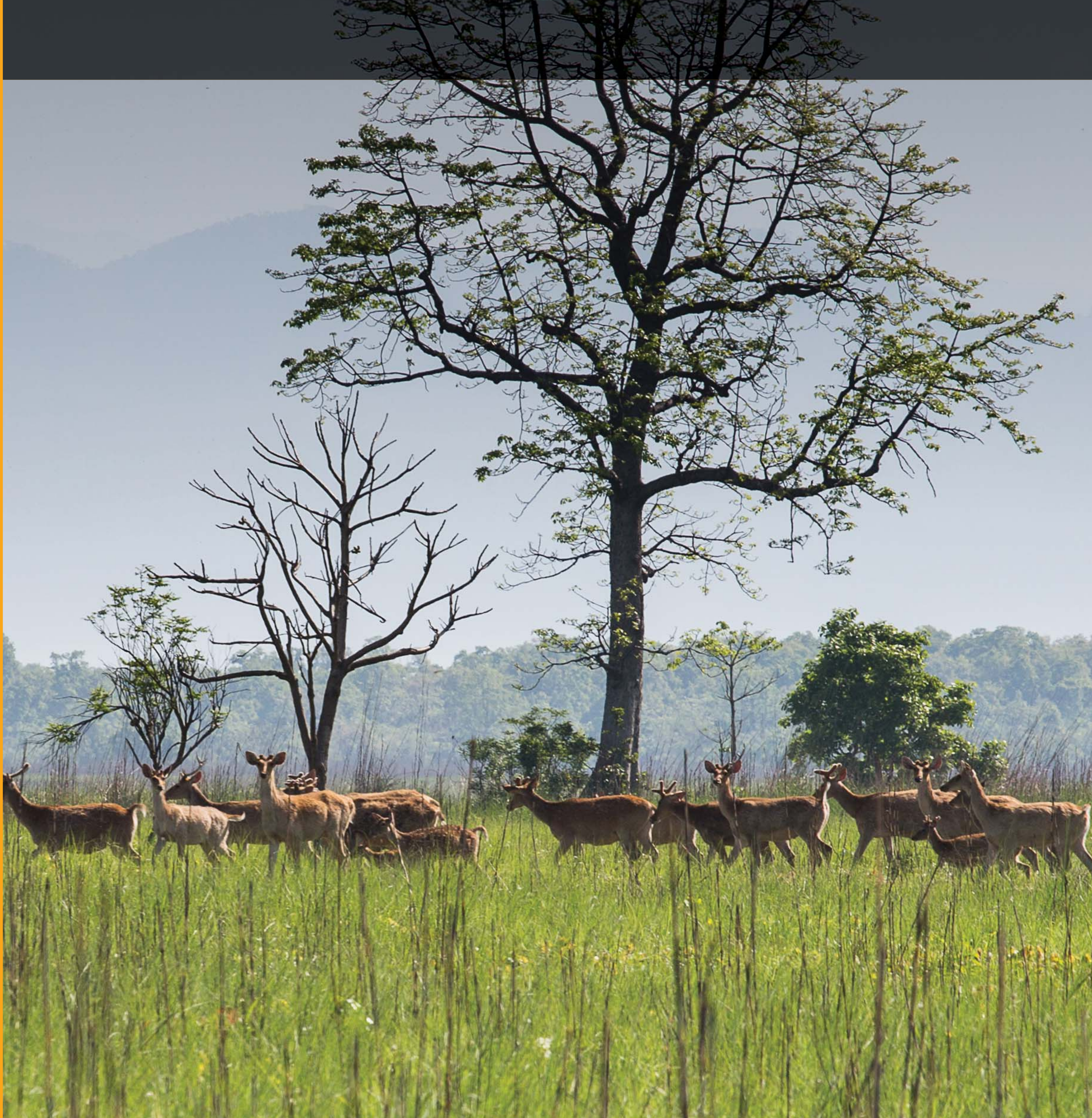
REALIGNING PRIORITIES

CLIMATE VULNERABILITY ASSESSMENT

TERAI ARC LANDSCAPE

REALIGNING PRIORITIES: CLIMATE VULNERABILITY ASSESSMENT, TERAI ARC LANDSCAPE



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Publisher
WWF Nepal, Post Box No: 7660
Baluwatar, Kathmandu, Nepal
Phone: +977-1-4434820
Email: hariyobanprogram@wwfnepal.org
Website: wwfnepal.org/hariyobanprogram

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Swamp deer (Barasingha), Shuklaphanta Wildlife Reserve, Kanchanpur- WWF Nepal, Hariyo Ban Program/ Nabin Baral

Foreword

Predictions of global climate change for Nepal and the Himalayas suggest significant changes in temperature and precipitation with more frequent extreme weather events and extended droughts between periods of intense rain. WWF globally recognizes that the impacts of climate change are having detrimental effects on ecosystems that are essential in sustaining both biodiversity and human well-being. Our core business – conservation – is one of the sectors most at risk from climate change. We acknowledge the above fact and prepare ourselves by realigning our conservation goals and targets, working through strategies which have higher chances of success under a changing climate, while continuing to address more familiar, non-climate related threats.

Considering the potential impacts of climate change this assessment was commissioned to undertake a broad review of possible vulnerabilities of key species, land use and land cover and infrastructures in the Terai Arc Landscape and identify major interventions to reduce the vulnerabilities. The assessment was carried out through rigorous consultations with key stakeholders in the landscape and review of available documents. The assessment used the Flowing Forward methodology, a systematic approach to determine the impacts of climate changes and assess the vulnerability of socio-ecological systems at a broader scale of river basins or landscapes. The approach and scale of the assessment allowed for a comprehensive depiction of the ecological processes and dynamics that maintain the important ecosystems and the biodiversity therein, and the ecological services that sustain the socio-economic well-being of people and socio-economic systems. I hope that this document will help conservationists better comprehend the challenges and opportunities to enhance their understanding on climate change impacts in the landscape at the basin level, its implications on conservation targets and possible adaptation measures to plan and increase the effectiveness of our investments.

I would like to thank the Government of Nepal for its support and contribution throughout this study. I would also like to thank United States Agency for International Development (USAID) for supporting this assessment under the Hariyo Ban Program, and the Department for International Development (DFID) for its support through the People in Participatory Action for Life (PIPAL) Programme.

Anil Manandhar
Country Representative
WWF Nepal

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This work would not have been possible without the support of the Government of Nepal. We would like to thank senior officials in the Ministry of Forests and Soil Conservation (MoFSC), the Department of Forests and the Department of National Parks and Wildlife Conservation. Special thanks also go to the heads of several government line agencies, particularly Parsa Wildlife Reserve, Chitwan National Park, Banke National Park, District Forest Offices, District Soil Conservation Offices, District Agriculture Development Offices, District Livestock Services Offices, District Roads Offices, Divisional and District Irrigation Offices, Department of Water Supply and Sewerage, and Drinking Water and Sanitation Offices. Several organizations and individuals made significant contributions to the assessment through their participation in the two cluster-level workshops held in Sauraha (Chitwan) and Nepalgunj (Banke). I would like to thank individual experts and representatives of district chapters of the Nepal Red Cross Society, NGO Federation, Buffer Zone User Committees, and other civil society organizations who generously provided their valuable time and inputs to the assessment process. Representatives from the Hariyo Ban consortium partners – WWF Nepal, CARE Nepal, NTNC and FECOFUN district chapters including Community Forest User Groups made significant contributions during the consultations.

Gokarna J. Thapa deserves special appreciation for his untiring efforts in GIS analysis and mapping, while Jyoti Shrestha managed the complex production process efficiently with support from Amit Pradhan. Thank you also to Dr. Ghana Shyam Gurung, Senior Conservation Program Director, WWF Nepal for providing valuable inputs.

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Judy Oglethorpe
Chief of Party
Hariyo Ban Program

Executive Summary

Global climate change projections for Nepal and the Himalayas suggest significant changes in temperature and precipitation, including increased monsoon (summer) precipitation and more variable and highly unpredictable actual rainfall patterns. The projections also suggest warmer winters and more frequent extreme weather events, with extended droughts between periods of intense rain. The assessment used the flowing forward approach to determine the impacts of climate change and to assess vulnerability of socio-ecological systems in the Terai Arc Landscape, Nepal (TAL). The approach examines the three components of vulnerability defined by the Intergovernmental Panel on Climate Change (IPCC): exposure, sensitivity, and adaptive capacity. The Flowing Forward approach divides the Terai Arc Landscape into Units and Subunits. The Units are the nine major river basins in the landscape, selected because they are the most prominent ecosystems each with major ecological processes that operate relatively independently. Changes in rainfall patterns due to climate change will affect the water flows in the river basins.

Within the Units, the Subunits are key features of natural and anthropogenic land use/cover and structural components that can be assessed, ranked, and prioritized for climate vulnerability and for which tangible intervention strategies can be developed. Climate change could affect these Subunits of land cover or structures, disrupting the survival and sustainability of biodiversity and human livelihoods, health, and lives. The analysis combines the individual vulnerabilities of Subunits to determine the total vulnerability of the larger Units in the basin or ecosystem.

The Subunits chosen for the TAL are:

1. selected species/species assemblages representative of functional ecosystems of the TAL;
2. major land-cover and land use in the TAL; and
3. major infrastructure that supports the socio-economic status of the TAL and affects the natural systems vulnerable to the impacts of climate change.

The report is divided into four parts. Part one provides recommended strategies based on the flowing forward workshop outputs, expert opinions, and background research material from unpublished and published literature. The executive summary and part one offer a 'stand-alone' section for readers, who can then refer to the subsequent sections for details on the specific process and analysis. Part two introduces the flowing forward approach and methodology. Part three provides an overview of the Terai Arc Landscape, including its key natural and anthropogenic systems, and the conservation goals, objectives, and priorities. Part three concludes with a summary of the projected impacts of climate change in the TAL, how they could affect ecological and human communities, economic development plans for the landscape, and projected climate change scenarios. Part four presents the workshop objectives, the supporting policies, and enabling conditions for conservation and climate adaptation. It concludes with the workshop outputs and an analysis and interpretation of the outputs used to develop the climate adaptation recommendations.

The workshop outputs suggest that more intense, highly erratic precipitation could cause severe floods resulting in habitat loss and degradation, especially for key species that require active conservation. The floods could displace people over large areas, causing losses of lives, livelihoods, and property. They could cause extensive damage to agricultural crops resulting in food insecurity and destruction of infrastructure, with loss of social and economic connectivity. The combination of increasing temperatures andperiodic droughts could increase the likelihood of more frequent forest fires and the spread of invasive species that cause changes to habitat. These changes could include the loss of palatable food, nesting, and roosting plants and trees for wildlife, especially for those focal species with specialized habitat and dietary requirements. People affected by droughts or displaced by floods could exert more pressure on the protected areas, corridors and forests, creating feedback loops that exacerbate ecosystem degradation, loss of natural forest resources, and wildlife population declines.

The workshop selected and assessed 14 species as Subunits, of which seven are considered to be vulnerable to climate change affecting the landscape. The most vulnerable species are vultures, dolphins, and gharial. The workshop did not find two of Nepal's most important flagship species, the tiger and rhinoceros, to be vulnerable to climate change impacts at the landscape level. However, in specific river basins -the Bagmati, Babai, and Bakaiya -the tiger populations are more vulnerable than in other basins. And in the Babai basin the rhinopopulation is more vulnerable to climate impacts than in the Mahakali basin. Urban areas, rural settlements, rural roads, and irrigation systems are the most vulnerable infrastructure Subunits across the TAL. The workshop assigned low resilience scores to almost all the infrastructure in all the river basins. Most roads have high exposure scores, including those in the Babai, Karnali, and Bakaiya basins that are vulnerable to floods due to climate change. The Bhandara Malekhu road, *Hulaki Sadak* (Postal road), and the Mahakali highway are especially vulnerable to floods, and prioritized for modifications in engineering designs to adapt to climate changes.

Major recommended climate adaptation interventions to decrease vulnerability of the landscape and the Units and Subunits are identification and conservation of connectivity, translocation of key endangered species to create founder populations, manage and maintain waterholes and wetlands as habitats for critical species, manage river basins in the Churia with an ecosystem approach for its services and develop systems to monitor the impacts of climate change on species including spread of invasive species. Consideration of climate impact studies in design and construction of infrastructures is emphasized while institutional strengthening in the form of technical and institutional capacity building, establishment of river basin level institutions and developing research, monitoring and communication mechanisms is also recommended.

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RECOMMENDATIONS FOR CLIMATE ADAPTATION IN THE TERAI ARC LANDSCAPE

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PART

As climate change advances, more frequent extreme events, including erratic rainfall and extended hot and cold periods, will result in severe floods and landslides, droughts, and cold snaps that can destroy natural ecosystems and crops, and create harsher living conditions. Projections regarding climate change suggest that it will result in shifts and changes to seasonal precipitation patterns. In most parts of the TAL, pre-monsoon and winter rainfall is expected to increase and total monsoon rainfall to decrease, with shorter periods of intense rainfall instead of relatively evenly distributed monsoon rainfalls. These intense bouts of rainfall could result in severe floods, interspersed with water scarcity during other times of the year.

The following climate adaptation interventions are recommended to decrease vulnerability of the TAL to climate change impacts. These recommendations are based on analyses and interpretation of the flowing forward outputs and other sources of information, such as expert opinions and literature review. They cover species conservation, land use and land cover including agriculture, infrastructure, management of river basins, and other institutional arrangements.

1.1 Recommendations for species conservation and adaptation

- **Identify and conserve connected habitat patches for endangered flagship species**
  Tigers, rhinoceros, and elephants are three endangered terrestrial flagship species of Nepal. All three require forest or natural grassland connectivity to conserve their ecological, demographic, and genetic viability. Therefore, habitat patches that provide connectivity for these species should be identified and conserved. The corridors should be integrated with ecological connectivity for environmental flows and habitat requirements of other important species. Connectivity should also consider access to climate refugia.

- **Translocate endangered species to establish founder populations in suitable habitat**
  Endangered species such as swamp deer, rhinoceros, and wild water buffalo should be translocated into other suitable sites, following proper assessments that take into account impacts of climate change. Establishing these founder populations and augmenting existing small populations will help to reduce the risk of extirpation (local extinction) due to climate change impacts to habitat and species populations. Loss of food and water sources due to climate change-induced habitat changes and disasters, physiological intolerances, and diseases can decimate small, isolated populations of these endangered species.

- **Regulate and monitor mining and extraction from rivers to conserve ecosystem connectivity**
  River ecosystems should be conserved to maintain connectivity for dolphins and fishes, with adequate waterflows to enable seasonal movements. For instance, many riverine fish species have to migrate upstream to spawn. Extraction of gravel and boulders from rivers should be strictly regulated and monitored. Mining and gravel extraction alters riverbeds and river hydraulics, causing the rivers to shift course, exacerbating flooding, and creating flashfloods. The result is the destruction of infrastructure and property, and loss of livelihoods and lives.

