Though scores for the EPA are high, participants note that there is still room for improvement for inclusion of climate change and better enforcement. For the AAPA, the group noted very minimal implementation, rare review and revision, minimal research and resources, and only poor coherence with the national wetlands policy. The NWP, though well written around concepts of river basin management and forward thinking in terms of adaptation, was ranked low due to poor implementation, insufficient resources, and a lack of synergy with other national resource management plans and policies.

For the assessment of freshwater institutions, the two breakout groups indicated relatively low scores for the Ministry of Water Resources (2.6) for lacking leadership, inadequate financial resources, poor information access, and limited collaboration with other organizations (Table 31). Water users' groups and associations, on the other hand, were rated both relatively high (3.8) and low (2.4) by the two freshwater Subunit breakout groups indicating diverse capacity among such groups in the landscape. Though both breakout groups rated them similarly for resources and collaboration, they diverged on mandate and authority, competence of management and leadership and transparency.

### Table 31. Adaptive Capacity Rankings: Freshwater Institutions

| Freshwater Ecosystems and Subcatchments Adaptive Capacity Assessment: Institutions | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Institution** | **Mandate and Authority** | | **Competence** | | **Resources** | | **Transparency** | | **Collaboration** | | ***Avg.*** |
| Ministry of Water Resources | well established institutional framework. | 4 | Visionary leadership not present, inadequate accountability and responsive, no favorable working environment | 2 | Inadequate financial resources, highly dependent for external support, | 3 | Less access of information to stakeholders like general public even district line agencies, government audit conducted but no social and public audit | 2 | Work closely with donor agencies, community based water user groups, hydro projects | 2 | ***2.6*** |
| Water Users Groups (Subcatchment) | no clear manadate of the user group but has a mandate for water user group network, not in policy and guideline (drinking water) | 2 | ad hoc managemet and not very efficient | 2 | financial capacity less, human capacity is not tehnical but number is good | 2 | enough consultations with relevant stakeholders | 2 | coordination and collaboration with govt agencies and other relevant organizations | 4 | ***2.4*** |
| Water Users Groups (Ecosystems) | Presence of clear mandate documented in paper as constitution, authority in social norms but no legal authority for punishment or charging fines | 4 | Accountable to community, community leaders present, presence of social norms and guidelines | 4 | Human resources present, increasing technical capacity, presence of traditional knowledge, limited financial resource | 3 | PHPA, regular and periodic consultation with community and local stakeholders | 4 | Forestry users groups, youth clubs, mother groups, donors- Helvetas, saving and credit groups | 4 | ***3.8*** |

**Note:** scores are ranked from 1-5, with 1 representing low and 5 high adaptive capacity. Scores in the final right-hand column are averages of the five factors. As policies for sub-basins and freshwater ecosystems are the same, this table represents the rankings of both groups.

For freshwater information sources, participants gave the lowest scores for how subsistence farmers use information like precipitation, crop, and weather data (1.0); and information on glacial extent and the snow line, which is critical to measuring the impact of climate change in the landscape (1.6) (Table 32). In both cases, such information was determined to be infrequently collected and analyzed, of low quality, and particularly poorly communicated (it is often inaccessible to local communities and farmers). In what is a theme across all information analyses from the breakout groups, these last two factors were the lowest rated, indicating a need for substantial improvements in information communication, dissemination, and accessibility at the local level.

## Table 32. Adaptive Capacity Rankings: Freshwater Information

| Freshwater Ecosystems and Subcatchments Adaptive Capacity Assessment: Information Sources | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of Information** | **Frequency of Collection** | | **Iterative Processing & Analysis?** | | **Quality** | | **Acessibility** | | **Communications** | | ***Avg.*** |
| how ppl access and absorb information (subsistance) | once in two years is needed and nothing is there now | 1 | once in two years but not there now | 1 | spaital coverage is needed | 1 | not accessible | 1 | not communicated | 1 | ***1.0*** |
| Glacial extent and snow line | very limited information | 1 | limited analysis | 2 | limited research but has quality work | 3 | very limited to general public. Only limited to researcher | 1 | | 1 | ***1.6*** |
| water quality (silt, mining, urban/peri-urban) | once in a year but need atleast 4 times a year | 2 | annual publication but we will need quarterly | 2 | spatial gaps and temproral gaps | 2 | accessible through DHM publications | 3 | Communication is not adequate | 3 | ***2.4*** |
| Extreme events | Recorded when happens | 3 | Based on existing events but not forward lookin | 3 | Based on research methodology but not performed on all events | 3 | It is not so accessible to public but in increasing trend | 3 | Trend of packaging information as per required community is increasing and improving | 3 | ***3.0*** |

**Note:** scores are ranked from 1-5, with 1 representing low and 5 high adaptive capacity. Scores in the final right-hand column are averages of the five factors. As policies for sub-basins and freshwater ecosystems are the same, this table represents the rankings of both groups.

In a somewhat surprising result—given the overall lack of such information throughout Nepal—Information on extreme events was rated the highest relative to all other sources due to higher scores for all factors, including communication and accessibility. As participants note in the explanation of the scores for these two factors, there is improved communication and awareness around extreme events (and climate change) in the landscape in general.

### Infrastructure

Social adaptive capacity ratings for infrastructure were similar to freshwater, as policies and information sources were generally rated much lower than institutions, which of all the breakout Unit groups, were rated highest here (Table 33). In contrast, the rural energy policy was rated much higher across all factors (3.6), with better implementation and resources available, and a more forward-thinking approach focused on current technology.

## Table 33. Adaptive Capacity Rankings: Infrastructure Policies

| Infrastructure Adaptive Capacity Assessment: Policies | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Policy and Year | Relevant SubUnits | Forward Thinking | | Implementation and Enforcement | | Iterative | | Resources | | Coherency | | *Avg.* |
| Mines and Minerals Act 1985 | sand and gravel extraction | Does not take environmental consideration seriously and cover modern industries | 2 | even existing provisions are not applied or monitored | 1 | absencec of periodic revisions and assessment of its application | 1 | poor level of capacity and willingness, high fidutiary risk | 1 | weak environemetnal and good governance provisions | 2 | ***1.4*** |
| Local Infrastructure Development Policy 2004 | All | takes a simplistic and traditional view on infrastructure development | 2 | poorly implemented and high level of fidutial risk | 1 | not updated due to political instability | 1 | increasing technical and oversight capacity but low level of motivation, high level of corruption | 2 | environemental and social safeguards in place but poorly implimented | 3 | ***1.8*** |
| Rural Energy Policy 2002 | micro and small hydro | takes environment into considerations and uses latest technologies | 4 | increasing enforcement due to gap in supply | 4 | reviewd periodically | 4 | visible efforts put into increasing capacity of implimentation | 3 | increasing environmental and social safeguards applied | 3 | ***3.6*** |

**Note:** scores are ranked from 1-5, with 1 representing low and 5 high adaptive capacity. Scores in the final right-hand column are averages of the five factors.

Ratings for infrastructure information sources reflected a wide range, with a very high score for energy use (4.4), and the lowest possible score for information on infrastructure flexibility and management for climate change impacts and extremes (1.0) (Table 34).

## Table 34. Adaptive Capacity Rankings: Infrastructure Information

| Infrastructure Adaptive Capacity Assessment: Information Sources | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of Information** | **Frequency of Collection** | | **Iterative Processing & Analysis?** | | **Quality** | | **Acessibility** | | **Communications** | | ***Avg.*** |
| Information on infrastructure management & flexibility, & ability to withstand extremes | Doubtful that any information is being collected | 1 | If no data it's not being used | 1 | Lack of collection means lack of quality! | 1 | Lack of collection means lack of availability | 1 | Lack of availability means lack of communication | 1 | ***1.0*** |
| Planned infrastructure (roads, comms, energy) | Information is not holistically collected but some is - less so than existing | 2 | Even though it's being collected it's not being used well enough; also less than existing | 1 | Lots of gaps on smaller/local infrastructures and worse than for existing | 2 | Should be quite readily available but more so for existing infrastructure | 3 | Moderately well communicated | 2 | ***2.0*** |
| Energy use | There's some uncertainty over how often data is collected and by who | 3 | We know there's lots of data on energy collected | 5 | It's relatively good | 4 | Considered good | 5 | It's widely available and communicated | 5 | ***4.4*** |

**Note:** scores are ranked from 1-5, with 1 representing low and 5 high adaptive capacity. Scores in the final right-hand column are averages of the five factors.

These scores are contradicted by the relatively high scores for infrastructure management institutions in the landscape (Table 35), indicating there is capacity in the organizations to improve information generation. Scores for the Nepal Electricity Authority (NEA) were the lowest (2.6), due to low ratings for competence (overall management and leadership), and transparency and collaboration. The overall rating for the District and Village Development Committees (DDCs and VDCs) was somewhat higher (3.6), due to higher ratings in transparency and collaboration, but similar low scores for overall management and resources.

## Table 35. Adaptive Capacity Rankings: Infrastructure Institutions

| Infrastructure Adaptive Capacity Assessment: Institutions | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Institution** | **Relevant Unit/SubUnits** | **Mandate and Authority** | | **Competence** | | **Resources** | | **Transparency** | | **Collaboration** | | ***Avg.*** |
| Nepal Electricity Authority (NEA) | Dams<br>Urban settlements<br>Rural settlements<br>Small hydro | Strong mandate | 4 | No - or there would be no load shedding! When implementing hydro power they actually do it quite well | 2 | Good human and informational and technical; not good financial as is loss-making | 3 | Poor | 2 | Poor | 2 | ***2.6*** |
| District Development Committee (DDC)/ Village Development | District roads<br>Local roads<br>Rural settlements<br>Riverbed mining<br>Irrigation | Excellent mandate | 4 | Ward level and village level planning and prioiritisation, but it's not implemented | 3 | Significant financial resources but very poor human and technical | 3 | Consultative when planning and setting priorities - good | 4 | Strong as works with community and district based orgs eg CBOs, social orgs | 4 | ***3.6*** |

**Note:** scores are ranked from 1-5, with 1 representing low and 5 high adaptive capacity. Scores in the final right-hand column are averages of the five factors.

### Species

In comparison with the other Unit groups, adaptive capacity ratings for species are mid-range, with very few high or low scores. Ratings for two policies relevant to key species in the landscape are indicative of this (Table 36). The overall rating for the National Biodiversity Strategy of 2002 is the lowest of all domestic policies (2.4) due to poor flexibility in design, lack of regular revision, and poor coherence with other relevant biodiversity conservation policies. The overall rating for the National Parks and Wildlife Conservation Act of 1973 is somewhat higher due to better implementation, resource availability, and a forward-thinking approach, but also faces similar deficiencies in a lack of coherence or regular review. Neither is rated particularly high or low.

## Table 36. Adaptive Capacity Rankings: Species Policies

| Species Adaptive Capacity Assessment: Policies | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Policy and Year | Forward Thinking | | Implementation and Enforcement | | Iterative | | Resources | | Coherency | | *Avg.* |
| National Biodiversity Strategy (2002) | Not much forward thinking in light with CC | 2 | As per the need and not effectively implemented | 3 | Done only in 10 years | 2 | Financial problem and focused in PAs, good technical knowledge, few specialist | 3 | Less consultation with field people and is formulated in center and it needs to be improved | 2 | ***2.4*** |
| National Parks and Wildlife Conservation Act 1973 | protection oriented and army model in Terai and community models have taken start in mountains | 3 | in core areas impementation is up to the satisfactory level. | 4 | Need to be revised in line with present day context | 2 | Technically sound but improved in line with biodiversity and CC aspects intervention | 4 | Minimal consistency in policy and needs to be improved further | 2 | ***3*** |

**Note:** scores are ranked from 1-5, with 1 representing low and 5 high adaptive capacity. Scores in the final right-hand column are averages of the five factors.