- **Manage and maintain waterholes and wetlands as habitat for critical species**
  Waterholes and wetlands should be managed and maintained to prevent them from silting and drying up. Many ox-bow lakes in the Terai have disappeared, even within protected areas. These ecosystems are critical habitat for a number of species, from rhinos and wild water buffalos that require wallows, to aquatic birds, amphibians, and insects. Restoration of the natural ecological communities in the protected areas could maintain these wetland ecosystems. For instance, reintroducing wild water buffalos into Chitwan and Bardia National Parks may help to maintain wetlands, waterholes, and wallows that also benefit other species.

- **Develop systems to monitor the impacts of climate change on species**
  To enhance adaptive capacity of species through management, the development of a monitoring system would make information accessible to scientists, managers, and communities. This involves assessment of the type of information required to monitor climate change impacts on species and ecosystems and establishment of mechanisms for data storage, sharing, and communication of analyses.

- **Establish institutions in each river basin for research and monitoring**
  Plan and implement basin specific research to address the context specific vulnerabilities by building proper institutional structures at the river basin level.

Wetlands are vital source of water for biodiversity and humans, Tikauli Lake Chitwan.
© WWF Nepal, Hariyo Ban Program/ Nabin Baral

1.2 Recommendations for Land Use and Land Cover (LULC)

- **Conserve and restore forests in the Churia range for ecosystem services**
  The Churia range is the source of critical ecosystem services that sustain the socio-ecological and economic fabric of the Terai and beyond. Therefore, the existing forests should be conserved and degraded forests restored to prevent further erosion and landslides in the Churia hills, floods in the Terai, and siltation and aggradation of the rivers. These natural disasters may become more frequent and severe with climate change, causing ecological degradation, substantial economic losses, and wide spread losses of lives and livelihoods. These impacts would lead to social and political instability.

- **Prioritize conservation of existing climate resistant forests for watershed protection**
  Conserve the large, climate resistant and resilient patches of forests in the Terai and Churia that help to buffer against disasters induced by climate change, including landslides, erosion, and flash floods. Securing these forests and wetlands will also help to conserve habitat for endangered, climate-vulnerable species. Prioritize the climate-resistant forest patches that contribute to watershed protection and corridor connectivity using the existing landscape-scale spatial analysis to identify these forests.

- **Identify and plan safe areas for relocation and resettlement of vulnerable communities**
  During climate change-induced disasters, vulnerable people need safe areas to which they can relocate in a planned way. In the past five years, severe floods have already affected the river basins in the western part of the TAL, displacing and dispossessing people and causing property damage and destruction. The people affected by the flood move into available forest lands—usually state forests—where they clear forests to establish settlements and some people stay temporarily while others stay permanently. These ad hoc and unplanned changes in land use can exacerbate cycles of natural disasters through feedback loops. For example, clearing steep-sloped lands for unplanned relocation can increase erosion and landslides, causing more flash floods and more extensive floods downstream, resulting in more people being displaced and more property damaged. For these reasons, it is important to include designated safe areas for relocation and resettlement in land use plans for districts and river basins.

- **Reforest and manage vulnerable vacated land and flood prone areas**
  Through community or leasehold forestry, flood vulnerable vacated lands can be reforested and managed to restore land cover, increase resilience, and provide local communities with sources of forest resources. The riverine areas and flood plains that are most vulnerable to flooding can be restored to riparian forests and grasslands that will serve as buffers against severe floods and river cutting. The land use plans should prioritize flood prone areas in the TAL corridors (Khata, Basanta, Mohana Laljhadi, Kamdi) for reforestation and management.

- **Provide farmers with crop varieties that are climate resistant or adaptive and high yielding**
  To increase productivity in existing agricultural lands in the TAL areas, high yielding crop varieties that are climate resistant or climate-adaptive should be identified and provided to farmers by the relevant agencies.

- **Monitor and control the spread of invasive plant species**
  The spread of invasive species should be controlled and monitored because it could increase with climate change. Invasive species can compromise the integrity of natural ecosystems, including important wildlife habitat and livestock grazing areas. They can reduce the productivity of agricultural areas and industrial plantations. Thus effective monitoring and control of invasive species is recommended.

- **Mobilize community institutions to prevent and control forest fires**
  Make arrangements to prevent and control forest fires because the frequency and intensity of fires could increase under the conditions caused by climate change. This is best done by mobilizing Community Forest User Groups, Buffer Zone Management Committees, and Collaborative Forest User Committees. For example, man-made fires could get out of control during prolonged droughts due to climate change. While natural forest fires

are necessary to maintain some ecosystems, the extreme fire regimes could drive some ecosystems past a threshold ('tipping point') from which they cannot recover, permanently changing the vegetation composition of these ecosystems.

- **Manage and monitor changes in grassland succession**
  A combination of fire and flood regimes usually maintain grasslands through a complex process of succession. Changes in precipitation patterns and seasonality can cause grassland succession processes to change. Thus, active management and monitoring are recommended to maintain the desired spatial configuration, extent, and type of grassland communities, especially in the protected areas and climate refugia.

- **Develop information communicated in a useful and understandable form for all stakeholders**
  Information about threats to biodiversity, drivers of deforestation and degradation, and vulnerabilities are important to address the impact of climate change on ecological and human communities. The capacity to forecast weather and to communicate complex scientific information in an understandable form to forest managers and communities is important to prepare for extreme weather events and changing climatic conditions. Providing information on climate smart agriculture practices, agro forestry, farm forestry, and canal bund plantations may help to decrease the vulnerability of agricultural production to climate changes.

1.3 Recommendations for infrastructure

Infrastructure development is very important for the overall development of any country. However, two conditions are necessary to reconcile infrastructure and the environment. First, the infrastructure should not impact or damage the natural and cultural heritage of the country and degrade the ecosystem services that sustain people's lives and livelihoods. Second, the infrastructure, built at great expense, should be adaptive to climate change. Therefore, several recommendations relate to the planning of infrastructure.

- **Plan, design, and build infrastructure carefully, with due consideration of impact studies**
  Infrastructure development should be carefully planned, designed, and built, with appropriate safeguards, from environmental and social impact studies to climate change resilient engineering designs. Site selection should carefully consider exposure and environmental impacts. Green transportation systems should be promoted to reduce carbon emissions.

- **Compile information for informed decisions and policies**
  Information on environment degradation and infrastructure development must be collected and provided for policymakers to take informed decisions and to promulgate climate friendly policy instruments. The compilation of information should be done by appropriate institutions at the river basin level tasked with monitoring the impact of climate change on the environment.

- **Redesign and realign roads and bridges to reduce their vulnerability to floods**
  Infrastructure development plans need to more strategically consider likely situations due to climate change and the wider implications and consequences of climate-induced natural disasters. Despite the greater initial costs associated with climate-proofing infrastructure, in the longer term the economic investments will become more cost-effective and remain viable if built with good design that considers ecological scenarios. Within TAL, Mohana, Karnali, Babai, Tinau, East Rapti, Bakaiya, and Bagmati river basins are most likely to experience extreme rainfall events due to climate change. The current roads are not designed to withstand severe floods, as evident from the many roads and bridges destroyed by floods in recent years. Most roads and other linear infrastructure are constructed perpendicular to the rivers and streams that carry silt and debris-laden flood waters during intense rainfall periods.

  Thus, these major infrastructures, built at great economic cost, require climate change-adaptive engineering designs to decrease vulnerability to floods, landslides, and other natural disasters. Road and railroad tracks can be realigned to areas that are less exposed to climate change related natural disasters. Infrastructure should incorporate appropriate climate resilient building safeguards in their design, structure, and use. For instance, roads in areas vulnerable to frequent floods could be elevated on overpasses to prevent them from becoming submerged, impassable, and even from being washed away during floods. Roads built on overpasses will allow water to flow unimpeded, present less resistance to the force from flood water flows and debris, and prevent prolonged inundation behind the embankments which can cause people to be displaced for longer periods. Further, reducing the likelihood and severity of floods and landslides through better watershed protection and management will decrease vulnerability of infrastructure.

- **Construct small reservoirs to capture, store, and regulate water flows**
  In most parts of the TAL, climate change is expected to result in shifts and changes to seasonal precipitation patterns and shorter periods of intense rainfall resulting in floods interposed with water scarcity. Thus, the construction of numerous small reservoirs is recommended to capture, store, and regulate the release of water to sustain more even flows throughout the year, even during the dry periods. The storage reservoirs will also prevent flash floods downstream during periods of heavy rainfall. Small reservoirs scattered throughout the Churia, designed and engineered to ensure the stability of the hills, would be more appropriate due to the fragile and brittle geology of the Churia. The design and engineering requires consultations with geologists, engineers, and other relevant technical resource professionals.

- **Protect catchment areas as part of upgrading and maintaining irrigation systems**
  Irrigation systems should be upgraded and maintained to make them climate-resilient. The upper catchment areas will require restoration and effective protection from further degradation to ensure that the irrigation systems remain workable. Indigenous irrigation management systems can be promoted for better maintenance of irrigation canals.

- **Develop Payments for Ecosystem Services (PES) to finance watershed protection initiatives and maintain irrigation systems**
  PES projects can be initiated as a strategy to maintain the irrigation systems, where watershed protection by upstream communities can be compensated by downstream communities that receive and benefit from the services.

Sikta irrigation canal in Banke, infrastructures such these will have greater importance under dry conditions.
© WWF Nepal/ Dipesh Joshi

1.4 Recommendations for implementation and institutions

- **Institutionalize monitoring programs involving community participation**
  Monitoring programs are needed to detect: a) vegetation changes; b) changes in the population status, range shifts of conservation-dependent species; c) spread of invasive species, diseases, and pests; d) changes in ecosystem processes and service delivery (from water to pollination); and e) potential natural disaster risks. Appropriate indicators should be identified with institutionalized monitoring programs that include local community participation through a Citizen Scientist program.

- **Build the technical and institutional capacity to monitor and support climate adaptation**
  Conduct an assessment of technical and institutional capacity required to support climate adaptation in the TAL, and build the necessary capacity from the field to central levels. Ensure that appropriate institutions exist at the river basin level for monitoring the impact of climate change on the environment and human activities.

- **Link and harmonize local level adaptation plans with those at the basin level**
  Link adaptation plans at community and VDC levels (CAPAs/LAPAs) to basin-level adaptation plans and strategies. While the CAPAs/LAPAs provide necessary adaptation strategies at the local level, without the larger basin perspective at which many ecosystem services, climate change drivers, and consequent disasters operate, some local-scale strategies could be ineffective, and even maladaptive.

1.5 Recommendations for 'climate change adaptation zone'

- **Manage river basins to the north of TAL for an ecosystem approach**
  A critical recommendation is the management of the river basins that originate in the Churia range and sub-basins of the antecedent rivers to the north of the TAL as a 'Climate Change Adaptation Zone' for the TAL. The northern boundary of the TAL was originally delineated based on the distribution and habitat requirements of tigers- the focal species used to develop the TAL concept. This boundary follows the ridge of the Churia range. However, to develop climate adaptation strategies, an ecosystem-based approach that includes the upstream basins and sub-basins as the basis for the boundaries is more appropriate, especially with the emergence of climate change impacts as an important conservation issue and the impact of climate change on ecosystem service delivery.

  A proposed boundary of the Climate Change Adaptation Zone is indicated in Figure 1.

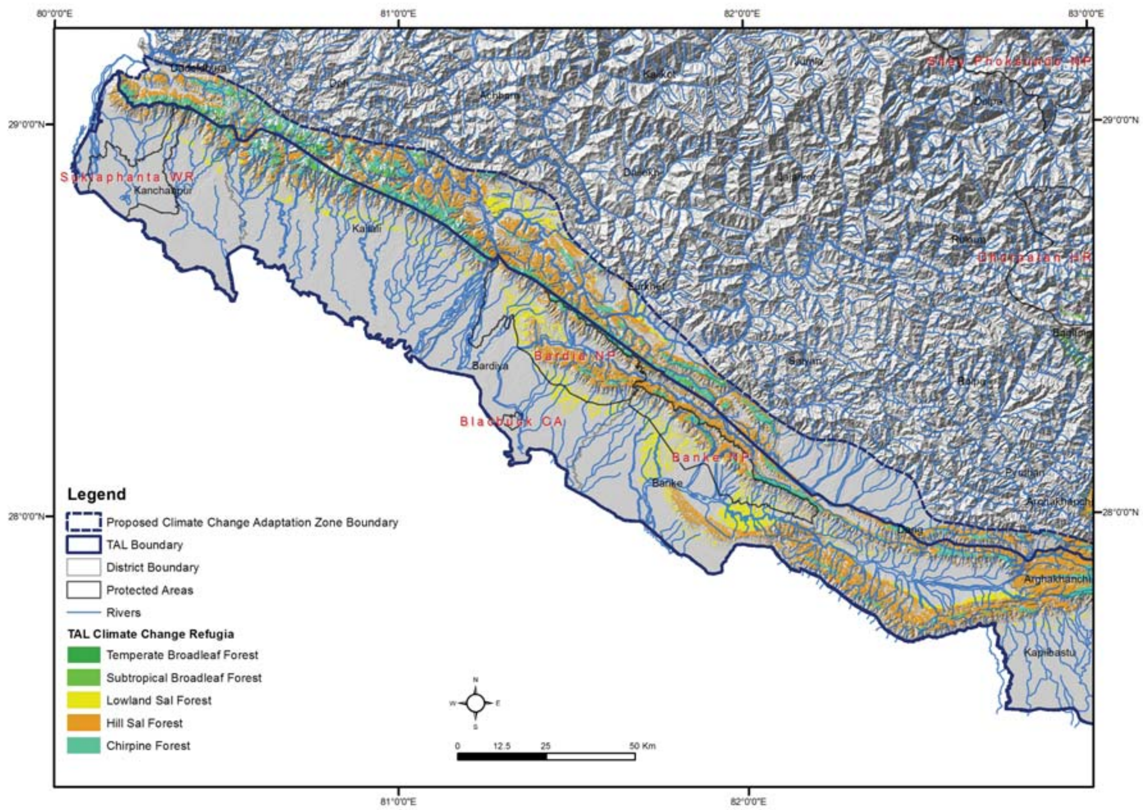


Figure 1. *Climate refugia for forest vegetation in the TAL based on analysis by Thapa et al. (2015). The proposed Climate Change Adaptation Zone will include these climate refugia.*

- The boundary will include sub-basins of the rivers that originate from the Churia and Mahabharat ranges and of the antecedent rivers immediately to the north of the Churia, that is, the Mahakali, Karnali, and Gandaki basins. The definition of this zone uses the geology, topography, and river basins of the Terai, Churia, and nearby regions to identify potential climate refugia for species and ecological communities, environmental services and flows, and common geological attributes.
- In the western region of the TAL the northern boundary will be further north to include all alluvial and conglomerate geological formations; that is, the Quaternary Alluvial river deposits (Qg and Qs) and Middle-Miocene to pho Pleistocene molassic fluvial deposits, conglomerates, sandstone and shale (Si) in the inner Dun valleys, including Dang Valley, southern Surkhet district, and northern Kailali and Dadeldhura districts comprising of Churia hills.

A view of Laljhadi across the Mohana River.

THE FLOWING FORWARD APPROACH AND METHODOLOGY

2
PART

2.1 Introduction

Flowing Forward is a systematic approach to determine the vulnerability of socio-ecological systems at river basin or landscape scales to the impacts of climate change. The outputs of the approach provide a better understanding of the larger drivers of vulnerability and help identify interventions to address these drivers. The approach is designed to:

1. 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

2. assess the vulnerability of natural systems that sustain biodiversity in the landscape or river basin to climate change.

The Flowing Forward methodology builds upon local level vulnerability assessments conducted at community levels. These focus on developing Community Adaptation Plans of Action (CAPAs), but tend to lack the broader landscape perspective necessary to effectively make the links with ecosystem services that flow and manifest at larger scales. The approach assesses the larger scale system-level vulnerabilities to better plan adaptation efforts.The Flowing Forward process is conducted in a participatory workshop during which stakeholders and experts (including community members, resource managers, academics, and technical experts) convene to determine the vulnerability of key systems in the landscape.

The workshop participants receive an information package that serves as a resource to guide the workshop and for the post-workshop assessment and analysis to prioritize vulnerabilities and develop adaptation measures. The package includes basic information on ecosystems and infrastructure in the landscape, and an evaluation of trends in climate (temperature and precipitation), biodiversity, economic development and assets, and socioeconomics and demographics. The background information for this assessment is presented in Part 3 of this document.

2.2 The workshop phases

1. **Determination of Units and Subunits for assessment:** The Units and Subunits of the target landscape 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 and presented at the workshop, but are subject to modification or change based on feedback from the workshop participants.

2. **Vulnerability ranking of Units and Subunits:** After the participants accept the Units and Subunits, they score and rank each Unit and Subunit according to the three IPCC components of vulnerability: i.e., exposure, sensitivity, and adaptive capacity.

3. **Determination and prioritization of most vulnerable Subunits:** Vulnerability scores are computed to determine the most vulnerable Subunits to prioritize adaptation options.

4. **Discussion of adaptation interventions:** Participants discuss optimal adaptation interventions for specific Units and Subunits.

5. **Strategy Development:** When the final interventions are chosen and presented, they discuss larger regional adaptation strategies, including key next-steps and priorities for the coming years of the program.

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

In Nepal, the Flowing Forward approach has already been applied in the Indrawati sub-basin (2011[1]) and in the Gandaki basin (2013). It was effective as a framework for analyzing vulnerability to ecosystems and human systems at the larger river basin scale.

2.3 Flowing forward workshop process[2]

The flowing forward process has the five phases described above, for a discussion of the three components of vulnerability, as defined by the IPCC: i.e., exposure, sensitivity, and adaptive capacity. During the workshop, participants analyze key natural and anthropogenic systems or Units and Subunits for each of the three components and rank them for their vulnerability. The ranked scores help to prioritize these systems for planning adaptation interventions. The process is illustrated in Figure 2.

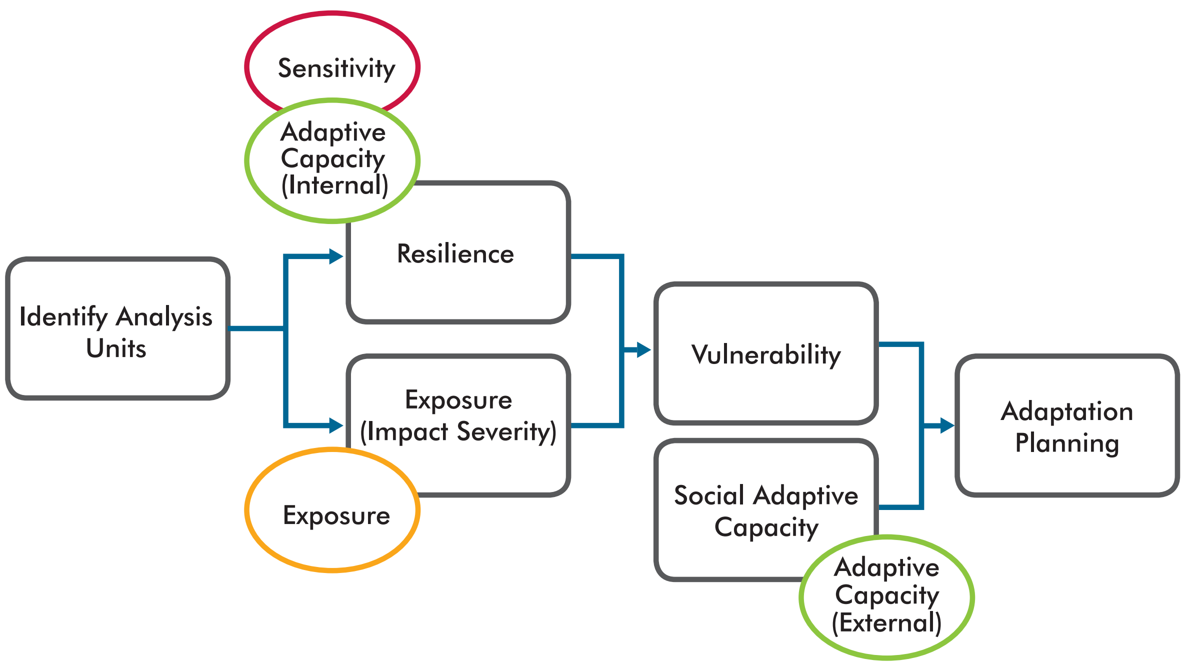


***Figure 2.** Flowing Forward process. Figure from Hariyo Ban Program. Climate Vulnerability Assessment of the Chitwan-Annapurna Landscape (CHAL), Nepal. Workshop Report. 2013.*

[1] https://nicholasinstitute.duke.edu/sites/default/files/publications/freshwater-ecosystem-vulnerability-assessment-indrawati-sub-basin-nepal-paper.pdf

[2] Adapted from: Hariyo Ban Program. Climate Vulnerability Assessment of the Chitwan-Annapurna Landscape (CHAL), Nepal. Workshop Report. 2013.

The following sections describe the key inputs, methods, and results for each step in the process.

Phase 1. Defining Assessment Goals and Targets (Units and Subunits)

The assessment process focuses on Units and Subunits for determining the vulnerability of the major socio-ecological systems in the landscape. Therefore, it is important to select Units and Subunits carefully to reflect livelihood and biodiversity priorities.

First, the landscape is divided into the larger Units. Depending on the main objectives of landscape management, the Units are based on either political or ecological boundaries. Then, each Unit is divided into Subunits representing key natural and anthropogenic systems.

Units and Subunits are identified before the workshop, where they are validated by the participants and modified as appropriate, based on feedback. The accepted list of Units and Subunits then serves as the organizing structure for the workshop's breakout analysis groups.

Phase 2. Assessing Socio-Ecological System Vulnerability

Researchers and practitioners refer to two types of adaptive capacity:

1. social or human adaptive capacity refers to actions by human communities to better cope, manage, or adjust to climate change and related impacts (Smit and Wandel 2006). It is a measure of the human and institutional ability to respond to climate change impacts; and

2. the adaptive capacity of natural systems refers to the ability of ecosystems and species populations to be resilient and able to adapt and adjust to changing climate (Hansen and Hoffman 2011). It is a measure of the inherent ability of ecosystems to resist and recover from impacts.

Flowing Forward considers these two types of adaptive capacity at different phases in the process, but the final ratings of vulnerability are a function of only the inherent adaptive capacity. Social adaptive capacity is measured separately to identify social and institutional barriers to implementing adaptation options (Figure 2). Each Subunit is assessed and scored for resilience and exposure to calculate a vulnerability score (Figure 3). Resilience is a function of the inherent qualities that define a system's sensitivity and ability to resist and recover from impacts. In natural systems, six factors determine these qualities (Le Quesne et al. 2010):

1. Connectivity (or degree of fragmentation)
2. Climate variability
3. Presence of refugia
4. Functional redundancy
5. Natural productivity
6. Biodiversity

For human systems, five of these factors (i.e., biodiversity, natural productivity, functional redundancy, and refugia) are not relevant determinants of resilience or sensitivity. Connectivity, however, is relevant.

Climate variability is interpreted differently for ecosystems where it measures the extent to which they experience naturally fluctuating climates. Whereas, for human systems it is assessed by two separate measures, first, the extent to which climate variability is/was a factor in planning, design, and construction, and second, the extent to which climate variability is addressed in operations and maintenance (Le Quesne et al. 2010). The scores for the resilience factors are important guides in the final phase of developing adaptation options since they identify specific aspects of the Subunits to be targeted. For example, a group may want to develop options that enhance functional redundancy or connectivity in the system as part of the strategy to improve overall resilience.

- **Exposure (Impact severity) is assessed as a four step process (Figure 3):**

1. Clarify, elaborate, and modify the current and future economic development trends and impacts on the Subunits.

2. Review, confirm, or revise the current and future trends in climate variability that were identified through literature reviews and studies done prior to the workshop.

3. Combine the two analyses to determine the combined impacts of climate variability and development trends.

4. Rate the combined impacts in terms of their severity on each Subunit, through three measures of severity: a) intensity (degree of damage that can be caused by the impact); b) extension (size of the Subunit affected); and, c) manifestation (when the impact will occur – already happening, in less than a year, or in more than 10 years).

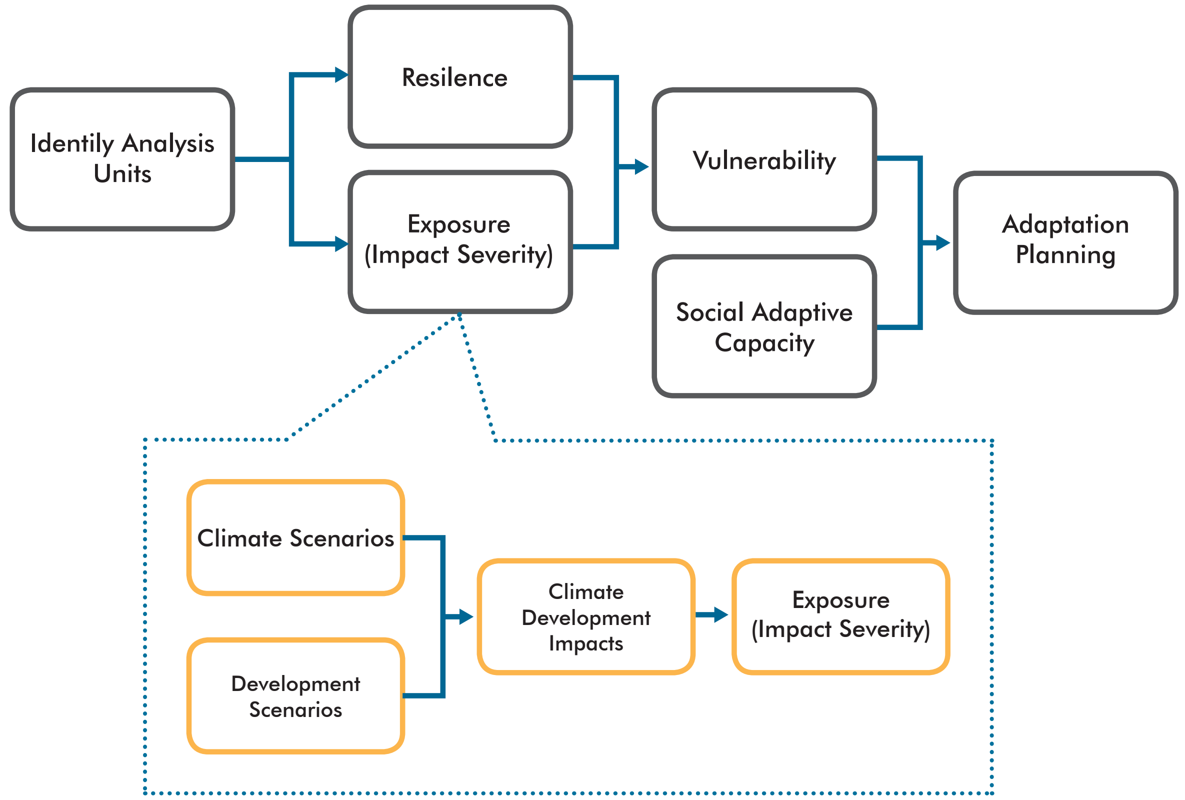


Figure 3: *Four step process to analyse exposure. Figure from Hariyo Ban Program. Climate Vulnerability Assessment of the Chitwan-Annapurna Landscape (CHAL), Nepal. Workshop Report. 2013.*

- Vulnerability is calculated as a function of the inherent system resilience and average exposure as determined above. Its computation is based on a complex equation -- not a simple average of exposure and resilience scores. As expected, the most vulnerable systems will have the lowest resilience and highest exposure scores (Le Quesne et al. 2010).

Phase 3. Social Adaptive Capacity

Flowing Forward considers social adaptive capacity as a function of three factors; policies, institutions, and information systems for the Units and Subunits. Participants will discuss and rate each of the three factors with several parameters.

1. Policies should be forward thinking, and consider future conditions through flexible approaches that plan for multiple future scenarios. They should be:

- implemented and enforced effectively to achieve goals -not merely approved;
- iterative in that they are reviewed and revised periodically to meet objectives and changing conditions;
- appropriate in terms of having adequate human, informational, technical, and financial resources and capacity; and
- coherent and consistent with other policies across all scales.

The status of the policies was reviewed and scored on pre-populated excel sheets with lists of policies and regulation related to biodiversity, environment, and development issues.

2. Institutions should have:

- mandates to meet the goals of the institution;
- authority and leadership to set priorities, make decisions, and carry out responsibilities efficiently and effectively;
- resources and human, informational, technical, financial capacities to function effectively;
- transparency and consultation with other stakeholders; and
- collaboration and coordination with other relevant institutions.

The status of the relevant institutions was reviewed, assessed, and scored on spread sheets listing the institutions.

3. Information should be assessed for the following:

- Frequency – how often is data collected through time
- Iterative Process – repetition of data collection for trend analysis
- Quality – Data gaps? How reliable is the data?
- Accessibility – How easy is it to get the data from other institutions? Constraints?
- Communications – is the data made available to the audiences in an easy to understand way? And on time?

The requirement and availability of Information was assessed and scored with the criteria in each of the Units and Subunits.

Phase 4. Adaptation Planning

Each group is asked to prioritize a set of assigned (or chosen) Subunits. These steps allow the participants to reflect on and reconsider their decisions, and then, if necessary, go back and revise their initial rankings of the exposure and sensitivity scores they used to determine vulnerability.