Adaptive capacity ratings for institutions important to species management in the CHAL are some of the highest of all Unit groups (Table 37). The Department of National Parks and Wildlife Conservation (DNPWC) was rated lowest (3.0) due to a need for improvement in collaboration with local stakeholders (local communities), and improvements in management to move away from a hierarchical, top-down structure, but has a clear mandate and collaborates effectively. The Department of Forests (DoF) was rated highest (3.8) due to high ratings across all factors, with the exception of weak financial and human resources.

## Table 37. Adaptive Capacity Rankings: Species Institutions

| Species Adaptive Capacity Assessment: Institutions | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Institution | Relevant Unit/SubUnits | Mandate and Authority | | Competence | | Resources | | Transparency | | Collaboration | | *Avg.* |
| DNPWC | All species | Clear mandate and sufficient authority (it has its own act to enforce law in biodiversity) | 5 | Set priorities, makes decision but weak role in HWC, a bit heirarchy so less top down information sharing | 2 | Good financial in CNP and ACA, less technicians, technically strong, weak information | 3 | Gap in park and people | 2 | Good coordination and collaboration with relevant institutions | | ***3*** |
| Department of Forests | Tiger, rhino, orchids, snow leopard, red panda, gharial, wild dog, hornbill, migratory birds | Clear mandate and sufficient authority | 5 | Community handed over and DFO has the full authority | 3 | Financial weak, Inadequate human resources | 3 | Good consultation with other stakeholders | 4 | Good coordination with relevant institutions | 4 | ***3.8*** |

**Note:** scores are ranked from 1-5, with 1 representing low and 5 high adaptive capacity. Scores in the final right-hand column are averages of the five factors.

The lowest rated information source was fire occurrence and extent (2.2) due to poor data collection and analysis, data quality, and accessibility, with a slightly better rating for communication (Table 38). On the other end of the spectrum, human-wildlife conflict occurrence was rated highest (3.4), due to better data collection and analysis, and quality. Data accessibility and communication were also rated high.

## Table 38. Adaptive Capacity Rankings: Species Information

| Species Adaptive Capacity Assessment: Information Sources | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Type of Information | Relevant Unit/SubUnits | Frequency of Collection | | Iterative Processing & Analysis? | | Quality (temporal gaps, spatial gaps) | | Accessibility (e.g. free to public, accessible for a fee, or | | Communications (Across scales, packaging, Communication Networks) | | *Avg.* |
| fire occurance and exent | Tiger, rhino, gharial, snow leopard, red panda, hornbill, migratory birds, mahaseer, orchids | Very poor collection by all parties (WWF, ICIMOD, department), local communities collect information | 2 | We document sites or incidents and inform DFO about it. There are forest fire squads to support DFO and are in voluntary basis. | 2 | ICIMOD has the quality but not well disseminated | 2 | The maps from ICIMOD is not well circulated to DFO and wardens | 2 | The maps from ICIMOD are not well communicated to all, and the department communicate through FMs but not updated information | 3 | ***2.2*** |
| human wildlife conflict occurance | Snow leopard, tiger, rhino, red panda | Timely collected by organizations but still to be improved | 3 | Done in project level or site level to devise the compensation measures | 3 | Not covered whole of the landscape only in PAs | 3 | Widely accessible by all organizations | 4 | Well communicated through media | 4 | ***3.4*** |

**Note:** scores are ranked from 1-5, with 1 representing low and 5 high adaptive capacity. Scores in the final right-hand column are averages of the five factors.

Though these results are inherently biased by diverse and limited participant perspectives, they are nevertheless helpful in guiding future adaptation planning in the landscape, especially with engaging specific institutions and overcoming information or policy barriers or opportunities that might impede or facilitate the success of any adaptation efforts in the landscape.

## Adaptation Interventions and Planning

### Approach

During this final stage in the process, each breakout group was tasked with prioritizing two Subunits and developing adaptation interventions—conservation or development-focused projects or programs—that specifically reduce impacts, address capacity barriers, and enhance the resilience or reduce the vulnerability of these two priority Units. Over the course of two hours, each group went through the initial stages of the planning process to develop concept projects, addressing questions around cost, location, time frame, and synergies with other programs (Table 40).

Given the time constraints participants were not expected to present fully conceptualized programs or projects to address complex issues. These should be seen as initial ideas and examples of the process that has to be followed to develop adaptation interventions. It is recommended that relevant stakeholders in the landscape should develop interventions based on the vulnerability analyses and include them in strategic management plans in the landscape.

### Table 39. Example Species Group Adaptation Interventions

| | Adaptation Intervention 1 | Adaptation Intervention 2 |
|---|---|---|
| **Sub Unit and Impact** | **Snow leopard:**<br>Increasing temperature leading to longer stay of livestock and people with intensive grazing pressure (fire caused by herders) in snow leopard habitat and increasing HWC (retaliatory killing) | **Gharial:**<br>Siltation and floods (pollution and dams) in river disturbs the quality of water for gharial, and increasing cold spell will affect gharial egg hatching, leading to population decline |
| **Intervention** | **Prey base and range management**<br>Awareness of protection of snow leopard, zoning allowing and not allowing for livestock grazing and rotational grazing and rangeland management, invasive species, protecting prey base which are blue sheep and Himalayan tahr | **Watershed management**<br>Better road construction, bioengineering in upper watershed to reduce soil erosion and landslides, improved livelihood opportunities for river dependent communities that reduce environmental pressure |
| **Why that intervention** | Rotational grazing for sustainable management and prey base will be well managed, and zoning for maintaining the linkages of snow leopard horizontally and to north | Critically endangered species with 1% survival in wild and excessive pressure on ecosystem, indicator of river health |
| **Where to implement** | In situ in ACA, Manaslu Conservation Area, LNP outside of PAs in sub alpine and alpine zones | Narayani and Rapti |
| **Who to implement** | NTNC, DNPWC, DoF, WWF, CSOs/CBOs | NTNC, TAL, DNPWC |
| **Timeframe** | 2014 – 2024 | 2014 – 2024 |
| **Funding (Y/N)** | Yes - in awareness program and inadequate including Hariyo Ban and Annapurna Conservation Area Project budget | Yes - some funds from TAL, DNPWC, NTNC, Hariyo Ban |
| **Are there any risks/drawbacks** | Communities may or may not agree to zoning plans; the temperature is increasing day by day; yarchagumba (*Cordyceps)* is found in the areas and the people may not be interested in conservation | River dependent communities should be provided with appropriate livelihood options otherwise the intervention may not work; Dam construction is still a problem (Tribeni) |
| **Synergies/opportunities to work with others?** | Good opportunity to work with NTNC, herders or rangeland management groups/committees | Work synergy and opportunity since 1970's when gharial pool was established and good baseline for gharial; only found in India and Nepal; Multi-stakeholders Forestry Program |

Almost all breakout groups proposed at least two interventions in this final stage of the workshop, some more fully developed than others. While each is directed at very different Subunits, there are clear similarities across them, including: improved monitoring and analysis of hydrological and climate data, in part to provide early warning systems; increased capacity for improved institutional oversight; and direct site-based interventions to change resource management practices (Table 40). See Annex 1 for detailed descriptions of interventions proposed for each Unit.

### Table 39. Summary Adaptation Interventions Proposed for each Unit

| Focus Area | Proposed Interventions | Targeted Subunit(s) |
|---|---|---|
| Forests | Promote alternative energy sources and improved cook stove programs to reduce fuel wood demand and deforestation/degradation, especially in the lower temperate broadleaf forests in the middle mountains and Churia, hence reducing non-climate pressures and building forest resilience. | Lower temperate broadleaf forests (Middle Mountains) |
| | Promote "climate-smart" community-based forest management, with institutions and protocols for fire prevention and control. Reforest denuded areas in the Subtropical Broadleaf Forests of the Churia. | Subtropical broadleaf forests (Siwaliks) |
| Freshwater | Protect and where possible restore climate-vulnerable spring sources through reforestation of watersheds and control of damaging land uses such as grazing, over-harvesting of forest products, poorly constructed roads, and inappropriate agriculture. | Spring sources (Siwaliks) |
| | Enhance monitoring for freshwater systems, focusing on glacial extent and snow line, and snow-water equivalent in higher altitudes; and water quality in lower lying areas of the Middle Mountains and Siwaliks | Lakes (Middle Mountains) |
| Sub-basins | Install early warning systems in communities that regularly experience flooding, alongside climate change sensitization and disaster preparedness programs. | Seti Sub-basin |
| | Conserve headwaters and riparian areas to reduce impacts of more intense rainfall in the future | All sub-basins |
| | Limit development in floodplains, taking into account likely future flooding, and allow the river to flood and change course | Seti Sub-basin |
| Species | Identify and conserve important wintering and nesting areas, summer habitats, and intervening staging habitats for altitudinal migrant birds. Use the results of the climate scenario models to identify suitable resilient habitats and corridors along gradients in the Gandaki Basin. | Migratory birds basin-wide |
| | Work with upstream watershed communities to reduce fertilizer and pesticide use and develop soil management practices to reduce runoff and siltation during intense rainfall to conserve habitat and maintain water quality and quantity for gharial and their prey species in the lower reaches of the river system. | Gharial |
| Agriculture | Increase funding and capacitate government extension services to provide climate-smart agriculture support, including climate adaptive farming techniques, crops, and climate change awareness programs. | Pakho, Tar, Khet, and Tar (Middle Mountain, Siwalik) |
| | Improve access to seasonal climate information for farmers, including suggested planting dates and weather forecasts. | Pakho, Tar, Khet, and Tar (Middle Mountain, Siwalik) |

| | | |
|---|---|---|
| Infrastructure | Mandate climate vulnerability assessments for all proposed and existing large infrastructure developments in CHAL including national and local roads and hydropower developments, and incorporate results into design/operation. | Hydropower dams, district and national roads |
| | Eliminate unplanned road construction in all districts and at local level, and promote "green road" construction alternatives that have proper drainage and gradation that allow for more extreme weather events in the future, in order to reduce the risk of soil erosion and landslides. | District, local roads |

## Analysis and Interpretation of Workshop Results

Climate change is expected to become manifested as a general increase in temperature with shifts in the relatively predictable seasonality of precipitation, and more extreme climate events (Ministry of Environment, 2010). The outputs from the workshop (and information gleaned from the literature) indicate that different socio-ecological Subunits will be affected in different ways, including where they are located geographically in the landscape.

Since vulnerability is a function of resilience and exposure, the most vulnerable Subunits in general were not surprisingly those with the highest ratings for exposure and lowest for resilience (Table 40). Notable exceptions include the Narayani and Trishuli sub-basins which were rated as being resilient, but because of the very high exposure were also rated as being highly vulnerable. Adaptation strategies to reduce vulnerability of Subunits can focus on either reducing exposure or increasing resilience of Subunits (or doing both), based on the outputs from the analyses presented here.