Each group is given time to brainstorm the primary components of each intervention. These include the Subunits and specific climate impacts that are being addressed with a brief description of the intervention. For instance, considering why the intervention was chosen and where it should be implemented; how it connects to higher-level adaptation planning processes; what the ideal timeframe for implementation would be; whether funding is already available for implementation; and any potential drawbacks and synergies with other ongoing projects.

Phase 5. Strategy Development

When the final interventions are chosen and presented, participants are asked to develop a strategy for implementing their chosen interventions in the short, medium, and long terms.

BACKGROUND INFORMATION ON TERAI ARC LANDSCAPE

3 PART

3.1 The Terai Arc Landscape and its conservation priorities

The Terai Arc Landscape (TAL) covers the western and central Terai, including the south-facing slopes of the Churia range of hills of the outer Himalaya and the inner Dun valleys (Figure 4). East to west, it extends from the Bagmati River in central Nepal to the Yamuna River in Indian state of Uttarakhand.

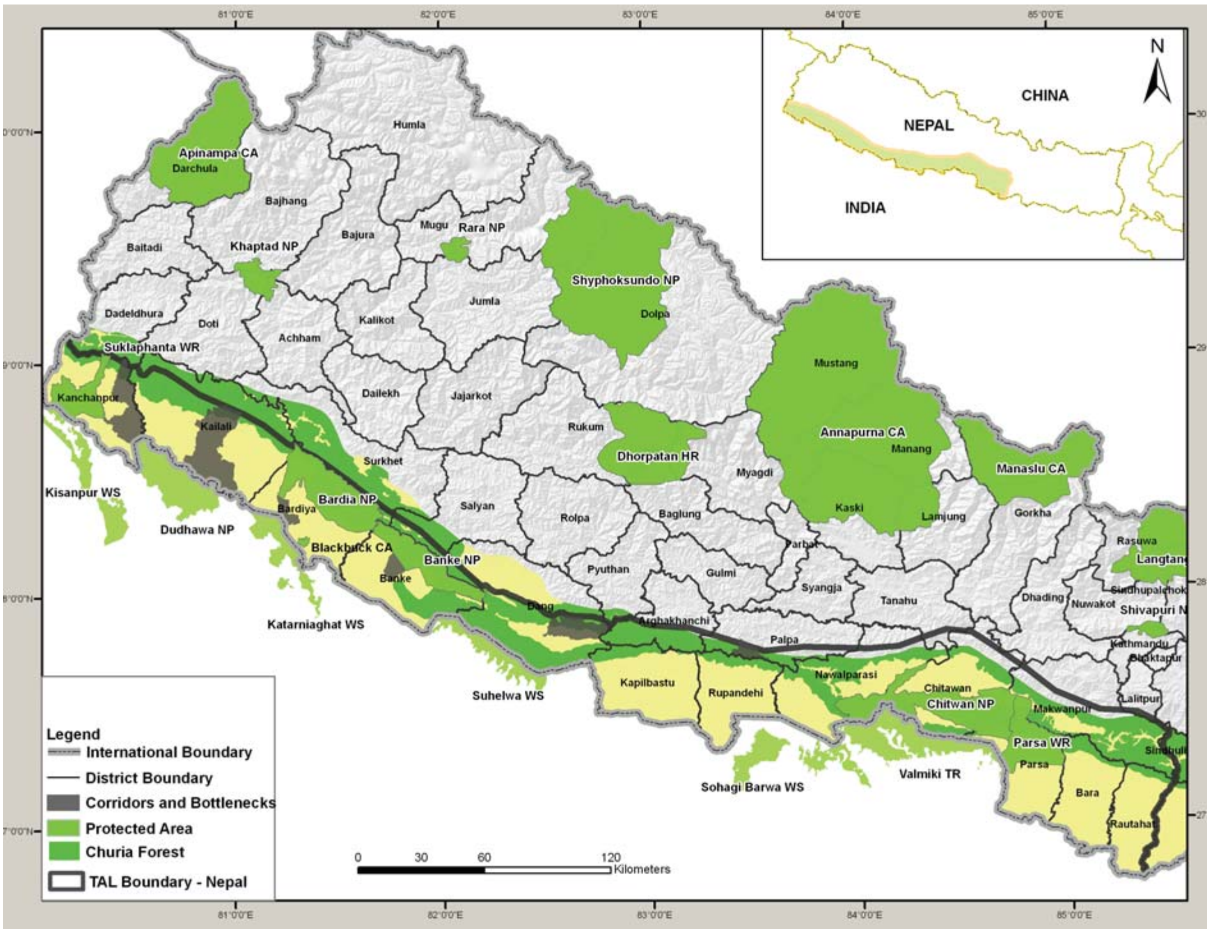


Figure 4: *The Terai Arc Landscape in Nepal.*

Government of Nepal with financial support from WWF Nepal initiated the TAL program in 2001 as a landscape-scale approach to conserve some of Asia's most important biodiversity, especially the globally important populations of endangered large vertebrates (Wikramanayake et al. 2010). The landscape consists of the Terai Duar Savanna and Grasslands and the Himalayan subtropical broadleaf forests eco regions (Figure 5), which are globally important for biodiversity conservation (Wikramanayake et al. 2001).

The TAL supports globally important populations of Tiger *(Panthera tigris)*, Greater one-horned rhinoceros *(Rhinoceros unicornis)*, Asian elephant *(Elephas maximus)*, Gaur *(Bos gaurus)*, Swamp deer *(Rucervus duvaucelii)*, Gangetic dolphins *(Platanista gangetica)*, Gharial *(Gavialis gangeticus)*, Lesser Adjutant Stork *(Leptoptilos javanicus)*, several species of vultures *(Gyps spp.)*, Bengal Florican *(Houbaropsis bengalensis)*, and Sarus crane *(Grus antigone)* (MFSC 2004).

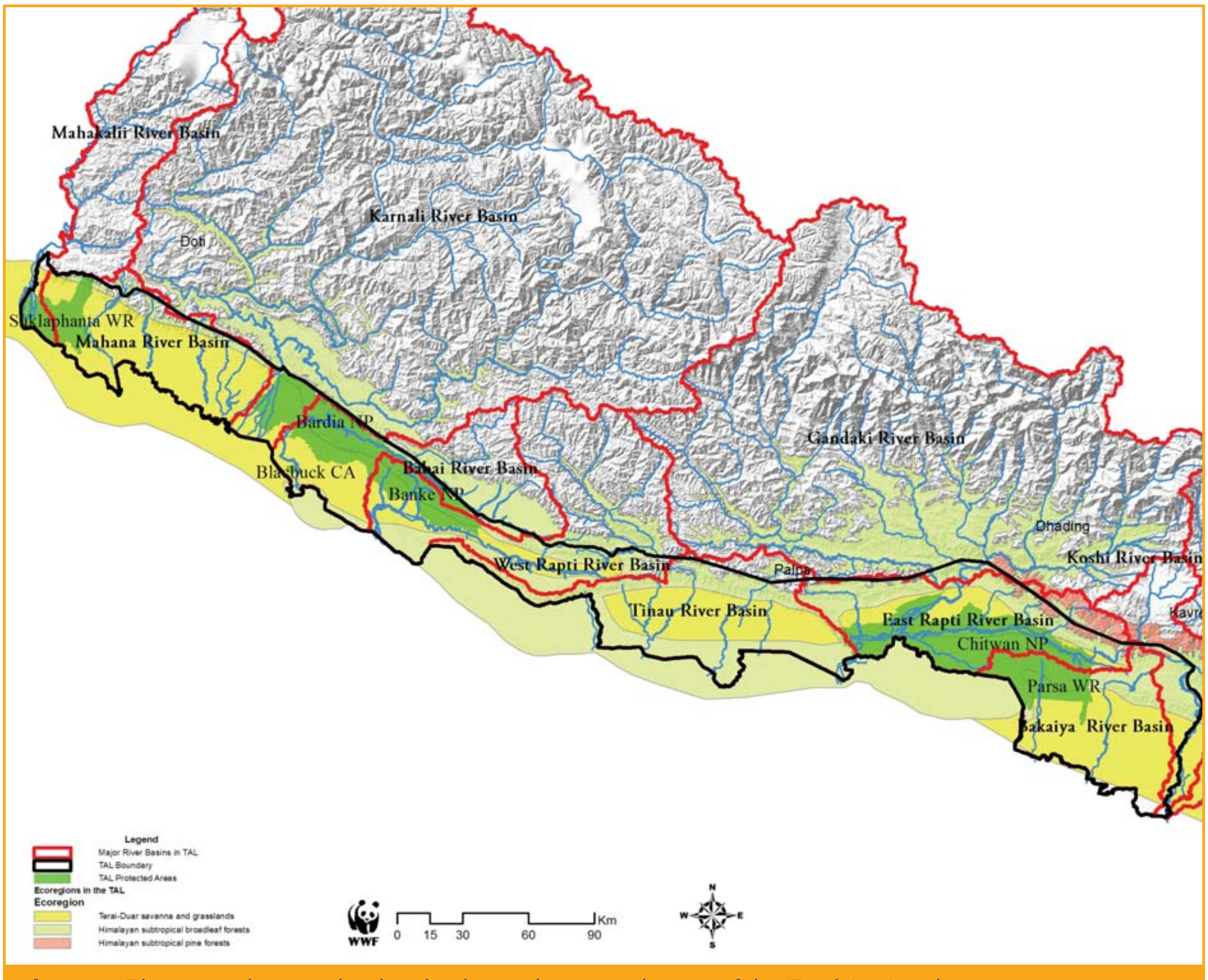


Figure 5: *The ecoregions, major river basins and protected areas of the Terai Arc Landscape.*

Most species in this list require relatively large areas of habitat and a variety of habitat types to maintain their ecological, demographic, and genetic viability. They are considered as 'umbrella species' for other biodiversity in the TAL, meaning that conservation efforts for these species provide conservation cover for other species requiring less space and variety.

Since these 'umbrella species' are also threatened or endangered, the TAL program aims to connect the protected areas in the TAL with habitat corridors that enable the species to move and disperse between the protected areas (MFSC 2004). The populations that are linked through dispersal are termed meta-populations, and considered to have greater ecological and genetic viability than smaller, isolated populations (Reed 2004).

The Churia hill range is an important east-west corridor along the length of the landscape. This low mountain range is geologically fragile because it consists of sedimentary limestone and clay conglomerate deposits (GoN 2008, Singh 2010). The forests of the Churia hills stabilize the fragile slopes preventing erosion and landslides, which are common where the forests have been cleared or degraded (GoN 2008).

Forested watersheds play an important role in sustaining and regulating flows in the rivers that originate from the Churia (Singh 2010). Intact, forested watersheds retain water through the sponge effect and release water in a sustainable regime, whereas rainfall on degraded and cleared slopes runs off without percolating into the ground (Recha et al. 2012). River flow regulation for sustainable flows throughout the year is essential, because precipitation comes mostly in the mid-year monsoon months. This water supports the agrarian economy of the Terai, the human communities, and the important biodiversity of the TAL (Singh 2010). Thus, another goal of the TAL program is conservation of Churia forests to maintain hydrological flows as ecosystem functions that support and sustain biodiversity and human communities (MFSC 2004, GoN 2008).

The TAL has nine major rivers that generally flow north to south. These TAL rivers are classified according to their dry-season discharge and source; namely from the Himalayan, Mahabharat, or Churia ranges (Figure 5). Three of Nepal's four Himalayan rivers; the Narayani (Gandaki), Karnali, and Mahakali fed by perennial snow and glaciers, flow through the TAL. The Bagmati, West Rapti, and East Rapti are rain-fed perennial rivers originating in the Mahabharat or middle mountains. The East Rapti becomes confluent with the Narayani (Gandaki) in the East Rapti Basin. The Tinau, Mohana, Babai, and Bakaiya originate from the Churia range (Figure 5). These rivers are seasonal, with very low or no flows during the dry season, but highly variable and unpredictable flows during the monsoon season.

3.2 Economic development scenarios in the Terai Arc Landscape

Until the 1960's, the Terai region was sparsely populated because malaria kept most people away. Only the indigenous Tharu tribal people were able to survive because they have a natural immunity to malaria (Terrenato et al. 1988). A concerted malaria eradication program implemented in the late 1950s encouraged an influx of people from the hills, attracted by the high productivity and agricultural potential of the Terai.

There has been extensive development of infrastructure due to the ready access to markets in India, which has also served to attract people to migrate to this region. Since the early 1960s, the Terai and Churia region has had the highest population growth rates in Nepal, and now has the highest population density in the country (Figures 6 and 7).

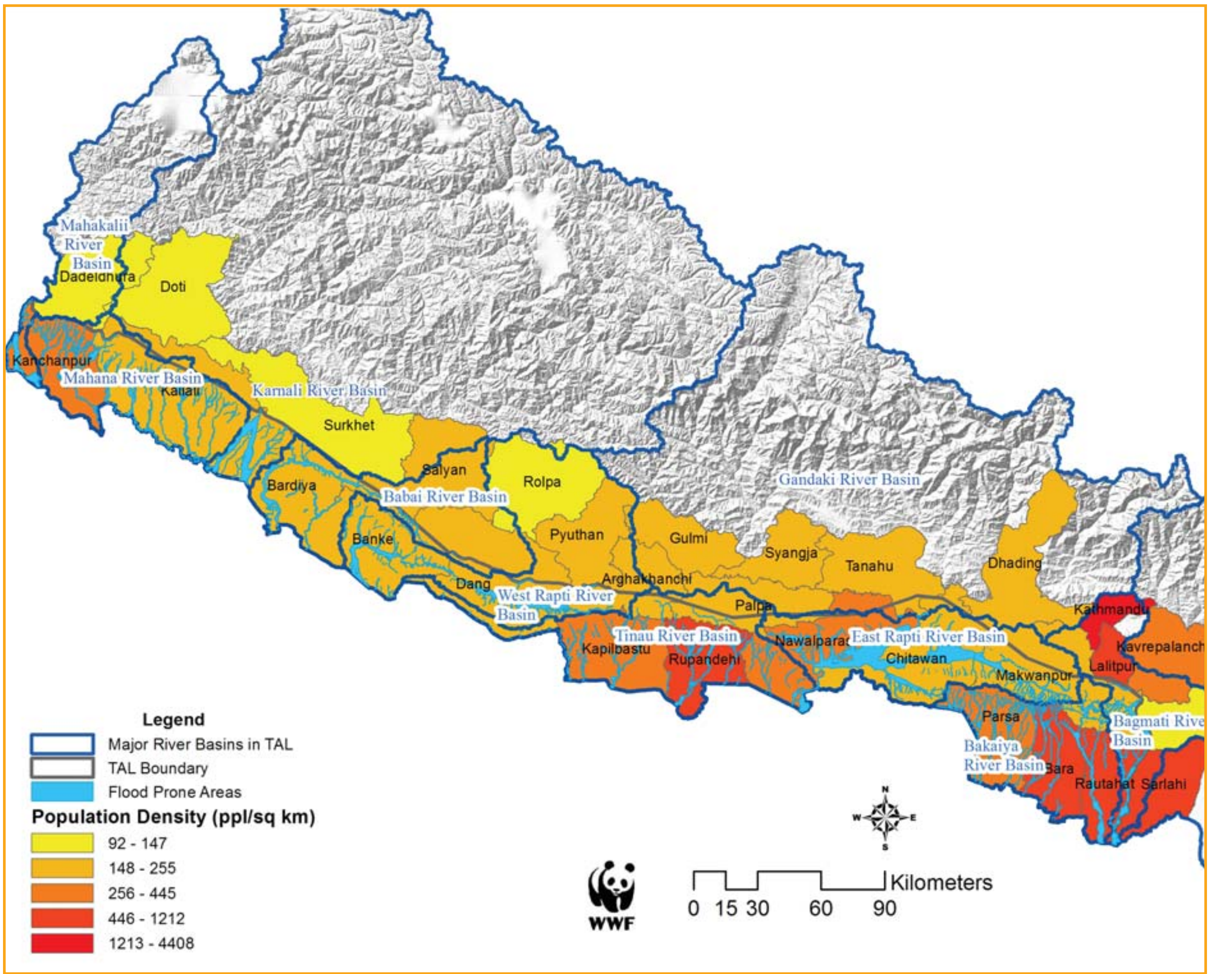


Figure 6: *Human population numbers in the Terai Arc Landscape. The terai districts have some of the highest human population densities in Nepal, Data source: GoN 2012.*

With the rapid population growth in the Terai, land availability became limited so new migrants and poor people were relegated to the less productive Churia hills (GoN 2008).The population of the Churia hills is about 1.5 million as compared to the highly productive Terai and Dun valleys with a population of 8.3 million (GoN 2008).

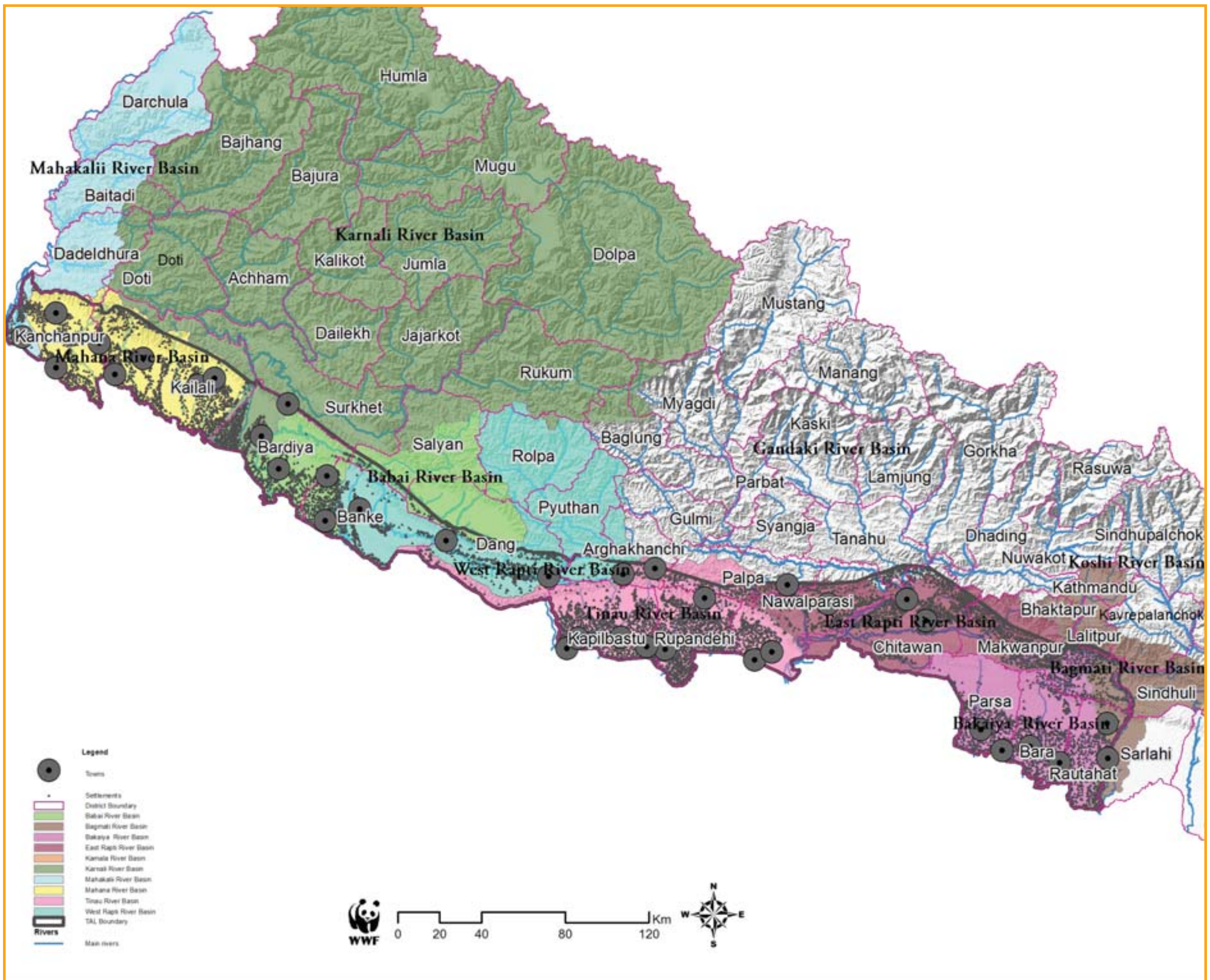


Figure 7: *Distribution of human settlements in the Terai Arc Landscape. The Churia range is relatively less populated than the terai. Most settlements are along the rivers and river plains.Data source: GoN 2012.*

3.3 Land use and land productivity

The soil in the alluvial flood plains of the Terai is very fertile, so people migrating to the Terai converted most of the region's natural forests, grasslands, savannas, and wetlands to agricultural fields or plantations. About 81% of the land in the Terai region is now under cultivation (Figure 8), more than 4% is degraded forestland, and about 6% is riverbeds and channels (GoN 2008). Natural vegetation covers only about 7% of the land in the Terai, mostly within the protected areas.

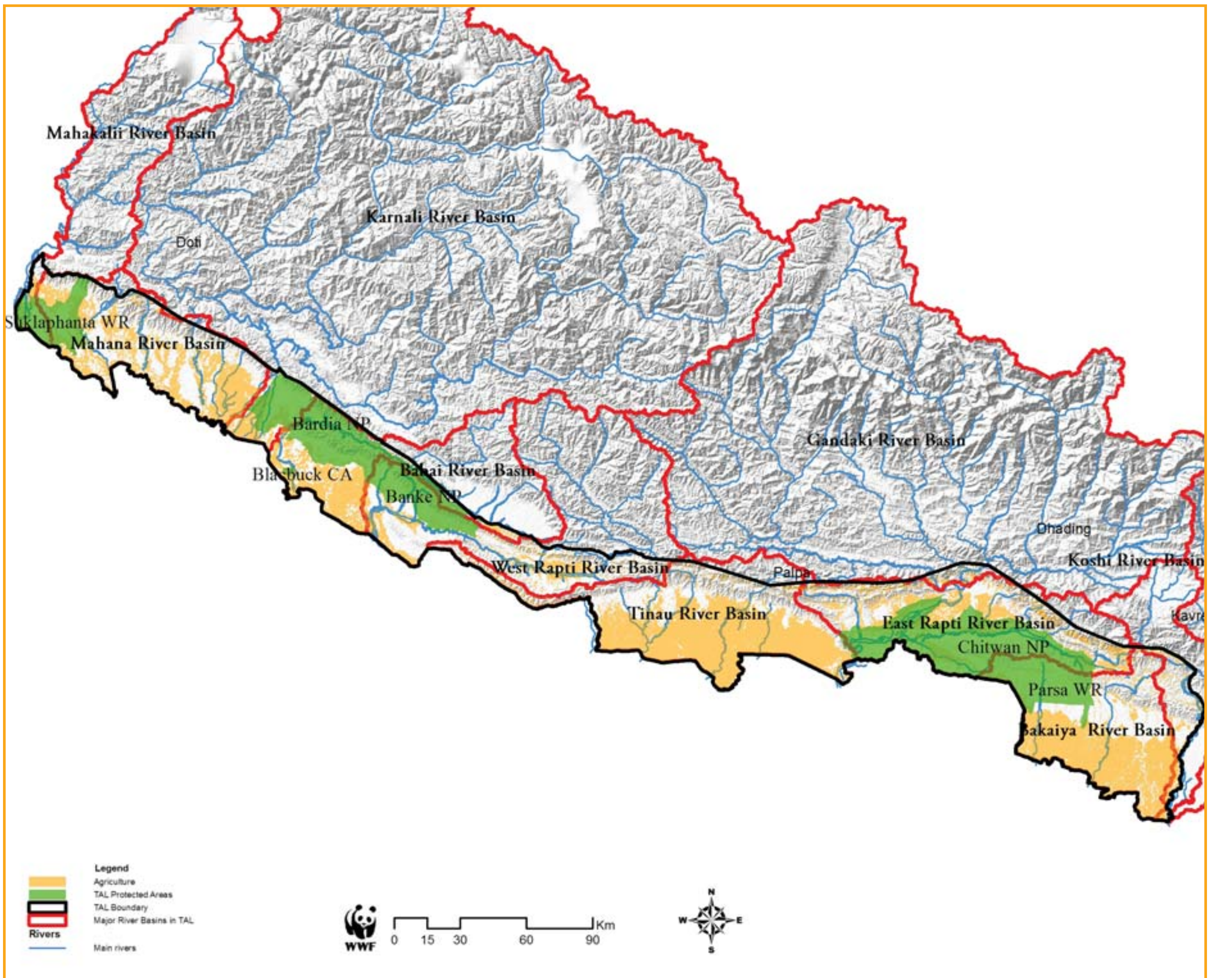


***Figure 8:** Main agriculture areas in the Terai Arc Landscape. Data derived from Nepal land use/land cover map.*

Encroachment of state forests in the Churia hills and the Terai is becoming widespread (GoN 2008) as people displaced by landslides, floods, and other natural disasters in the Terai take refuge in the higher elevation forests or other public land (GoN 2008). Politically driven causes, such as 'vote-buying' during elections or proxy landgrabbing, also contribute to forest encroachment (GoN 2008).

The people encroaching on the forests do not have land title or formal tenure. They are usually unwilling to adopt sustainable agricultural practices, such as terracing, agro-forestry, and horticulture, because they cannot make the high initial investment required nor wait for the long-term return on the investment (GoN 2008). Therefore, people may clear forests and ground cover for maladaptive and unsustainable agricultural practices, such as clearing and cultivating slopes greater than 40 degrees without terracing for soil and water retention; practicing shifting cultivation on steep fragile slopes; and clearing riparian areas to plant short-term crops.

In these situations, people allow livestock to free-graze in forests, where they remove the ground cover and loosen the fragile soils, making the slopes more prone to erosion (Table 1) (MoPE 2004, Karkee 2004).

People also burn the forests to create temporary pasture. As the exposed, eroding slopes lose the nutrients and top soil, farmers abandon them and clear new areas; a feedback process that results in widespread land degradation (GoN 2008, MoEST 2008, MFSC 2010). The TAL program initiated community forestry projects to restore degraded forests in the TAL corridors and buffer zones (Figure 9).

Table 1: *Estimated soil erosion rates.*

Land use category	Erosion rate (tonnes/ha/yr
Well managed forest land	5-10
Well managed terraced paddy and maize	5-10
Poorly managed sloping terraces	20-100
Degraded rangelands	40-200

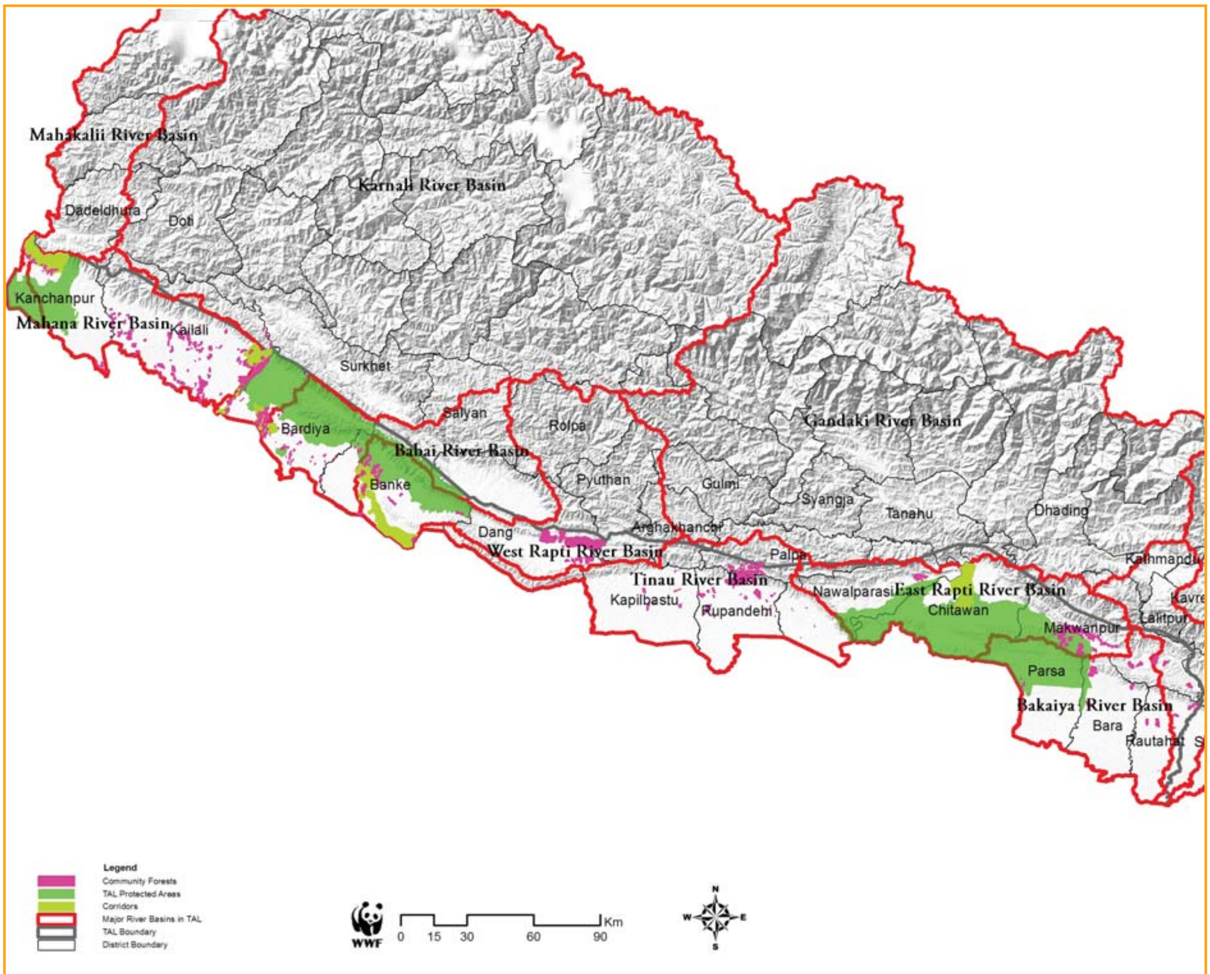


Figure 9: *Community forests established in the terai under the Terai Arc Landscape program. Data from WWF Nepal Program.*

The major agricultural crops in the Terai are rice, pulses, and vegetables; while in the Churia hills the major crops are rice, millet, and maize (GoN 2012). However, the production of rice and millet is decreasing with farmers deciding to grow maize instead with the availability of improved maize seeds and ability to grow maize using rain-fed irrigation. Products from agro-businesses in the Churia hills include citrus, ginger, honey, turmeric, *amriso* (Broom grass), and *babio* (Bhabbar grass).