In general, the most vulnerable Subunits are found in the lower altitude areas of the Middle Mountains and Churia, with none from the High Mountains or Trans-Himalayan Region. Given that the majority of the landscape's human population lives in the lowlands and development is concentrated there, this result is not surprising. Subunits in these areas are less naturally resilient due to persistent anthropogenic pressures, while also exposed to many of the most detrimental impacts of climate change. Existing unsustainable natural resource management and direct impacts of rapid infrastructure development and urbanization here are likely to exacerbate the effects of climate change. And as people and infrastructure increasingly experience the impacts of climate change, coping strategies may increase pressure on natural systems.

There are, however, also a number of highly vulnerable Subunits that cut across the entire basin, including four of the nine sub-basins, species such as migratory birds that use multiple zones, and rural settlements throughout the entire landscape whose vulnerability is a function of landscape-level drivers.

**Table 40. The top quartile of most vulnerable Subunits across all Unit groups.**

| Physiographic Zone | Unit (Group) | Subunit | Resilience | Exposure | Vulnerability |
|---|---|---|---|---|---|
| Multi-zone | Sub-basins | Seti | 2.2 | 4.0 | 3.7 |
| Churia | Freshwater | Spring Sources | 2.0 | 4.0 | 3.7 |
| Churia | Species | Gharial | 2.0 | 3.8 | 3.6 |
| Multi-zone | Species | Migratory Birds | 1.8 | 3.7 | 3.5 |
| Churia | Forests | Subtropical Broadleaf Forest | 2.5 | 3.9 | 3.5 |
| Multi-zone | Freshwater | Floodplain | 3.2 | 4.0 | 3.3 |
| Middle Mountains | Agriculture | Pakho | 2.6 | 3.7 | 3.3 |
| Multi-zone | Sub-basins | Rapti | 2.5 | 3.8 | 3.3 |
| Multi-zone | Sub-basins | Narayani | 4.0 | 4.0 | 3.1 |
| Multi-zone | Sub-basins | Trishuli | 3.8 | 4.0 | 3.1 |
| Middle Mountains | Agriculture | Tar (irrigated) | 3.4 | 3.7 | 3.0 |
| Multi-zone | Species | Tiger | 2.8 | 3.3 | 3.0 |
| Multi-zone | Infrastructure | Rural Settlements | 2.0 | 2.7 | 2.9 |

**Note: Red to green color spectrum indicates most to least vulnerable, respectively. Green indicates high resilience. For Subunits exposed to multiple impacts, scores across those impacts are averaged to calculate final vulnerability rating.**

### Forests

Most potential impacts on forests are manifested through deforestation, degradation, and conversion, but with different primary causes enhanced by climate change. The Subtropical Broadleaf Forests in the lowlands—especially the Churia and the Middle Mountains—were most vulnerable to climate change, whereas the forests in the upper mountain zones are more resilient. These results are consistent with the climate models produced by Thapa et al. (2015). Forests are also vulnerable to increased anthropogenic pressures that can act in synergy with climate change making them more vulnerable. For instance, as productivity of agricultural lands declines with changing climatic conditions (i.e., increasing temperatures, unpredictable rainfall, and prolonged droughts) there could be agricultural encroachment into forests as people attempt to increase production by planting larger areas. Furthermore, increased demand for fuelwood and other forest resources from a shrinking forest area can increase degradation pressure.

Improvements in social adaptive capacity to enhance forest management, with appropriate monitoring are necessary, especially in collecting information, overall quality of information collected, and dissemination of good information to local communities and other stakeholders.

### Agriculture

The agriculture systems in the lower elevation areas were rated as more vulnerable, with the Pakho and irrigated Tar in the Middle Mountains rated as most vulnerable (Table 40). These agricultural systems were considered likely to become highly exposed to more outbreaks of disease and to be vulnerable to pests (including pest species new to the areas) with climate change. As more pesticides are used to eradicate pests, there will be feedback loops as the rivers and soils become polluted and poisoned, creating health hazards. As productivity declines, people may begin to move out, creating fallow lands that are exposed to erosion. Sedimentation of waterways can cause irrigation systems and hydropower systems to become damaged and dysfunctional. More intense rainfall can cause landslides, blocking rivers and streams and causing flashfloods.

The high scores for all social adaptive capacity factors for the private agriculture sector indicate its success, and a need for other sectors to learn from the sector and expand their capacities as well. For example, subsistence-based farmers in the CHAL could improve productivity and income through relevant learning and capacity building exchanges with larger-scale farmers. Improving and expanding implementation of the Agribusiness Promotion Policy is one avenue to enhance such collaboration.

### Freshwater systems

The non-lotic freshwater systems—lakes, floodplains, spring sources—in the lower elevations were most exposed, and thus vulnerable. The spring sources in the Churia and flood plains in all physiographic zones of the CHAL were rated as being the most vulnerable (Table 40). The impacts described are largely focused on existing issues in the landscape—with a particular focus on water quality—but exacerbated by climate change. These include: more conflict over increasingly limited water supplies; reduced water availability due to deforestation and poorly planned infrastructure like electricity and road networks that have reduced river and stream discharge and overall volume in spring sources; reductions in snow-fed river flows due to rapid snow and ice melt; and declining agricultural productivity and biodiversity loss due to reduced water quality associated with increasing siltation and erosion from extreme storms.

The Middle Mountain lakes, though not receiving the highest overall exposure score, should nevertheless be considered highly exposed because they were determined to be affected by more potential impacts than any other freshwater Subunit. Their highest exposure rating—increased conflict over increasingly limited sources—is particularly important to note, given their importance in providing drinking water and other important ecosystem services in the landscape.

The social adaptive capacity assessment ratings indicated that the existing national-level freshwater policies, particularly of the NWP and the EPA, require improving. More resource allocation to institutions such as the Water and Energy Commission Secretariat (WECS), which is responsible for implementing the NWP, is needed, along with endowing WECS with a mandate to coordinate water policy at the national level.

Institutionally, the water user groups and associations in the landscape would be more effective institutions for collaboration and implementation of adaptation efforts at the local level, but capacity improvements are needed, particularly in creating the proper legal authority, improved management, technical capacity, financial resources, and collaboration with other local institutions.

### Rivers and Sub-basins

The spatial extent of analysis of rivers and sub-basins was from source to outlet, or confluence. Thus, the Subunits transcended physiographic zones within the CHAL. In general, the sub-basins in the lower elevations were more exposed and vulnerable, which is not surprising given that the majority of current climate-development impacts is experienced in these areas. The Seti and Rapti were rated as being very highly exposed and with very low resilience, contributing to the high vulnerability (Table 40). But despite the high resilience of the Narayani and Trishuli sub-basins they were considered to have high exposure, and thus were rated as highly vulnerable to climate change. The major impacts of climate change on these sub-basins are considered to be: an increased flood risk; higher sedimentation rates and lower agricultural productivity due to fluctuating water volumes associated with glacial melt; reduced hydropower production due to fluctuating flows and increased sedimentation associated with greater climate variability and increasing frequency and intensity of extreme events; increased incidence of water borne disease due to more high flood events; increased conflict over declining water supplies due to lowering water tables and increasing rainfall variability; and loss of aquatic species due to increased river temperatures and rainfall variability.

### Infrastructure

This analysis was focused on analyzing how vulnerability to infrastructure itself can contribute to the larger vulnerability of other systems in the landscape. As a result, it analyzed more direct impacts of climate change on infrastructure, focusing in particular on how changes in precipitation patterns and resulting downstream flows can degrade and destroy infrastructure, resulting in even greater impacts on the larger landscape. Rural settlements across all physiographic zones in the CHAL stood out for their high vulnerability to climate change (Table 40), as did all local roads (Table 22). The major climate change hazards for infrastructure were considered to be increased frequency and intensity of extreme events like floods and droughts. Impacts included: increased soil erosion due to increasing climate variability; more rapid infrastructure wear and tear due to increased runoff intensity and poor engineering design; rapid surface deterioration of roads due to channeling created by increased soil erosion; increased disrepair due to destruction of drainage structures resulting from increased flow variability; rapid wear and tear due to lack of designs adapted for climate change; and higher siltation rates that can be expected under extreme weather conditions due to climate change.

The ratings for policies such as the Mines and Minerals Act of 1985, the Local Infrastructure Development Policy, and the Rural Energy Policy during the social adaptive capacity assessment provide an interesting snapshot of the level of effectiveness of overall policy in the infrastructure sector (Table 33). Not surprisingly, given the problems of poor oversight and regulation in the sand and gravel mining sector, the rating for the Mines and Minerals Act was very low (1.4) because of weak enforcement and implementation and a general inconsistency with other regulations at different scales of governance. The same can be said of the Local Infrastructure Development Policy (1.8), which participants note takes “a simplistic and traditional view on infrastructure development,” and has poorly implemented environmental and social safeguards. Given the widespread historical challenges in rural development in Nepal, this low score is also not surprising. Overall, these ratings provide obvious avenues for improving adaptive capacity in the infrastructure sector. Critical revisions are needed for the minerals and local development policies to improve implementation and enforcement through capacity building, while the already successful rural energy development policy could be further promoted and serve as an example for other rural development approaches.

Availability of good information on infrastructure was also poor. This is particularly worrying because of the current rapid infrastructure development trends, coupled with increasing frequency and intensity of extreme events—floods and landslides—that are expected to worsen. The total lack of collection and communication of even basic information on planned infrastructure (as indicated by the low rating for planned infrastructure (2.0)) indicates a critical need to increase adaptive capacity and reduce overall vulnerability in the sector.

Overall, as is the case with other Unit groups, these ratings indicate multiple focus areas for improving adaptive capacity in the infrastructure sector. These include: improved oversight, capacity and resources for implementation of key regulations like the Mines and Minerals Act and the Infrastructure Development Policy; improvements in information collection around basic infrastructure development planning and consideration of future climate change impacts; and better management and technical and human resources for the DDCs and VDCs, and improvements in management, transparency, and collaboration for the NEA.

### Species

Gharial and migratory birds were considered to be the most vulnerable species to climate change (Table 40), from among the 10 species selected for analysis. Direct and indirect impacts of climate change include: increased habitat degradation and human-wildlife conflict, for example if people spend more time in high altitude areas with rising temperatures; degradation of water quality due to increased erosion, landslides and siltation as a result of unplanned road development and road disrepair coupled with more intense rainfall; range shifts and population reductions, especially as human encroachment progresses further into forests and invasive species displace indigenous species; and temperature changes causing skewed sex ratios in species whose sex is determined by incubation temperature (e.g., gharial and crocodile).

The ratings for social adaptive capacity provide guidance for improving adaptive capacity for species management in the landscape. Potential policy reforms could focus on more regular revisions to the National Biodiversity Strategy and National Parks and Wildlife Conservation Act, including better consideration of climate change impacts, and improved coordination across other ministries and departments at the local and regional levels. Management of DNPWC could be strengthened, and increased financial and human resources should be provided to the DoF. Improved collection of information on fires will also improve adaptive capacity, and is especially necessary as temperatures increase and drought-induced fires become increasingly common, especially in the rich forests and grasslands of the national parks.

Overall, the analysis identified several key socio-ecological indicators that are most vulnerable to climate change related impacts. The workshop participants identified a limited set of adaptation strategies. A landscape conservation management plan should consider these strategies as a starting point, but should take the exercise further to develop more comprehensive climate adaptation strategies.