The rivers originating in the Churia hills provide water for irrigation to large agricultural areas in the foothills and Terai (IUCN 2009, Singh 2010, Figure 10). However, these sources of irrigation water are now completely dry by April or May (IUCN undated), which causes considerable economic and livelihood losses. The current value of the water in crop production is about Rs. 500 per kattha (≈US$231/ha) in paddy production and about Rs. 258 per kattha (≈US$119/ha) in wheat production per year (Table 2).

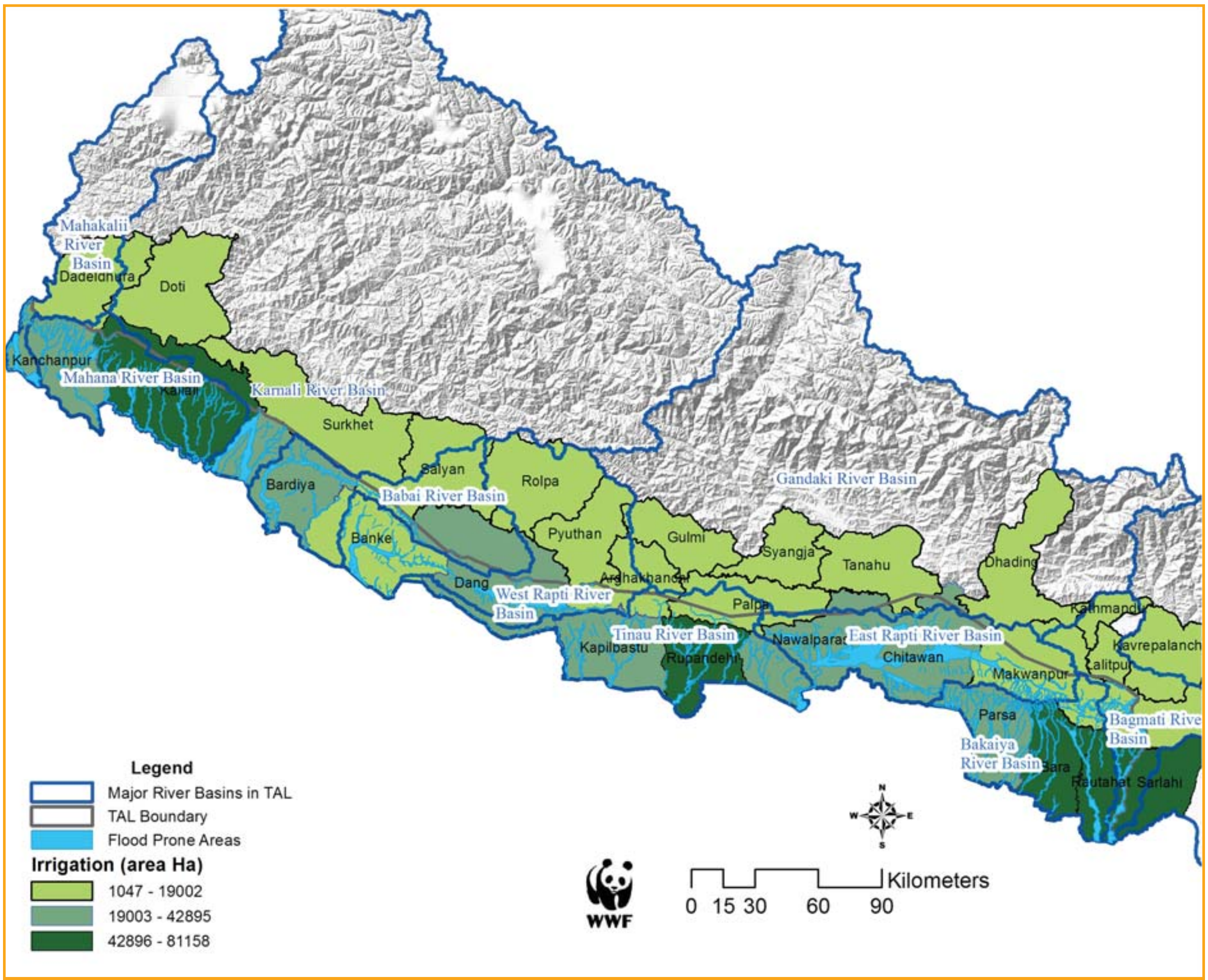


Figure 10: *Extent of irrigated agriculture in the Terai Arc landscape. Irrigation systems include systems of canals that regulate and divert water from rivers, streams, and spring sources in the TAL region.Data source: GoN 2012.*

3.4 Natural resource extraction

In Nepal, the rural poor use several hundred species of plants as non-timber forest products (NTFPs) (Shrestha et al. 2004). For example, a study in the Khata corridor showed that the local people collect over 100 species of plants from the forests for uses ranging from fruit and vegetables, to fish poisons and fermentation material, to thatch, fiber, fodder, and medicinal uses (Uprety et al. 2010).

Table 2: *Economic value of water (Rs./ kattha) in irrigated agriculture*

Across physio-zones	Foot hills	Bhabar	Terai	Total
Econ. value of water from paddy	397.3	315.5	541.2	499.8
Econ. value of water from wheat	44.3	251.3	277.3	258.2
Total value of water	441.6	566.8	818.5	757.9

Many people—especially most ethnic minorities *(Janajati)*, freed bonded laborers *(mukta kamaiya)*, and landless settlers *(sukumbasi)*—in the Terai and Churia, who are poor, collect these NTFPs for everyday use. The NTFPs make significant contributions to their livelihoods, helping to alleviate poverty and enhance food-security, health, and income (FAO 1995). Thus, the Churia and Terai forests are a 'safety net' from which the rural poor can obtain natural resources. However, a rapidly growing population is causing extensive forest degradation through over-extraction of the forest resources,unsustainable agriculture practices, and free grazing of livestock in forestlands (GoN 2008).

The consequences of forest degradation and erosion in the Churia slopes affect the Terai as floods and siltation of agricultural lands. The Terai also suffers a loss of irrigation and drinking water as the water sources in the Churia dry up (GoN 2008). Besides compromising the lives and livelihoods of the people, these concerns are threats to the survival of globally important biodiversity in the Terai.

The TAL program has facilitated the transfer of degraded forests in buffer zones of protected areas to local communities with usufruct rights for management. The local community user groups get substantial benefits from these forests by collecting NTFPs, and will conserve endangered species and ecosystem services through 'conservation friendly' management (Baral and Heinen 2007a,b).

Unregulated sand, gravel, and boulder extraction from the rivers in the TAL is altering river profiles and river bed hydrography (Khanal et al. 2007). The changing flow patterns and increasing rates of water flow result in bank scouring, river cutting, and aggradation that destroys infrastructure along the rivers (especially bridges, irrigation canals, houses, farms, etc.) and causes significant economic losses. Mining sand from rivers is also causing the groundwater table to drop, drying up wells in the surrounding areas (Scott Wilson 2014).

Displaced people move to, clear, and settle in the remaining forests, especially in the Churia hills, which offer higher ground as flood refugia. Their use of the forests creates feedback loops triggering more floods and landslides, which are now the natural disasters causing the most economic losses and human deaths in Nepal (WECS 2011).

There are plans for oil and gas exploration in the Terai, including in the TAL (WWF 2005). GoN has designated ten exploration blocks,[3] some of which are within protected areas and corridors set aside forthe conservation of globally endangered wildlife species. Oil exploration activities in flood prone areas could potentially contaminate ground water, affecting water sources for people, and threatening the agriculture-based economy.

3.5 Infrastructure development

Rapid economic development in the TAL region has brought supporting infrastructure including extensive road networks, highways, airports, irrigation canals, and large commercial centers (Figure 11). The GoN is planning new infrastructure, including additional roads, express ways, airports and a railroad (Scott Wilson 2014). These structures usually have negative impacts on the natural environment, which are greater if there is not proper planning for safeguards to mitigate the loss or degradation of the ecosystem integrity and service provision.

[3] http://sustainablenepal.org/misadventures-in-oil-exploration-texana-and-cairn-in-nepal/#.VNv6jS6r-WA

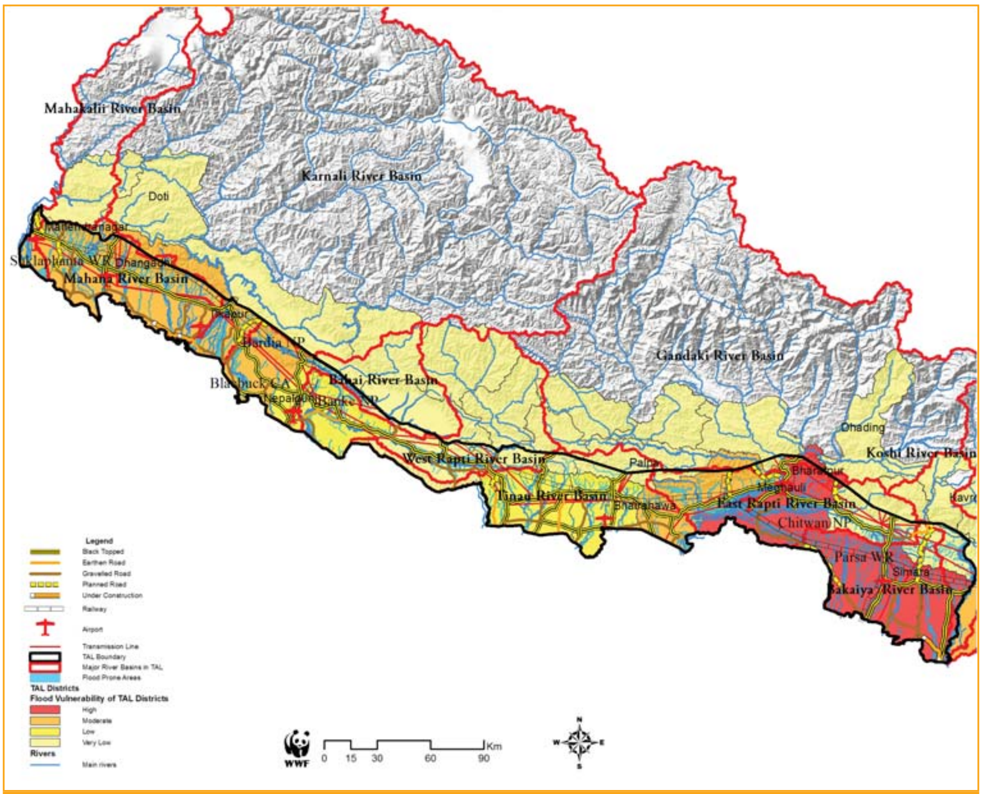


Figure 11: *Major infrastructure and flood vulnerability.*

For instance, several national and rural roads are under construction or in the planning stages. Their construction requires clearing vegetation along the road track, which causes considerable collateral loss and degradation of important forests. Cleared vegetation, bare areas are vulnerable to landslides and erosion. Long stretches of settlements along the roads increase pressure on the natural resources and biodiversity, and increase the vulnerability of surrounding areas to natural disasters. Rivers and streams close to roads become polluted and turbid from siltation.

Roads that traverse important biological corridors and protected areas have severe impacts on the conservation of endangered species. For example, the Bhurigaon-Telpani-Surkhet road will bisect Bardia National Park and the *Hulaki sadak* will several transboundary biological corridors established for endangered species such as tigers and rhinos. Accordingly, roads should incorporate appropriate environmental safeguards by locating them appropriately and their engineering design.

Major irrigation canals are necessary to increase agricultural production and support economic growth but can also have negative impacts (Scott Wilson 2014). The use of explosives to construct the contour canals along hill slopes can destabilize slopes, resulting in rock falls, landslides, and erosion. Silted canals and accumulating debris can impede the flow of water, resulting in overflow and local floods. Larger canals can sever movement pathways for wildlife, so wildlife crossings should be in the project design.

Loss of the natural capital from unplanned building of infrastructure can undermine the long-term sustainability of the development projects, thus compromising the returns on economic investments and the socio-economic benefits that they are supposed to provide.

3.6 Climate change scenarios in the Terai Arc Landscape

The National Adaptation Plan for Action (NAPA) (MoE 2010) provides the basis for strategies to adapt to climate change scenarios in Nepal. To provide strategies at sub-national levels, several Local Adaptation Plans for Action (LAPAs) have been prepared based on the broader-scale NAPA. Community Adaptation Plans for Action (CAPAs) have been prepared at the community or micro-catchment scale.

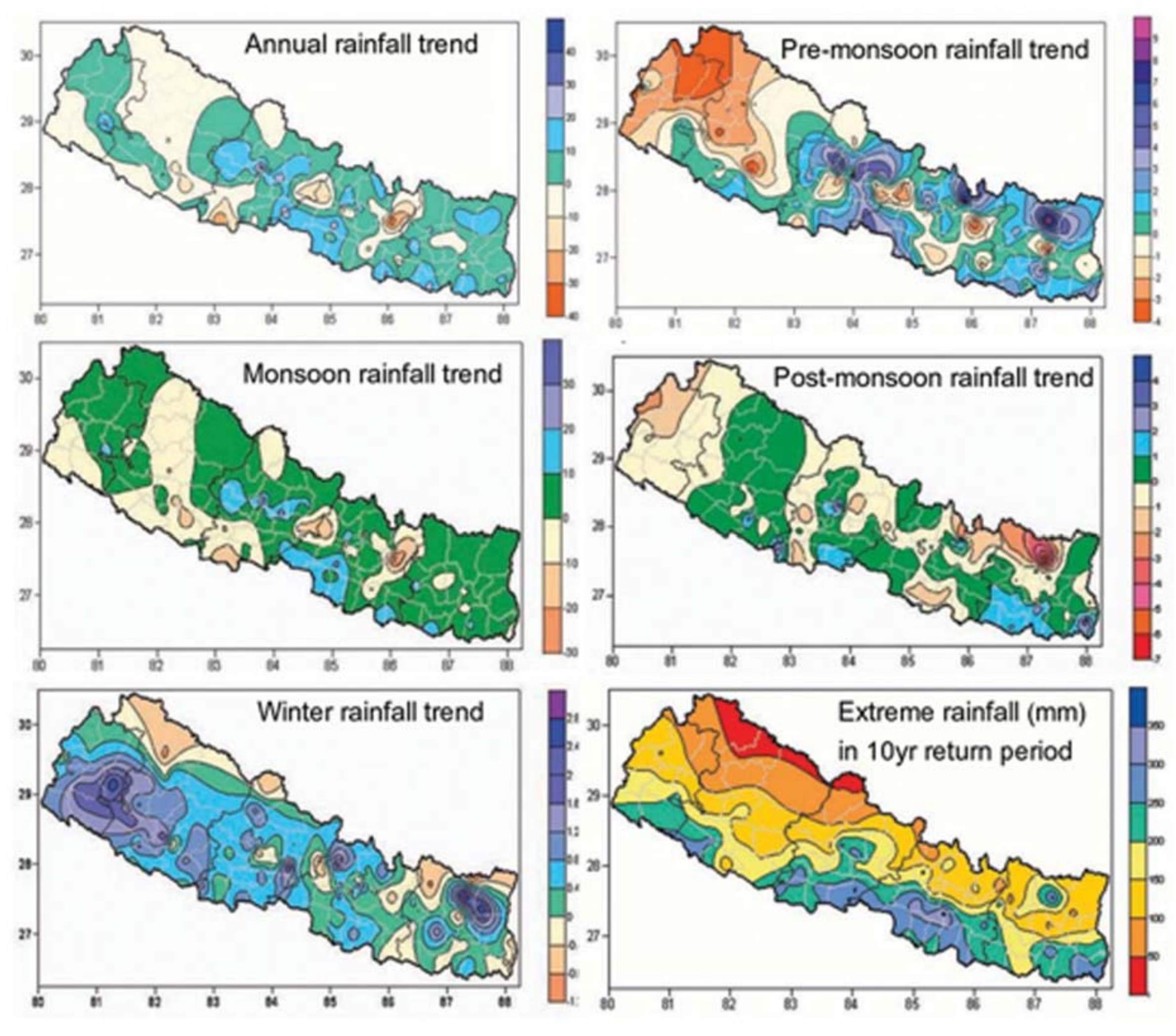


***Figure 12:** Projected annual and seasonal rainfall trends (mm/year) in Nepal. (Source: Practical Action 2009)*

However, the intermediate scale of river basins and landscapes ismore appropriate for consideration of the important ecological processes and dynamics that sustain the socio-economic systems (Colls, Ash and Ikkala 2009, IUCN 2009, Wiens 2002). The team applied the Flowing Forward approach at these intermediate scales to assess the vulnerability of socio-ecological systems of the TAL to projected scenarios due to climate change.

3.7 Rainfall and temperature trends in the Terai and Churia

The team assessed rainfall and temperature trends for the Terai and Churia areas from the national trend analysis (OECD 2003). This analys is shows that pre-monsoon rainfall is increasing in the low land areas of western, central, and eastern Nepal, and decreasing in the far southwest (Figure 12).

Monsoon and post-monsoon rainfall is decreasing in the far western Terai and Churia regions. However, winter rainfall is increasing considerably in southern Nepal, especially in the western and central regions with greatest increases in the far southwest.

These trends suggest higher winter rainfalls in almost all the TAL river basins (Table 3), with very high rainfall events in most southern regions, especially in the Mohana, Karnali, Babai, Tinau, East Rapti, Bakaiya, and Bagmati basins. Overall, the Terai and Churia region can expect higher pre- and post-monsoon rainfall and higher winter rainfall, but rainfall will vary in different basins.

Table 3: *Change in seasonal rainfall patterns in the river basins in the Terai Arc Landscape. '+' indicates and increase, 'o' indicates a decrease, and '-'indicates no change. (derived from Figure 12, Practical Action 2010)*						
River Basin	**Annual Rainfall trend**	**Pre-monsoon rainfall trend**	**Monsoon rainfall trend**	**Post monsoon rainfall trend**	**Winter rainfall trend**	**Extreme rainfall**
Mahakali	+	--	+	-	++	+
Mahana	o	+	o	o	++	++
Karnali	+	--	+	+	+++	++
Babai	o	+	o	+	++	++
West Rapti	+	+	+	+	++	+
Tinau	-	++	-	-	++	++
East Rapti	++	+++	++	+	++	+++
Bakaiya	++	-	++	-	+	++
Baghmati	+	+	+	+	+	++

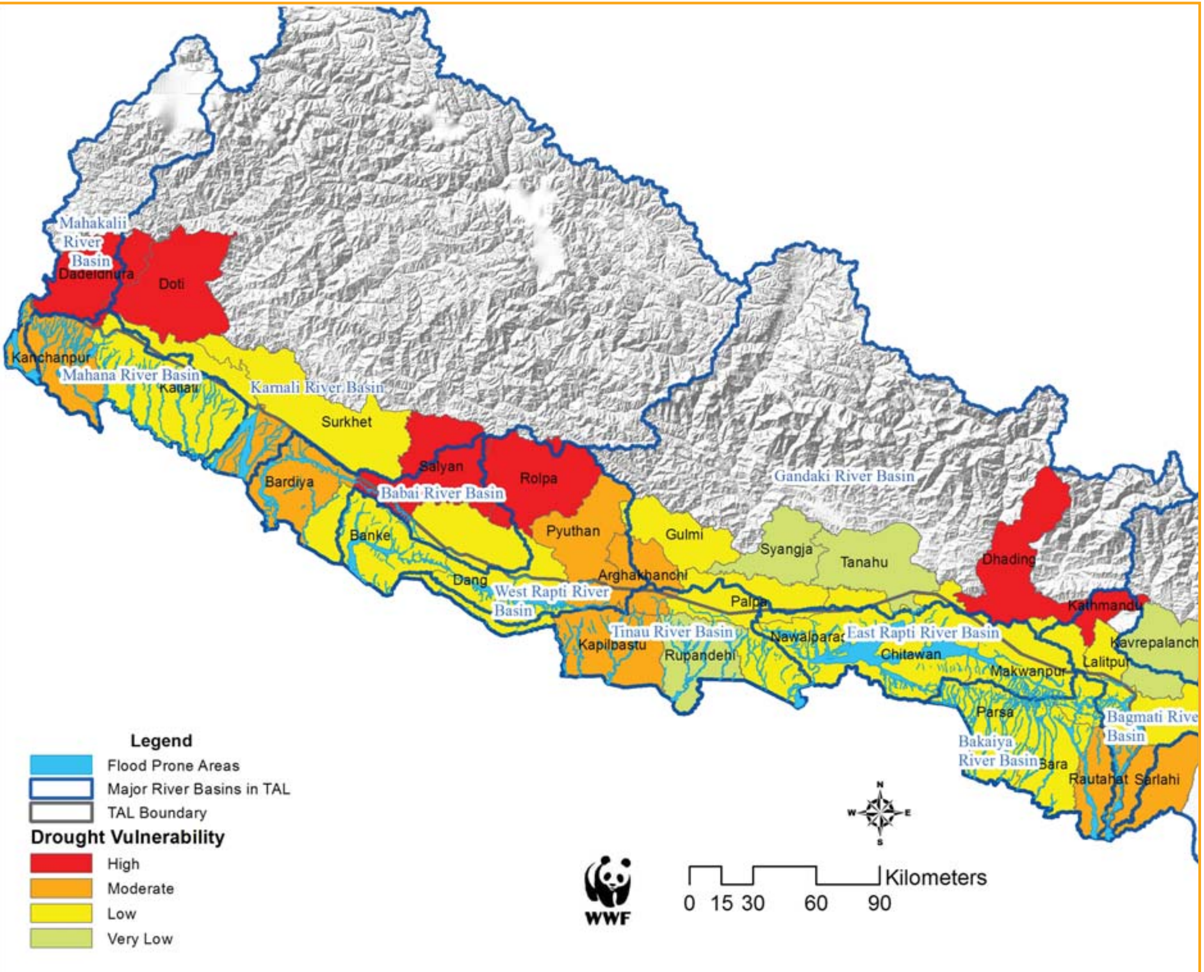


Figure 13: *Projected drought vulnerability of Terai Arc Landscape districts due to climate change. Source: National Adaptation Programme of Action. 2010. Ministry of Environment (MoE), Kathmandu, Nepal.*

However, the TAL region is predicted to receive less monsoon rain, which could reduce water availability during parts of the year and extend periods of drought (Figure 13).

Over the past decade, more intense and more frequent rainfall events have happened in this region resulting in several Terai districts being declared as flood vulnerable (Figure 14).

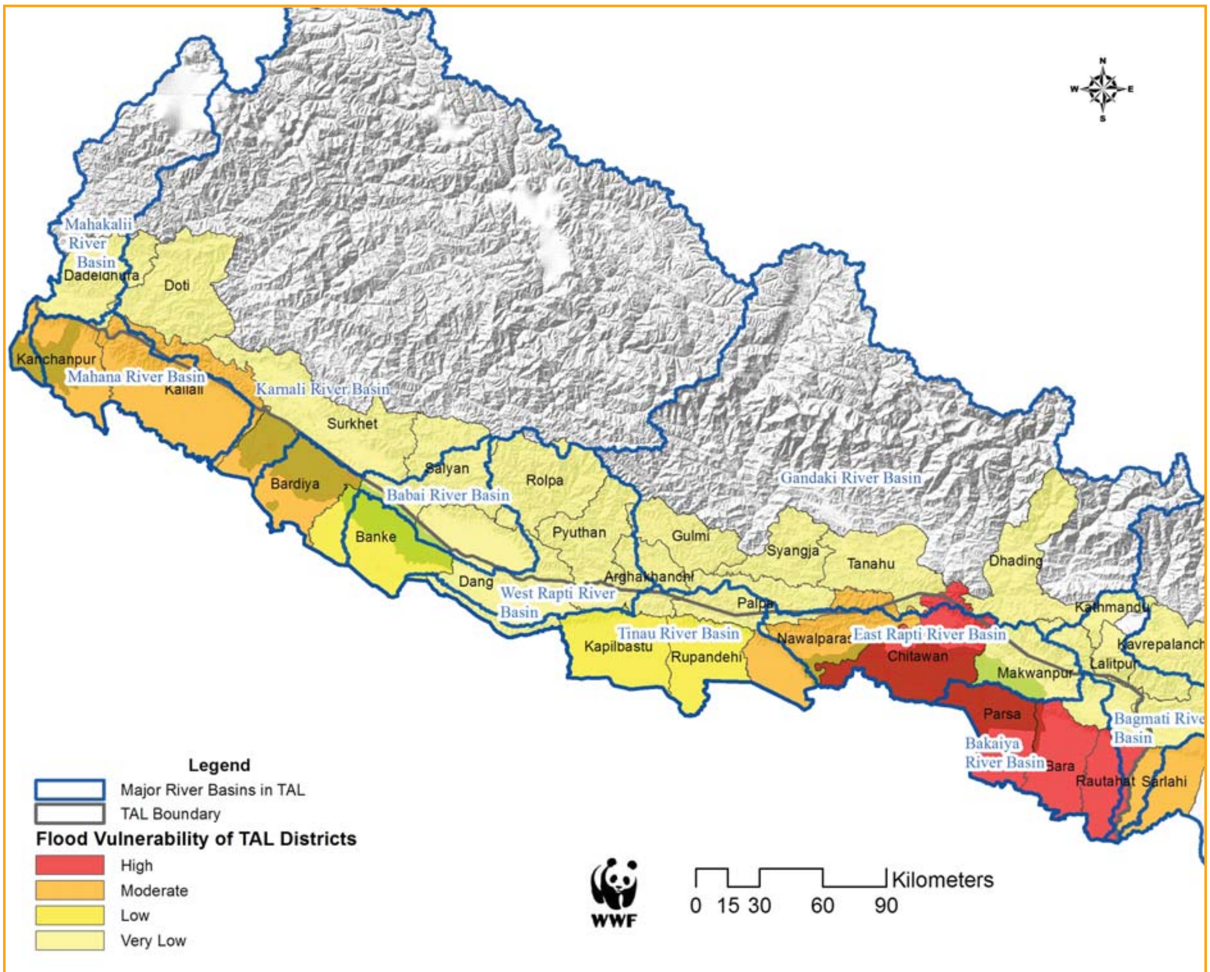


Figure 14: *Projected flood vulnerability of Terai Arc Landscape districts due to climate change. Source: National Adaptation Programme of Action. 2010. Ministry of Environment (MoE). Kathmandu, Nepal.*

Over the past five years, several areas have experienced several severe flood events, especially in the western part of the TAL (Figure 15).