## REFERENCES

Aase, T. H., Chaudhary, R.P. and Vetaas, O.R. 2010. Farming flexibility and food security under climate uncertainty: Manang, Nepal Himalaya. *Area* (Royal Geographical Society) 42: 228–238.

Asian Development Bank. 2012. *Nepal: Kali Gandaki "A" Hydroelectric Project.* Performance Evaluation Report, Independent Evaluation, Asian Development Bank.

Bhandari, 2009. Wise Use of Wetlands in Nepal. Banko Janakari, Special issue, February 2009. http://www.nepjol.info/index.php/BANKO/article/view/2206

Bhattarai, S., Chaudhary, R.P., Quave, C.L. and Taylor, R.S.L. 2010. The use of medicinal plants in the trans-Himalayan arid zone of Mustang district, Nepal. *Journal of Ethnology and Ethnomedicine* (BioMed Central Ltd.) 6 (14).

Birdlife International. 2013. Great Hornbill *Buceros bicornis.* www.birdlife.org (accessed 10 15, 2013).

Bolch, T., Kulkarni, A., Kääb, A., Huggel, C., Paul, F., Cogley, J.G., Frey, H., Kargel, J.S., Fujita, K., Scheel, M., Bajracharya, S. and Stoffel, M. 2012. The State and Fate of Himalayan Glaciers. *Science* 336: 310-314.

Central Bureau of Statistics. 2011. Nepal Living Standards Survey 2010/11. Volume 2: Statistical Report. Central Bureau of Statistics, Kathmandu, Nepal.

Chaudhary, P. and Bawa K.S. 2011. Local perceptions of climate change validated by scientific evidence in the Himalayas. *Biol. Lett.* 7: 767-770.

Choudhury, B.C., Singh, L.A.K., Rao, R.J., Basu, D., Sharma, R.K., Hussain, S.A., Andrews, H.V., Whitaker, N., Whitaker, R., Lenin, J., Maskey, T., Cadi, A., Rashid, S.M.A., Choudhury, A.A., Dahal, B., Win Ko Ko, U., Thorbjarnarson, J & Ross, J.P. 2007. *Gavialis gangeticus*. Vers. 2013.1. *IUCN Red List of Threatened Species.* www.iucnredlist.org (accessed 10 14, 2013).

Chundawat, R.S., Khan, J.A. & Mallon, D.P. 2011. *Panthera tigris* ssp. *tigris.* www.iucnredlist.org (accessed 10 15, 2013).

IPCC, 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC, 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change

[Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

Jackson, R., Mallon, D., McCarthy, T., Chundaway, R.A. & Habib, B. 2008. *Panthera uncia*. *IUCN Red List of Threatened Species.* www.iucnredlist.org (accessed 10 15, 2013).

Jha, B.R. & Rayamajhi, A. 2013. *Tor putitora.* www.iucnredlist.org (accessed 10 15, 2013).

Jolly, Joanna. 2011. Yarsagumba: Curse of Himalayan Annapurna region. *BBC News*, January 4, 2011.

Kansakar, S.R., Hannah, D.M., Gerrard, J. and Rees G. 2004. Spatial pattern in the precipitation regime of Nepal. *International Journal of Climatology* (Wiley Interscience) 24 (13): 1645–1659.

Manandhar, S., Pandey, V.P. andKazama, F. 2012. Hydro-climatic trends and people's perceptions: Case of Kali Gandaki River Basin, Nepal. *Clim Res* 54: 167-179.

Ministry of Environment. 2010. National Adaptation Programme of Action to Climate Change. Ministry of Environment, Kathmandu, Nepal.

NCVST. 2009. Vulnerability Through the Eyes of Vulnerable: Climate Change Induced Uncertainties and Nepal's Development Predicaments, Institute for Social and Environmental Transition-Nepal (ISET-N, Kathmandu) and Institute for Social and Environmental Transition (ISET, Boulder, Colorado) for Nepal Climate Vulnerability Study Team (NCVST) Kathmandu.

Panday and Ghimire. 2012.Time-series analysis of NDVI from AVHRR data over the Hindu-Kush Himalayan region for the period 1982–2006. International Journal of Remote Sensing, 33(21): 6710–6721.

Paudel, K.P. and Andersen, P. 2011. Monitoring snow cover variability in an agropastoral area in the Trans Himalayan region of Nepal using MODIS data with improved cloud removal methodology. *Remote Sensing of Environment* 115: 1234-1246.

Sharma, C.M. 2008. Freshwater fishes, fisheries, and habitat prospects in Nepal. *Aquatic Ecosystem Health and Management* (Taylor and Francis) 11 (3): 289-297.

Shrestha, A.B. and Aryal, R. 2011. Climate change in Nepal and its impact on Himalayan glaciers. *Reg Environ Change* 11: S67-S77.

Shrestha, T.K. 2003. *Conservation and Management of Fishes in the Large Himalayan Rivers of Nepal.* Central Department of Zoology, Tribhuvan University, Kathmandu, Nepal.

Shrestha, U.B., Gautam, S. and Bawa, K.S. 2012. Widespread Climate Change in the Himalayas and Associated Changes in Local Ecosystems. *PLoS ONE* 7 (5): 1-10.

Sovacool, B.K., Dhakal, S., Gippner, O. and Bambawale, M.J. 2011. Halting hydro: A review of the socio-technical barriers to hydroelectric power plants in Nepal. *Energy* (Elsevier) 36: 3468-3476.

Talukdar, B.K., Emslie, R., Bist, S.S., Choudhury, A., Ellis, S., Bonal, B.S., Malakar, M.C., Talukdar, B.N. and Barua, M. 2008. *Rhinoceros unicornis*. *IUCN Red List of Threatened Species.* www.iucnredlist.org (accessed 10 15, 2013).

Thapa, G.J., Wikramanayake, E. and Forrest, J. 2015*. Climate-change impacts on the biodiversity of the Terai Arc Landscape and the Chitwan-Annapurna Landscape*. WWF Nepal, Hariyo Ban Program, Kathmandu, Nepal.

Wang, X., Choudhury, A., Yonzon, P., Wozencraft, C. & Zaw T. 2008. *Ailurus fulgens. IUCN Red List of Threatened Species.* 2008. www.iucnredlist.org (accessed 10 15, 2013).

WECS. 2010. *Energy Sector Synopsis Report 2010*. Water and Energy Commission Secretariat, Kathmandu, Nepal.

WWF Nepal. 2013a. *Chitwan-Annapurna Landscape: A Rapid Assessment.* WWF Nepal, Hariyo Ban Program, Kathmandu, Nepal.

WWF Nepal. 2013b. Snow leopard. http://wwf.panda.org/what_we_do/endangered_species/snow_leopard/ (accessed September 10, 2013).

WWF Nepal. 2013c. Red Panda. http://www.wwfnepal.org/about_wwf/conservation_nepal/shl/thematic_solutions_nepal2/species_nepal/red_panda/ (accessed October 2, 2013).

WWF Nepal. 2013d. Greater one-horned rhinoceros. wwf.panda.org (accessed 10 15, 2013).

WWF Nepal. 2013e. Bengal (Indian) Tiger. http://wwf.panda.org/what_we_do/endangered_species/tigers/about_tigers/bengal_tiger/ (accessed 10 14, 2013).

WWF Nepal. 2013f. *Chitwan-Annapurna Landscape: Biodiversity important areas and linkages.* WWF Nepal, Hariyo Ban Program, Kathmandu, Nepal.

WWF Nepal. 2014. *Overview of Existing and Planned Key Infrastructure in Terai Arc Landscape and Chitwan-Annapurna Landscape and its Environmental and Social Impacts.* WWF Nepal, Hariyo Ban Program, Kathmandu, Nepal.

# ANNEX 1 | Summary Table of Results

| Subunit | Resilience Rating | Impact Severity | Vulnerability | Breakout Group | Unit | Impact Description |
|---|---|---|---|---|---|---|
| Alpine coniferous Forests (High Mountains) | 2.8 | 2.7 | 2.9 | Ecoregion & Forest | High Mountains | Increase deforestation for fuel wood demand and continued low supply of fuel wood due to deforestation will increase further deforestation/forest degradation |
| Alpine coniferous Forests (High Mountains) | 2.8 | 3.0 | 2.6 | Ecoregion & Forest | High Mountains | Increasing temperature and prolong drought enhanced forest fire that will damage forests |
| Alpine coniferous Forests (High Mountains) | 2.8 | 2.0 | 2.1 | Ecoregion & Forest | High Mountains | Increasing temperature and prolonged drought and intense rainfall will accelerate erosion, landslide, loss and damage of forest species and declines productivity |
| Alpine Scrub and Meadow and Rangelands (High Mountains) | 1.7 | 1.3 | 1.9 | Ecoregion & Forest | High Mountains | Increasing temperature and prolonged drought and intense rainfall will accelerate erosion, landslide, loss and damage of forest species and declines productivity |
| Bari [Middle Mountains] | 3.4 | 3.0 | 2.5 | Agriculture | Middle Mountains | Increasing temperature causes increased pest infestation, more chemical inputs to be used in intensive agriculture , which results in more external dependency for such as fertilizers and agrichemicals. Which puts makes agriculture unsustainable . |
| Bari [Siwalik] | 3.2 | 3.3 | 2.9 | Agriculture | Siwalik/Churia Mountains | Increasing temperature causes increased pest infestation, more chemical inputs to be used in intensive agriculture , which results in more external dependency for such as fertilizers and agrichemicals. Which puts makes agriculture unsustainable . |
| Budhi Gandaki | 3.7 | 1.7 | 1.6 | Freshwater (Rivers) | Freshwater | increased temperature will change the rate of glacier melt. That will increase volume of water resulting to the fluctuation of water flow. It will create the risk of flood and eventually lead to the high sedimentation, increase flood area, decrease agri productivity in the downstream of river network |
| Budhi Gandaki | 3.7 | 1.7 | 1.6 | Freshwater (Rivers) | Freshwater | increase temperature and unpredictable rainfall will fluctuate the water discharge. The hydropower production thus will be unpredictable, high sedimentation and infrastructure damage in the river system |
| Cryosphere (High Himalaya) | 2.8 | 2.7 | 2.7 | Freshwater (Lakes, Springs, Wetlands) | High Himalaya | Increase temperature<br>Chal area has many mountainous range. Temperature increase is rapidly impacting high Himalayan - high rate of ice melting, water sources depleting for snow fed rivers. |
| Dams | 3.0 | 3.0 | 2.8 | Infrastructure | Infrastructure | Extreme rainfall leads to higher/ extreme discharge, leading to higher siltation rate and worsening water quality |
| Dams | 3.0 | 2.0 | 2.0 | Infrastructure | Infrastructure | Extreme rainfall combined with human induced bad infrastructure planning leads more infrastructure to fall into disrepair |
| Dams | 3.0 | 2.0 | 2.0 | Infrastructure | Infrastructure | Intensive runoff due to unpredictable discharge, poor planning and design of infrastructure (not taking CC into account) causes rapid wear and tear of infrastructure |
| Daroudi | 2.8 | 3.3 | 3.1 | Freshwater (Rivers) | Freshwater | decreased rainfall will lead to decrease water table and will erode water source. It eventually will create water scarcity and increase demand of water in rural and urban areas leading to water conflict |
| Daroudi | 2.8 | 2.3 | 2.4 | Freshwater (Rivers) | Freshwater | increase temperature and unpredictable rainfall will fluctuate the water discharge. The hydropower production thus will be unpredictable, high sedimentation and infrastructure damage in the river system |
| Daroudi | 2.8 | 2.0 | 2.2 | Freshwater (Rivers) | Freshwater | increased temperature will change the rate of glacier melt. That will increase volume of water resulting to the fluctuation of water flow. It will create the risk of flood and eventually lead to the high sedimentation, increase flood area, decrease agri productivity in the downstream of river network |
| District Roads | 4.0 | 3.7 | 2.8 | Infrastructure | Infrastructure | Increased intensity of rainfall causing increased soil erosion leading to rut formation and channeling of roads, resulting in rapid surface deterioration of roads |
| District Roads | 4.0 | 3.0 | 2.2 | Infrastructure | Infrastructure | Rising temperature increases soil erosion, causing increasing siltation and encroachment around wetlands and lakes, urban and peri urban areas, causing impact on roads |
| District Roads | 4.0 | 2.7 | 2.2 | Infrastructure | Infrastructure | Extreme rainfall combined with human induced bad infrastructure planning leads more infrastructure to fall into disrepair |
| District Roads | 4.0 | 2.7 | 2.2 | Infrastructure | Infrastructure | Discharge unpredictability leads to cross drainage problems e.g. drainage structures being washed out, also due to inadequate and unplanned infrastructure development, leading to more infrastructure falling into disrepair |
| District Roads | 4.0 | 2.7 | 2.2 | Infrastructure | Infrastructure | Intensive runoff due to unpredictable discharge, poor planning and design of infrastructure (not taking CC into account) causes rapid wear and tear of infrastructure |
| District Roads | 4.0 | 2.7 | 2.2 | Infrastructure | Infrastructure | Changes in discharge leads to rural-urban migration causing pressure in urban areas where more infrastructure is required, causing increased road pressure and deterioration |
| District Roads | 4.0 | 2.3 | 2.0 | Infrastructure | Infrastructure | Increase in temperature results in faster plant growth enabling rapid rehabilitation of road side areas after road construction |
| Floodplain | 3.2 | 4.0 | 3.3 | Freshwater (Lakes, Springs, Wetlands) | Freshwater | Worsening water quality - siltation -variable trend in rainfall<br>Excessive rainfall cause flooding and leads to siltation. Deposition of siltation degrades water quality and negatively affects biodiversity loss and agricultural productivity. |

| | | | | | | |
|---|---|---|---|---|---|---|
| Gharial | 2.0 | 4.0 | 3.7 | Species | Species | Increase in temperature will impact farm/rural roads because soils will dry and cause more erosion. That will impact the rivers and streams, with more siltation, affecting gharial, mahseer. |
| Gharial | 2.0 | 3.7 | 3.5 | Species | Species | Longer cold spells will impact the hatching and incubation of gharial, and will also affect survival of migratory birds and hornbills (the latter through changes in phenology and fruiting of food trees) and at the same time brown-clouds formation are seen due to excessive industrialization in bordering country which is also due to excessive GHG emissions. |
| Hornbill | 2.2 | 2.0 | 2.3 | Species | Species | Longer cold spells in the terai will result in greater fuel wood demand in the terai, which will cause habitat/forest degradation and impact tiger, rhino, hornbills, migratory birds. Greater human presence in forests will also increase human-wildlife conflict |
| Irrigation | 3.0 | 2.0 | 2.0 | Infrastructure | Infrastructure | Extreme rainfall combined with human induced bad infrastructure planning leads more infrastructure to fall into disrepair |
| Irrigation | 3.0 | 2.0 | 2.0 | Infrastructure | Infrastructure | Intensive runoff due to unpredictable discharge, poor planning and design of infrastructure (not taking CC into account) causes rapid wear and tear of infrastructure |
| Kaligandaki | 3.8 | 3.7 | 2.7 | Freshwater (Rivers) | Freshwater | increased temperature will change the rate of glacier melt. That will increase volume of water resulting to the fluctuation of water flow. It will create the risk of flood and eventually lead to the high sedimentation, increase flood area, decrease agri productivity in the downstream of river network |
| Kaligandaki | 3.8 | 3.0 | 2.4 | Freshwater (Rivers) | Freshwater | increase temperature and unpredictable rainfall will fluctuate the water discharge. The hydropower production thus will be unpredictable, high sedimentation and infrastructure damage in the river system |
| Kaligandaki | 3.8 | 2.7 | 2.4 | Freshwater (Rivers) | Freshwater | Unpredictable rainfall and high risk of landslides in rural roads leading to high sedimentation in the river network |
| Khet [Middle Mountains] | 3.4 | 3.3 | 2.9 | Agriculture | Middle Mountains | Increasing temperature causes increased pest infestation, more chemical inputs to be used in intensive agriculture , which results in more external dependency for such as fertilizers and agrichemicals. Which puts makes agriculture unsustainable . |
| Khet [Middle Mountains] | 3.4 | 2.7 | 2.5 | Agriculture | Middle Mountains | Increasing temperature and erratic rainfall causes malfunctioning of planned infrastructures which affects irrigation, energy and transport, causes loss of productivity and access to market with soil erosion drought, and land slides. It causes out migration from Pakho, resulting in food insecurity. |
| Khet [Siwalik] | 3.6 | 3.3 | 2.8 | Agriculture | Siwalik/Churia Mountains | Increasing temperature causes increased pest infestation, more chemical inputs to be used in intensive agriculture , which results in more external dependency for such as fertilizers and agrichemicals. Which puts makes agriculture unsustainable . |
| Local Roads | 2.7 | 3.7 | 3.3 | Infrastructure | Infrastructure | Discharge unpredictability leads to cross drainage problems e.g. drainage structures being washed out, also due to inadequate and unplanned infrastructure development, leading to more infrastructure falling into disrepair |
| Local Roads | 2.7 | 3.7 | 3.3 | Infrastructure | Infrastructure | Intensive runoff due to unpredictable discharge, poor planning and design of infrastructure (not taking CC into account) causes rapid wear and tear of infrastructure |
| Local Roads | 2.7 | 3.0 | 2.9 | Infrastructure | Infrastructure | Extreme rainfall combined with human induced bad infrastructure planning leads more infrastructure to fall into disrepair |
| Local Roads | 2.7 | 2.7 | 2.8 | Infrastructure | Infrastructure | Increase in temperature results in faster plant growth enabling rapid rehabilitation of road side areas after road construction |
| Local Roads | 2.7 | 3.0 | 2.6 | Infrastructure | Infrastructure | Rising temperature increases soil erosion, causing increasing siltation and encroachment around wetlands and lakes, urban and peri urban areas, causing impact on roads |
| Local Roads | 2.7 | 2.7 | 2.6 | Infrastructure | Infrastructure | Changes in discharge leads to rural-urban migration causing pressure in urban areas where more infrastructure is required, causing increased road pressure and deterioration |
| Lower temperate broadleaf forest (Middle Mountains) | 2.8 | 4.0 | 3.4 | Ecoregion & Forest | Middle Mountains | Increasing temperature and prolong drought enhanced forest fire that will damage forests |
| Lower temperate broadleaf forest (Middle Mountains) | 2.8 | 3.3 | 3.1 | Ecoregion & Forest | Middle Mountains | Increase deforestation for fuel wood demand and continued low supply of fuel wood due to deforestation will increase further deforestation/forest degradation |
| Lower temperate broadleaf forest (Middle Mountains) | 2.8 | 3.3 | 2.9 | Ecoregion & Forest | Middle Mountains | Increasing trend of hydropower development and construction of electricity transmission lines from forest area will create deforestation, loss of biodiversity |
| Lower temperate broadleaf forest (Middle Mountains) | 2.8 | 3.3 | 2.9 | Ecoregion & Forest | Middle Mountains | Inadequate strategic planning for infrastructure in the landscapes leads to deforestation |
| Lower temperate broadleaf forest (Middle Mountains) | 2.8 | 3.0 | 2.7 | Ecoregion & Forest | Middle Mountains | Increasing temperature and prolonged drought and intense rainfall will accelerate erosion, landslide, loss and damage of forest species and declines productivity |
| Lower temperate broadleaf forest (Middle Mountains) | 2.8 | 2.3 | 2.2 | Ecoregion & Forest | Middle Mountains | Increasing temperature and prolong drought enhanced forest fire that will damage forests |
| Lower temperate broadleaf forest (Middle Mountains) | 2.8 | 2.0 | 2.1 | Ecoregion & Forest | Middle Mountains | Increase in temperature will result in low productivity of shifting cultivable area, Expansion of sifting cultivation area due to low productivity of the land |
| Lower temperate broadleaf forest (Middle Mountains) | 2.8 | 1.3 | 1.7 | Ecoregion & Forest | Middle Mountains | Increase temperature and unpredictable rainfall will create unfavorable condition for human settlements. This will promote human migration which will create more deforestation/forest degradation and increase grazing pressure in forest areas |

| | | | | | | |
|---|---|---|---|---|---|---|
| Madi | 3.0 | 3.3 | 2.8 | Freshwater (Rivers) | Freshwater | increased temperature will change the rate of glacier melt. That will increase volume of water resulting to the fluctuation of water flow. It will create the risk of flood and eventually lead to the high sedimentation, increase flood area, decrease agri productivity in the downstream of river network |
| Madi | 3.0 | 3.0 | 2.7 | Freshwater (Rivers) | Freshwater | increase temperature and unpredictable rainfall will fluctuate the water discharge. The hydropower production thus will be unpredictable, high sedimentation and infrastructure damage in the river system |
| Mahaseer | 2.5 | 2.7 | 2.5 | Species | Species | Increase in temperature will impact farm/rural roads because soils will dry and cause more erosion. That will impact the rivers and streams, with more siltation, affecting gharial, mahseer. |
| Marsyangdi | 3.2 | 3.0 | 2.8 | Freshwater (Rivers) | Freshwater | increase temperature and unpredictable rainfall will fluctuate the water discharge. The hydropower production thus will be unpredictable, high sedimentation and infrastructure damage in the river system |
| Marsyangdi | 3.2 | 2.3 | 2.3 | Freshwater (Rivers) | Freshwater | increased temperature will change the rate of glacier melt. That will increase volume of water resulting to the fluctuation of water flow. It will create the risk of flood and eventually lead to the high sedimentation, increase flood area, decrease agri productivity in the downstream of river network |
| Micro and small hydro | 3.5 | 3.0 | 2.7 | Infrastructure | Infrastructure | Extreme rainfall leads to higher/ extreme discharge, leading to higher siltation rate and worsening water quality |
| Micro and small hydro | 3.5 | 2.0 | 1.8 | Infrastructure | Infrastructure | Extreme rainfall combined with human induced bad infrastructure planning leads more infrastructure to fall into disrepair |
| Micro and small hydro | 3.5 | 2.0 | 1.8 | Infrastructure | Infrastructure | Intensive runoff due to unpredictable discharge, poor planning and design of infrastructure (not taking CC into account) causes rapid wear and tear of infrastructure |
| Middle Mountain Lakes | 3.2 | 3.7 | 3.1 | Freshwater (Lakes, Springs, Wetlands) | Middle Mountains | Unplanned migration/urbanization and increase in temperature and variable rainfall<br>Increase in population and migration caused high demand of water, on contrary there is less water sources to meet this high demand for multiple uses of water. Sources are drying up due to high increase of temperature and unreliable rainfall pattern. It results into increased conflict over water resources and higher extraction of water. It has negatively impacted lake ecosystem. |
| Middle Mountain Lakes | 3.2 | 3.0 | 2.8 | Freshwater (Lakes, Springs, Wetlands) | Middle Mountains | Decreased reliability in stream flow and Inadequate strategic planning - infrastructure<br>Unplanned development of infra-structures like hydropower and road network has affected discharge of river and streams. It has negatively affected water quantity there by impacting negatively to aquatic ecosystem of down stream. |
| Middle Mountain Lakes | 3.2 | 3.3 | 2.6 | Freshwater (Lakes, Springs, Wetlands) | Middle Mountains | Degradation of water quality- pesticide and fertilizer - increase in temperature<br>Extensive use of pesticides and fertilizers has degraded soil quality reducing its moisturizing capacity. It contributed in increased radiation. On the other hand, deposition of these chemicals in aquatic bodies has also contributed in reducing aquatic species of lakes and wetlands. |
| Middle Mountain Lakes | 3.2 | 2.3 | 2.1 | Freshwater (Lakes, Springs, Wetlands) | Middle Mountains | Worsening water quality - siltation -variable trend in rainfall<br>Excessive rainfall cause flooding and leads to siltation. Deposition of siltation degrades water quality and reduces aquatic biodiversity loss and agricultural productivity. |
| Migratory birds (altitudinal and transboundary) | 1.8 | 4.0 | 3.7 | Species | Species | Longer cold spells in the terai will result in greater fuel wood demand in the terai, which will cause habitat/forest degradation and impact tiger, rhino, hornbills, migratory birds. Greater human presence in forests will also increase human-wildlife conflict |
| Migratory birds (altitudinal and transboundary) | 1.8 | 3.3 | 3.2 | Species | Species | Erratic and unpredictable rainfall will influence water discharge from the dams, by storing water against the uncertainty and affect downstream flows. If there is too much rain, the water from the dams will be released creating sudden high water flows. These irregular water discharges will affect gharial, mahseer, wading migratory birds, and species such as rhinos, tigers that rely on water sources downriver. |
| Narayani | 4.0 | 4.0 | 3.2 | Freshwater (Rivers) | Freshwater | increased temperature will change the rate of glacier melt. That will increase volume of water resulting to the fluctuation of water flow. It will create the risk of flood and eventually lead to the high sedimentation, increase flood area, decrease agri productivity in the downstream of river network |
| Narayani | 4.0 | 4.3 | 3.2 | Freshwater (Rivers) | Freshwater | increased rainfall in the region will lead to increase incidents of flooding and will inundate the settlement in the urban areas and could lead to water borne disease outbreak |
| Narayani | 4.0 | 3.7 | 2.8 | Freshwater (Rivers) | Freshwater | increase temperature and unpredictable rainfall will fluctuate the water discharge. The hydropower production thus will be unpredictable, high sedimentation and infrastructure damage in the river system |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| National Roads (High Mountains) | 4.3 | 3.3 | 2.6 | Infrastructure | High Mountains | Increased intensity of rainfall causing increase soil erosion leading to rut formation and channeling of roads, resulting in rapid surface deterioration of roads |
| National Roads (High Mountains) | 4.3 | 2.3 | 1.7 | Infrastructure | High Mountains | Extreme rainfall combined with human induced bad infrastructure planning leads more infrastructure to fall into disrepair |
| National Roads (High Mountains) | 4.3 | 2.3 | 1.7 | Infrastructure | High Mountains | Changes in discharge leads to rural-urban migration causing pressure in urban areas where more infrastructure is required, causing increased road pressure and deterioration |
| National Roads (High Mountains) | 4.3 | 2.0 | 1.6 | Infrastructure | High Mountains | Increase in temperature results in faster plant growth enabling rapid rehabilitation of road side areas after road construction |
| National Roads (High Mountains) | 4.3 | 1.7 | 1.4 | Infrastructure | High Mountains | Discharge unpredictability leads to cross drainage problems e.g. drainage structures being washed out, also due to inadequate and unplanned infrastructure development, leading to more infrastructure falling into disrepair |
| National Roads (High Mountains) | 4.3 | 1.7 | 1.4 | Infrastructure | High Mountains | Intensive runoff due to unpredictable discharge, poor planning and design of infrastructure (not taking CC into account) causes rapid wear and tear of infrastructure |
| National Roads (Middle Mountains) | 4.3 | 3.0 | 2.2 | Infrastructure | Middle Mountains | Increased intensity of rainfall causing increase soil erosion leading to rut formation and channeling of roads, resulting in rapid surface deterioration of roads |
| National Roads (Middle Mountains) | 4.3 | 2.3 | 1.7 | Infrastructure | Middle Mountains | Extreme rainfall combined with human induced bad infrastructure planning leads more infrastructure to fall into disrepair |
| National Roads (Middle Mountains) | 4.3 | 2.3 | 1.7 | Infrastructure | Middle Mountains | Changes in discharge leads to rural-urban migration causing pressure in urban areas where more infrastructure is required, causing increased road pressure and deterioration |
| National Roads (Middle Mountains) | 4.3 | 2.0 | 1.6 | Infrastructure | Middle Mountains | Increase in temperature results in faster plant growth enabling rapid rehabilitation of road side areas after road construction |
| National Roads (Middle Mountains) | 4.3 | 1.7 | 1.4 | Infrastructure | Middle Mountains | Discharge unpredictability leads to cross drainage problems e.g. drainage structures being washed out, also due to inadequate and unplanned infrastructure development, leading to more infrastructure falling into disrepair |
| National Roads (Middle Mountains) | 4.3 | 1.7 | 1.4 | Infrastructure | Middle Mountains | Intensive runoff due to unpredictable discharge, poor planning and design of infrastructure (not taking CC into account) causes rapid wear and tear of infrastructure |
| National Roads (Siwalik/Churia Mountains) | 4.3 | 2.7 | 1.9 | Infrastructure | Siwalik/Churia Mountains | Increased intensity of rainfall causing increase soil erosion leading to rut formation and channeling of roads, resulting in rapid surface deterioration of roads |
| National Roads (Siwalik/Churia Mountains) | 4.3 | 2.3 | 1.7 | Infrastructure | Siwalik/Churia Mountains | Extreme rainfall combined with human induced bad infrastructure planning leads more infrastructure to fall into disrepair |
| National Roads (Siwalik/Churia Mountains) | 4.3 | 2.3 | 1.7 | Infrastructure | Siwalik/Churia Mountains | Changes in discharge leads to rural-urban migration causing pressure in urban areas where more infrastructure is required, causing increased road pressure and deterioration |
| National Roads (Siwalik/Churia Mountains) | 4.3 | 2.0 | 1.6 | Infrastructure | Siwalik/Churia Mountains | Increase in temperature results in faster plant growth enabling rapid rehabilitation of road side areas after road construction |
| National Roads (Siwalik/Churia Mountains) | 4.3 | 1.7 | 1.4 | Infrastructure | Siwalik/Churia Mountains | Discharge unpredictability leads to cross drainage problems e.g. drainage structures being washed out, also due to inadequate and unplanned infrastructure development, leading to more infrastructure falling into disrepair |
| National Roads (Siwalik/Churia Mountains) | 4.3 | 1.7 | 1.4 | Infrastructure | Siwalik/Churia Mountains | Intensive runoff due to unpredictable discharge, poor planning and design of infrastructure (not taking CC into account) causes rapid wear and tear of infrastructure |
| National Roads (Trans Himalaya) | 4.3 | 3.3 | 2.6 | Infrastructure | Trans Himalaya | Increased intensity of rainfall causing increase soil erosion leading to rut formation and channeling of roads, resulting in rapid surface deterioration of roads |
| National Roads (Trans Himalaya) | 4.3 | 2.3 | 1.7 | Infrastructure | Trans Himalaya | Extreme rainfall combined with human induced bad infrastructure planning leads more infrastructure to fall into disrepair |
| National Roads (Trans Himalaya) | 4.3 | 2.3 | 1.7 | Infrastructure | Trans Himalaya | Changes in discharge leads to rural-urban migration causing pressure in urban areas where more infrastructure is required, causing increased road pressure and deterioration |
| National Roads (Trans Himalaya) | 4.3 | 2.0 | 1.6 | Infrastructure | Trans Himalaya | Increase in temperature results in faster plant growth enabling rapid rehabilitation of road side areas after road construction |
| National Roads (Trans Himalaya) | 4.3 | 1.7 | 1.4 | Infrastructure | Trans Himalaya | Discharge unpredictability leads to cross drainage problems e.g. drainage structures being washed out, also due to inadequate and unplanned infrastructure development, leading to more infrastructure falling into disrepair |
| National Roads (Trans Himalaya) | 4.3 | 1.7 | 1.4 | Infrastructure | Trans Himalaya | Intensive runoff due to unpredictable discharge, poor planning and design of infrastructure (not taking CC into account) causes rapid wear and tear of infrastructure |
| Orchids | 3.3 | 3.0 | 2.6 | Species | Species | Increase in temperature will impact farm/rural roads because soils will dry and cause more erosion. That will impact the rivers and streams, with more siltation, affecting gharial, mahseer. (Extreme rainfall leading to excessive erosion and disturb the orchids) |
| Pakho [Middle Mountains] | 2.6 | 3.7 | 3.3 | Agriculture | Middle Mountains | Increasing temperature and erratic rainfall causes malfunctioning of planned infrastructures which affects irrigation, energy and transport, causes loss of productivity and access to market with soil erosion drought, and land slides. It causes out migration from Pakho, resulting in food insecurity. |
| Pakho [Middle Mountains] | 2.6 | 3.7 | 3.3 | Agriculture | Middle Mountains | Unreliable rainfall causes uncertainties in agricultural production, which enhances outmigration of male members from drought areas causing feminization of agriculture ultimately unsustainable. |
| Pakho [Siwalik] | 2.8 | 3.3 | 3.1 | Agriculture | Siwalik/Churia Mountains | Unreliable rainfall causes uncertainties in agricultural production, which enhances outmigration of male members from drought areas causing feminization of agriculture ultimately unsustainable. |
| Pakho [Siwalik] | 2.8 | 2.3 | 2.4 | Agriculture | Siwalik/Churia Mountains | Increasing temperature and erratic rainfall causes malfunctioning of planned infrastructures which affects irrigation, energy and transport, causes loss of productivity and access to market with soil erosion drought, and land slides. It causes out migration from Pakho, resulting in food insecurity. |

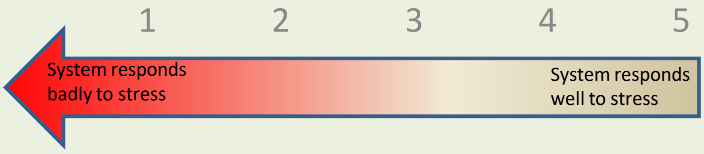
| | | | | | | |
|---|---|---|---|---|---|---|
| Ramsar Sites | 3.5 | 1.3 | 1.3 | Freshwater (Lakes, Springs, Wetlands) | Freshwater | Degradation of water quality- pesticide and fertilizer - increase in temperature<br>There is extensive use of pesticides and fertilizers in agricultural fields. It has degraded soil quality reducing its moisturizing capacity. It contributed in increased radiation. On the other hand, deposition of these chemicals in aquatic bodies that are far from ramsar sites has started showing some indication on reduction of aquatic species of lakes and wetlands. |
| Rapti | 2.5 | 4.3 | 3.7 | Freshwater (Rivers) | Freshwater | increase temperature and unpredictable rainfall will fluctuate the water discharge. The hydropower production thus will be unpredictable, high sedimentation and infrastructure damage in the river system |
| Rapti | 2.5 | 4.3 | 3.7 | Freshwater (Rivers) | Freshwater | increased rainfall in the region will lead to increase incidents of flooding and will inundate the settlement in the urban areas and could lead to water borne disease outbreak |
| Rapti | 2.5 | 2.7 | 2.5 | Freshwater (Rivers) | Freshwater | increase temp and decrease rainfall will result to increase water temperature in rivers thus leading to the loss of species |
| Red Panda | 2.2 | 2.3 | 2.6 | Species | Species | Drying of water spring in and around village areas compelled villagers to shift in cluster to low-lying areas where water Is available and normally they go down and encroach into forest areas |
| Rhino | 2.5 | 4.0 | 3.5 | Species | Species | Increasing temperature can affect habitats of snow leopards through encroachment of tree line and people into alpine areas. It can also affect gharial by affecting nesting temperatures and sex determination of incubating eggs. Increasing temperature can also encourage spread of invasive weed species (Michenia, etc.) and degrade habitat for rhinos and tigers (especially by affecting tiger prey species). Increasing temperature will also affect red panda habitat through changes in their bamboo food plants |
| Rhino | 2.5 | 2.3 | 2.3 | Species | Species | Longer cold spells in the terai will result in greater fuel wood demand in the terai, which will cause habitat/forest degradation and impact tiger, rhino, hornbills, migratory birds. Greater human presence in forests will also increase human-wildlife conflict |
| Riverbed Mining | 2.0 | 2.0 | 2.3 | Infrastructure | Infrastructure | Extreme rainfall combined with human induced bad infrastructure planning leads more infrastructure to fall into disrepair |
| Riverbed Mining | 2.0 | 2.0 | 2.3 | Infrastructure | Infrastructure | Intensive runoff due to unpredictable discharge, poor planning and design of infrastructure (not taking CC into account) causes rapid wear and tear of infrastructure |
| Rural Settlements | 2.0 | 2.7 | 3.0 | Infrastructure | Infrastructure | Extreme rainfall combined with human induced bad infrastructure planning leads more infrastructure to fall into disrepair |
| Rural Settlements | 2.0 | 2.7 | 3.0 | Infrastructure | Infrastructure | Intensive runoff due to unpredictable discharge, poor planning and design of infrastructure (not taking CC into account) causes rapid wear and tear of infrastructure |
| Rural Settlements | 2.0 | 2.7 | 2.8 | Infrastructure | Infrastructure | Variable rainfall causes a direct visible impact on migration, with migration from rural to urban/peri urban areas causing negative pressure on settlements |
| Semi-desert coniferous forest (Trans-Himalayan) | 1.7 | 4.3 | 3.9 | Ecoregion & Forest | Trans Himalaya | Increasing temperature and prolong drought enhanced forest fire that will damage forests |
| Semi-desert coniferous forest (Trans-Himalayan) | 1.7 | 3.7 | 3.8 | Ecoregion & Forest | Trans Himalaya | Increase deforestation for fuel wood demand and continued low supply of fuel wood due to deforestation will increase further deforestation/forest degradation |
| Semi-desert coniferous forest (Trans-Himalayan) | 1.7 | 1.7 | 2.3 | Ecoregion & Forest | Trans Himalaya | Increasing temperature, prolonged drought and intense rainfall will accelerate erosion, landslide, loss and damage of forest species and declines productivity |
| Semi-desert coniferous forest (Trans-Himalayan) | 1.7 | 1.3 | 1.9 | Ecoregion & Forest | Trans Himalaya | Inadequate strategic planning for infrastructure in the landscapes leads to deforestation |
| Semi-desert coniferous forest (Trans-Himalayan) | 1.7 | 1.0 | 1.8 | Ecoregion & Forest | Trans Himalaya | Increasing temperature and prolonged drought and intense rainfall will accelerate erosion, landslide, loss and damage of forest species and declines productivity |
| Seti | 2.2 | 4.0 | 3.8 | Freshwater (Rivers) | Freshwater | increase temperature and unpredictable rainfall will fluctuate the water discharge. The hydropower production thus will be unpredictable, high sedimentation and infrastructure damage in the river system |
| Seti | 2.2 | 4.0 | 3.6 | Freshwater (Rivers) | Freshwater | increased temperature will change the rate of glacier melt. That will increase volume of water resulting to the fluctuation of water flow. It will create the risk of flood and eventually lead to the high sedimentation, increase flood area, decrease agri productivity in the downstream of river network |
| Snow Leopard | 2.8 | 3.0 | 2.9 | Species | Species | Increasing temperatures could allow herders to spend more time in the alpine areas, and graze livestock longer, causing greater degradation of alpine meadows and allowing less recovery time, affecting snow leopards. Herders will also burn scrub to create pasture |
| Spring Sources [Middle Mountains] | 3.0 | 2.3 | 2.3 | Freshwater (Lakes, Springs, Wetlands) | Middle Mountains | Decreased reliability in stream flow and Inadequate strategic planning - infrastructure<br>Unplanned development of infra-structures like hydropower and road network has affected discharge of river and streams. It has negatively affected water quantity there by impacting negatively to bio-diversity of down stream. |
| Spring Sources [Siwalik] | 2.0 | 4.0 | 3.7 | Freshwater (Lakes, Springs, Wetlands) | Siwalik/Churia Mountains | Decreased reliability in stream flow and Inadequate strategic planning - infrastructure<br>Unplanned development of infra-structures like electricity infra-structure and road network has affected discharge of river and streams. It has negatively affected water volume thereby hampering water sources. |

| | | | | | | |
|---|---|---|---|---|---|---|
| Subtropical Broadleaf forest (Siwalik/Churia) | 2.5 | 4.7 | 4.0 | Ecoregion & Forest | Siwalik/Churia Mountains | Increasing temperature and prolonged drought and intense rainfall will accelerate erosion, landslide, loss and damage of forest species and declines productivity |
| Subtropical Broadleaf forest (Siwalik/Churia) | 2.5 | 4.3 | 3.7 | Ecoregion & Forest | Siwalik/Churia Mountains | Increase in temperature will result in low productivity of shifting cultivable area, Expansion of sifting cultivation area due to low productivity of the land |
| Subtropical Broadleaf forest (Siwalik/Churia) | 2.5 | 4.0 | 3.5 | Ecoregion & Forest | Siwalik/Churia Mountains | Increase temperature and unpredictable rainfall will create unfavorable condition for human settlements. This will promote human migration which will create more deforestation/forest degradation and increase grazing pressure in forest areas |
| Subtropical Broadleaf forest (Siwalik/Churia) | 2.5 | 4.0 | 3.5 | Ecoregion & Forest | Siwalik/Churia Mountains | Inadequate strategic planning for infrastructure in the landscapes leads to deforestation |
| Subtropical Broadleaf forest (Siwalik/Churia) | 2.5 | 4.0 | 3.5 | Ecoregion & Forest | Siwalik/Churia Mountains | Increase deforestation for fuel wood demand and continued low supply of fuel wood due to deforestation will increase further deforestation/forest degradation |
| Subtropical Broadleaf forest (Siwalik/Churia) | 2.5 | 2.7 | 2.7 | Ecoregion & Forest | Siwalik/Churia Mountains | Increasing trend of hydropower development and construction of electricity transmission lines from forest area will create deforestation, loss of biodiversity |
| Tar (irrigated) | 3.4 | 3.7 | 3.0 | Agriculture | Agriculture | Increasing temperature causes increased pest infestation, more chemical inputs to be used in intensive agriculture , which results in more external dependency for such as fertilizers and agrichemicals. Which puts makes agriculture unsustainable . |
| Tar (rain fed) | 2.6 | 3.3 | 3.0 | Agriculture | Agriculture | Increasing temperature and erratic rainfall causes malfunctioning of planned infrastructures which affects irrigation, energy and transport, causes loss of productivity and access to market with soil erosion drought, and land slides. It causes out migration from Pakho, resulting in food insecurity. |
| Tar (rain fed) | 2.6 | 3.0 | 2.8 | Agriculture | Agriculture | Unreliable rainfall causes uncertainties in agricultural production, which enhances outmigration of male members from drought areas causing feminization of agriculture ultimately unsustainable. |
| Temperate coniferous forest (Middle Mountains) | 2.8 | 3.3 | 3.1 | Ecoregion & Forest | Middle Mountains | Increase deforestation for fuel wood demand and continued low supply of fuel wood due to deforestation will increase further deforestation/forest degradation |
| Temperate coniferous forest (Middle Mountains) | 2.8 | 3.3 | 3.1 | Ecoregion & Forest | Middle Mountains | Increasing temperature and prolong drought enhanced forest fire that will damage forests |
| Temperate coniferous forest (Middle Mountains) | 2.8 | 3.0 | 2.7 | Ecoregion & Forest | Middle Mountains | Increasing temperature and prolonged drought and intense rainfall will accelerate erosion, landslide, loss and damage of forest species and declines productivity |
| Temperate coniferous forest (Middle Mountains) | 2.8 | 2.7 | 2.6 | Ecoregion & Forest | Middle Mountains | Increasing trend of hydropower development and construction of electricity transmission lines from forest area will create deforestation, loss of biodiversity |
| Temperate coniferous forest (Middle Mountains) | 2.8 | 3.0 | 2.6 | Ecoregion & Forest | Middle Mountains | Inadequate strategic planning for infrastructure in the landscapes leads to deforestation |
| Temperate coniferous forest (Middle Mountains) | 2.8 | 2.3 | 2.2 | Ecoregion & Forest | Middle Mountains | Increase in temperature will result in low productivity of shifting cultivable area, Expansion of sifting cultivation area due to low productivity of the land |
| Temperate coniferous forest (Middle Mountains) | 2.8 | 1.3 | 1.7 | Ecoregion & Forest | Middle Mountains | Increase temperature and unpredictable rainfall will create unfavorable condition for human settlements. This will promote human migration which will create more deforestation/forest degradation and increase grazing pressure in forest areas |
| Tiger | 2.8 | 3.7 | 3.2 | Species | Species | Extreme rainfall can cause flashfloods of rivers and streams and high flows, resulting in more river bank cutting and loss of top soil and erosion from watersheds, affecting gharial, mahseer, wading migratory birds. Floods from extreme rainfall will also displace people, who will encroach into forests, affecting habitats of tigers, wild dogs, orchids, migratory birds |
| Tiger | 2.8 | 3.0 | 2.7 | Species | Species | Longer cold spells in the terai will result in greater fuel wood demand in the terai, which will cause habitat/forest degradation and impact tiger, rhino, hornbills, migratory birds. Greater human presence in forests will also increase human-wildlife conflict |
| Trishuli | 3.8 | 4.3 | 3.2 | Freshwater (Rivers) | Freshwater | increase temperature and unpredictable rainfall will fluctuate the water discharge. The hydropower production thus will be unpredictable, high sedimentation and infrastructure damage in the river system |
| Trishuli | 3.8 | 3.7 | 2.9 | Freshwater (Rivers) | Freshwater | increased temperature will change the rate of glacier melt. That will increase volume of water resulting to the fluctuation of water flow. It will create the risk of flood and eventually lead to the high sedimentation, increase flood area, decrease agri productivity in the downstream of river network |
| Upper temperate broadleaf forest (Middle Mountains) | 3.7 | 3.3 | 2.8 | Ecoregion & Forest | Middle Mountains | Increase deforestation for fuel wood demand and continued low supply of fuel wood due to deforestation will increase further deforestation/forest degradation |
| Upper temperate broadleaf forest (Middle Mountains) | 3.7 | 2.7 | 2.3 | Ecoregion & Forest | Middle Mountains | Increasing trend of hydropower development and construction of electricity transmission lines from forest area will create deforestation, loss of biodiversity |
| Upper temperate broadleaf forest (Middle Mountains) | 3.7 | 2.3 | 1.9 | Ecoregion & Forest | Middle Mountains | Increasing temperature and prolong drought enhanced forest fire that will damage forests |
| Urban Settlements | 3.3 | 2.3 | 2.2 | Infrastructure | Infrastructure | Extreme rainfall combined with human induced bad infrastructure planning leads more infrastructure to fall into disrepair |
| Urban Settlements | 3.3 | 2.3 | 2.2 | Infrastructure | Infrastructure | Variable rainfall causes a direct visible impact on migration, with migration from rural to urban/peri urban areas causing negative pressure on settlements |
| Urban Settlements | 3.3 | 2.3 | 2.2 | Infrastructure | Infrastructure | Intensive runoff due to unpredictable discharge, poor planning and design of infrastructure (not taking CC into account) causes rapid wear and tear of infrastructure |
| Wild dogs | 3.5 | 3.7 | 2.8 | Species | Species | Erratic rainfall will also create uneven spatial distribution of water, affecting the water needs of tigers, rhinos, wild dogs |

# ANNEX 2 | Resilience / Sensitivity Factor Handout

## Connectivity

1 = Highly fragmented with key functions and processes severely affected

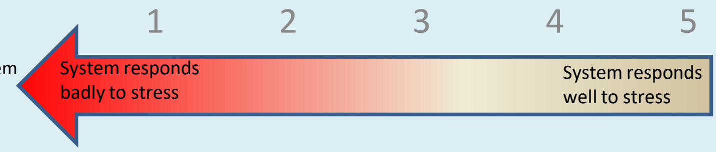



5 = No disruption and all functions and processes preserved

*Note: for urban centres this refers to infrastructure and services e.g. people are connected to key services (potable water, sanitation, economic, social services).*

## Ability to respond to climate variability

1 = Variability disrupts the system to a point that it cannot recover



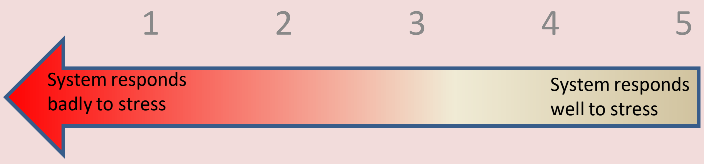

5 = Thrives on/is not effected by frequent & extreme variability (%functionality/time)

*Crops: seedlings withering or dry up immediately after rain stop showering*

*Selous GR: spatial and temporal utilization of different habitats in the reserve*

## Refugia

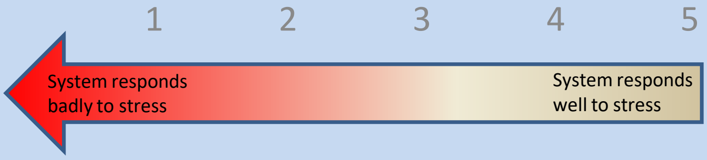
1 = No suitable places exist or are accessible that offer refuge and population is lost




5= Suitable places are available / accessible offering refuge and/or continuation of critical services for the ecosystem

## Functional redundancy

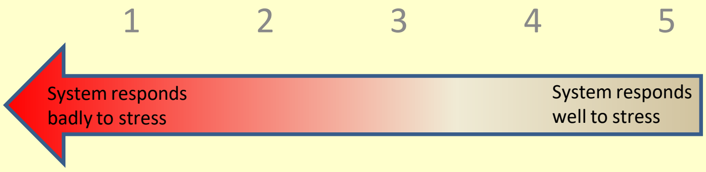
1 = High risk to ecosystem function if a species is lost




5 = Low risk to disruption to functionality if one species is lost. This is because the role of that species is performed by others.

## Natural productivity

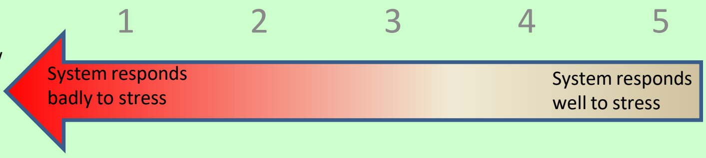
1 = No or very slow regeneration / reproductive rate




5 = Rapid regeneration of biomass/ high reproductive, survival and recruitment rates

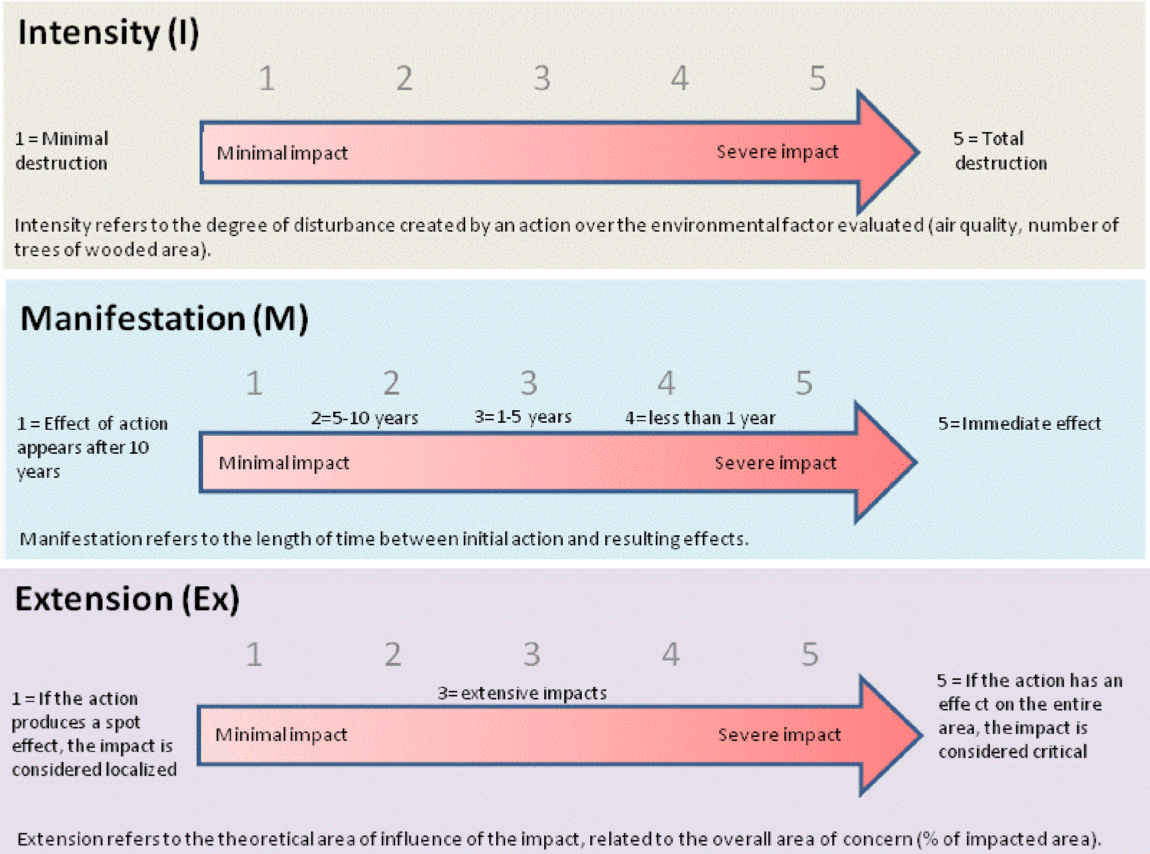
## Biodiversity / genetic diversity

1 (Genetic Diversity)= Very few subpopulations
1 (Biodiversity)= Very few species or monoculture




5 (Genetic Diversity) = Wide variety of subpopulations
5 (Biodiversity) = Wide variety of species

# ANNEX 3 | Impact Factor Rating Handout



## ANNEX 4 | Flowing Forward Vulnerability Formula

Although there are alternative ways to calculate vulnerability, with different authors and organizations calculating it differently (CITE), prior piloting of the approach in WWF landscapes has determined the following equation to yield the most rational final ratings:

$$V = \tfrac{1}{3}\left(E_{intensity} + \tfrac{1}{2} E_{manifestation} + \tfrac{1}{2} E_{extension} + (5-R)\right)$$

*Where:*

V represents the vulnerability ranking between 1 and 5, where 5 is the most vulnerable;

$E_{intensity}$ represents the intensity ranking of a given potential impact and sub-unit;

$E_{manifestation}$ represents the manifestation ranking of a given potential impact and sub-unit;

$E_{extension}$ represents the extension ranking of a given potential impact and sub-unit; and

R represents the resilience ranking of a given sub-unit, where 5 is the most resilient.

## ANNEX 5 | Workshop participants

The following table shows the workshop participants and the specialist groups they took part in.

| Forest | Freshwater (Lakes, etc.) | Freshwater (Rivers) | Agriculture | Infrastructure | Species |
|---|---|---|---|---|---|
| Keshav Khanal (group leader) | Aarati Gurung/ Shikha Shrestha (group leaders) | Ramesh Adhikari (group leader) | Sunil Regmi (group leader) | Pankaj Bajracharya (group leader) | Bijan Gurung (group leader) |
| Purna Kunwar | Lila Jung Gurung | Pratima Shrestha | Mahendra Shrestha | Shuva Sharma | Gokarna J Thapa |
| Rajan Subedi | Dev Raj Gautam | Ashok Subedi | Judy Oglethorpe | Anuja Shrestha | Eric Wikramanayake |
| Megh Raj Luitel | Prakash Gyanwali | Sudeep Kayastha | Anjana Shrestha | Cecilia Liszka | Bindu Basnet |
| Ramchandra Regmi | Rajkumar Gurung | Bimal Kunwar | Maina Malla | Santosh Mani Nepal | Ganga Neupane |
| Kamal Lamichane | Sita Ram Shrestha | Raj Kumar Gupta | Lila Pangeni | Arjun Neupane | Abdul Ansari |
| Birkha Shahi | Mana Dhwoj Gurung | Rajeshwor Hadkhale | Shambhu Raj Pandey | Khem Raj Sapkota | Deo Chandra Goit |
| Raj Kumar Shrestha | Niranjan Dhungana | Sabitri Thapa | Nabraj Paudel | Ram C. Tripathi | |
| Buddhi B. Tamang | Rabin Shrestha | Pradeep Budhathoki | Om Gurung | Bishnu K Shrestha | |
| Bidur Sapkota | | | Dan Bahadur BK | Sunmaya Nepali | |
| | | | | Judy Oglethorpe | |

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