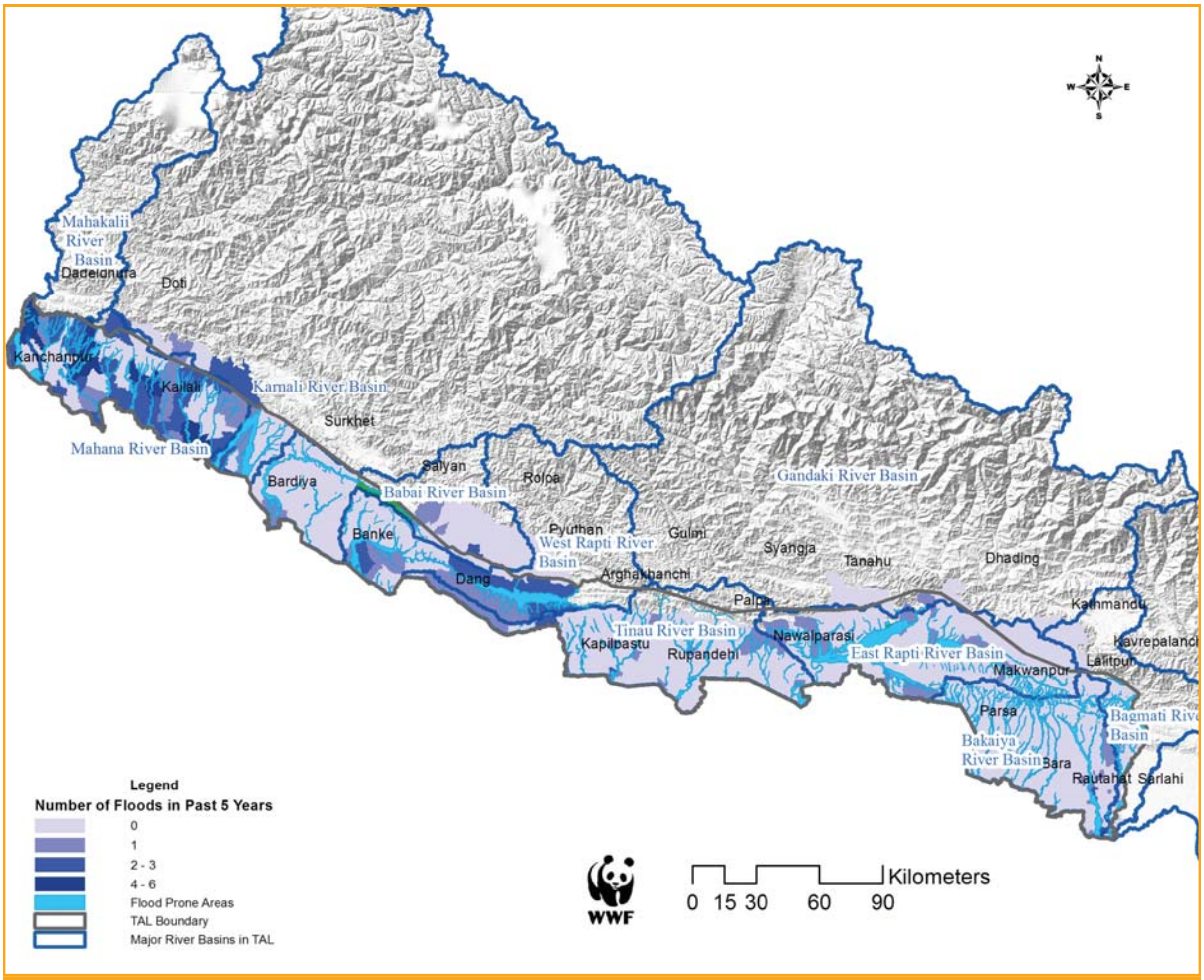


Figure 15: *Number of severe flood events during the past five years in the Terai Arc Landscape. Areas are based on the VDCs that were flooded.*

Climate trends also show increasing maximum temperatures across the western and central Terai and Churia, although in a few areas maximum temperatures are expected to decrease. Winter temperatures show decreasing trends (Figure 16). Climate projections suggest higher temperatures in the western and central regions (MoE 2010).

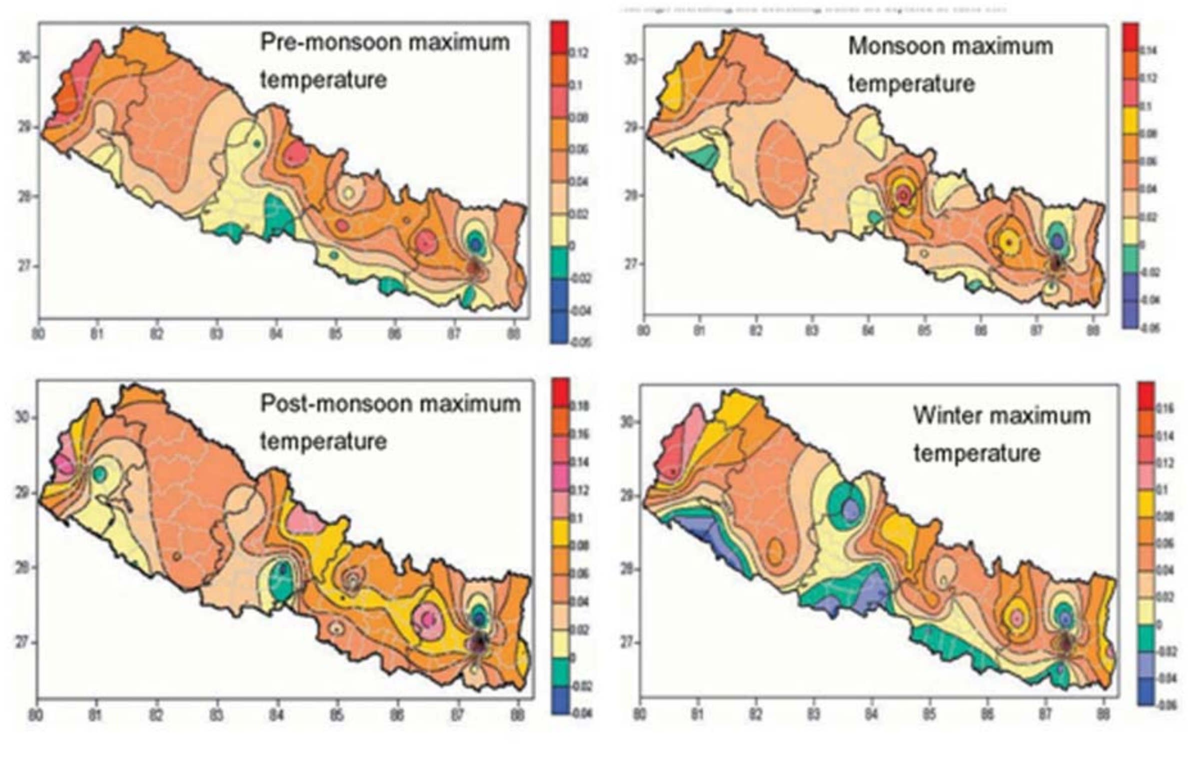


Figure 16: *Projected seasonal maximum temperature trends in Nepal. From Practical Action 2009)*

3.8 Potential impacts of climate change on biodiversity

Climate change is likely to affect the vegetation and forest types, and the ecological communities they support (Thapa et al. 2015). Forest types that are resilient to climate change should be protected to conserve the ecological communities and species assemblages. Uncertain and unpredictable rainfall and the ensuing floods could cut off habitat connectivity and prevent animals from seeking refuge. During drought periods, wildlife should be able to move to water sources and escape fires. Therefore, any corridors identified for wildlife movement or to connect habitats should be above flood level and have access to water sources in the dry season.

3.9 Potential impacts of climate change on economic development

Water resources: A Livelihoods and Good governance change monitoring survey (WWF 2013) shows that the quality of life and sustainable livelihoods of people could be affected by climate change due to the unpredictability of changing seasonal patterns, floods, changes in temperature, and droughts.The study shows that climate change will have direct impacts on both the quantity and quality of water resources over time.

The changes in temperature and rainfall will vary by season across the country, so changes to the water flows in the different basins will vary in different seasons. For instance, the current annual discharge of snow-fed Himalayan Rivers is increasing, except in the Narayani River (Practical Action 2010). The West Rapti and East Rapti rivers that originate in the middle mountains also have decreasing water flows because the water sources in the middle hills are experiencing drought at times when rainfall is normally expected (Practical Action 2010).

The changes in precipitation patterns (WECS 2011) and the development and degradation in the Babar areas are affecting the recharge of ground water in the Terai (Kansakar 2005). The ground water table in the Terai is already dropping and has made several tube wells dry. However, tapping ground water from deeper reservoirs is drawing up arsenic-tainted water, causing health hazards (Thakur et al. 2011). Watershed degradation and rising temperatures are resulting in less ground moisture, and soils and springs becoming dry (MoPE 2004, Practical Action 2010).

Agriculture: The expected changes in temperature, unpredictable precipitation patterns, and unregulated and extreme water availability will have profound impacts on agriculture (Practical Action 2010). Most highly productive, fertile agricultural lands in the TAL are in flood plain areas, which are vulnerable to floods and riverbank cutting. Extended periods of inundation from floods will destroy crops and deposit sand in agricultural fields making them less productive. At the other extreme, extended droughts will cause crops to fail.

Those people unable to cultivate their fields due to these changes will likely abandon the vulnerable farmlands and clear higher forested areas, creating feedback loops with more erosion that compound their vulnerability. In Kailali and Rupandehi, droughts are decreasing productivity so farmers are already leaving some lands barren due to lack of irrigation facilities.

Crops and cropping practices depend on reliable rainfall patterns—when rainfall occurs, how much, and over what time. This knowledge allows farmers to decide when to plant, what to plant, and where to plant. Therefore, crop yield and the evolved cultural practices connected with farming depend on the timely and predictable arrival of monsoon rains. Unpredictability disrupts these practices. For instance, the main agricultural crop in the Terai, rice, depends on predictable, seasonal rainfall.

The predicted changes in climate could reduce productivity (Karn 2014), which is already declining in some areas because harvesting and planting is delayed by changing weather patterns (NCVST 2009, Practical Action 2010). Consequently, farmers are starting to replace rice with crops that require less water. Since rice is a staple, lowerrice production could affect household food security (NCVST 2009). Since rice grown in the Terai is a market commodity supplying the rest of Nepal, a shift to other crops could result in a nationwide shortage of this staple food item.

Changes in temperatures can change the seasonal cycles of plants, including agricultural and horticultural crops (Shrestha, Gautam and Bawa 2012). Therefore, seasons when crops ripen can shift to become 'out of sync' with the associated cultural practices and natural relations, such as pollinators. Warmer temperatures also cause higher incidences of pests and diseases that affect crops.

The alternating periods of rainfall and drought could cause irrigation systems in the TAL to become less effective. Large areas of the TAL now depend on irrigation for crops (Figure 10). Therefore, unless water can be harvested and regulated better, crop failures could cause economic losses. Landslides and erosion from the degraded Churia slopes will clog the irrigation canals during heavy rains, which could overflow and cause flash floods that directly affect agricultural fields and villages. During drought periods, water sources will dry up affecting crops depending on sustained water supplies, especially from the Churia rivers.

Drinking water: Droughts and floods will cause a lack of clean drinking water and water for everyday use. In the Churia, springs are important sources of drinking water, but many are now dry in cleared or degraded forests (NCVST 2009, Practical Action 2010). With prolonged droughts, people have to travel longer distances for water, which could cause conflicts for access to limiting water supplies and sources. Floods could displace people and cause losses of lives, property, and livelihoods. After floods, months of inundation could allow the rapid spread of diseases, such as malaria, dengue, dysentery, and cholera.

However, several spring sources that had dried up in degraded Churia forests have begun to flow again after the restoration of forests through community forestry under the TAL program and the implementation of CAPAs. This offers some optimism for water replenishment through wider reforestation and conservation of the Churia forests by replicating these practices at landscape scales. Having forests in the Churia watersheds will reduce erosion and siltation of river and stream systems, especially during periods of extreme rainfall.

Water shortage in Uttarpani, Churiyamai. Water shortage can be a critical issue in the future.

Infrastructure: More intense rainfall events could lead to extreme flows that affect infrastructure. The major transportation arteries in the Terai are oriented east to west, perpendicular to the north-south flowing rivers. Thus, roads may impede water flows, especially if they are built on high embankments. Consequently, these areas near roads are highly susceptible to floods as water backs up behind the embankments. The water may inundate large areas, including agricultural fields, and become breeding grounds for diseases and disease vectors.

Stronger flows expected in scenarios of climate change will cause rivers to shift, especially where excessive silt, gravel and debris loads have caused aggradation (GoN 2008). The shifting river channels will destroy roads, bridges, agricultural fields, settlements, and other infrastructure along the banks. Heavy flows will scour and undercut bridges and already many bridges across Nepal have collapsed or been damaged by heavy flows. The situation is worse where mining of rivers removes and boulders (Scott Wilson 2014).

To withstand the impacts related to climate change, infrastructure should incorporate appropriate safeguards in their design, structure, and use. For instance, roads in areas at risk of frequent floods could be elevated on overpasses to prevent them from becoming submerged, impassable, or washed away. Roads built on overpasses allow water to flow unimpeded, causing less damage to the infrastructure and preventing prolonged floods.

Thus, development plans have to be strategic to adapt to projected events related to climate change. Despite the higher initial costs associated with climate-proofing infrastructure, ultimately the economic investments will be more cost-effective if good design and sustainable ecological services reduce the impacts of climate change.

TERAI ARC LANDSCAPE: FLOWING FORWARD WORKSHOP

4
PART

4.1 Workshop objectives

The workshops' objectives were to:

1. Develop an understanding of the potential impacts of climate change facing the TAL.
2. Assess the landscape-wide vulnerabilities with respect to the NAPA and LAPAs to develop ecosystem-based adaptation strategies for 'climate-smart' landscape management.
3. Prioritize adaptation interventions at the levels of landscapes and river basins.

4.2 Units and Subunits used in the flowing forward approach

The Units for the TAL are the major river basins. The Subunits are key features representing the natural and human systems that climate change could affect. Strategic interventions target Subunits to decrease the vulnerability of these systems to climate impacts and increase their resilience within the landscape. The Units and Subunits are shown in Table 4.

Table 4: *Units and Subunits selected for the flowing forward analysis in the Terai Arc Landscape.*

UNITS	SUBUNITS		
	Species	**LULC**	**Infrastructure**
Mahakali River Basin	• Tiger	• Protected areas	• Large cities
Karnali River Basin	• Greater One-horned Rhinoceros	• Corridors	• Rural settlements
Babai River Basin	• Swamp Deer	• Agricultural areas	• Airports
Bagmati River Basin	• Gangetic Dolphins	• Plantations	• National roads
East Rapti River Basin	• Great Pied Hornbill	• Livestock grazing areas	• District roads
Bakaiya River Basin	• Vultures	• Watershed protection forests	• Local roads
Tinau River Basin	• Bengal Florican	• Community managed forests	• Hydro power
West Rapti River Basin	• Sarus Crane		• Irrigation systems
Mohana River Basin	• Lesser Adjutant Stork • Grassland Birds • Gharial • Fishes/Fish Community		• Railroad

4.2.1 Units

River hydrology has a major influence on the dynamics of ecosystems and their representative biodiversity, the livelihoods and lives of the local people, and the larger economic status of the TAL region. The TAL has nine major river basins (Figures5-7 above), which the team selected as the primary Units for the Flowing Forward analysis. The rationale is that hydrology is the main ecosystem process that climate change will affect, mostly through changes to rainfall patterns. The impacts will manifest as changes in water flows and extremes that cause severe floods and dry rivers. The dynamics in the river basins will be relatively independent of each other, making them the most logical Units.

4.2.2 Subunits

The Subunits represent important socio-ecological systems that climate change and related impacts will affect. The Subunits are: 1) selected species and species assemblages representing functional ecosystems of the TAL; 2) major landcover and land use in the TAL; and 3) major infrastructure that supports the socio-economic status of the TAL.

Species Subunits

The species selected represent:

a) endangered species with globally important populations that could be affected by changes to habitat and other ecological requirements, such as food and water;

b) species that are physiologically sensitive to changes in climatic conditions;

c) species with specific habitats that could be affected by changes to the vegetation or ecosystem; and

d) umbrella species that conserve other biodiversity and ecosystems (Table 5).

Table 5: *Species Subunits selected for the flowing forward analysis of the Terai Arc Landscape*

Species Subunits	Endangered Species population of global importance	Habitat specialist species	Physiology is highly sensitive to climate conditions	Umbrella Species
Tiger	X			X
Greater One-horned Rhinoceros	X	X		
Swamp Deer	X	X		
Gangetic Dolphins	X	X		
Great Pied Hornbill	X	X		X
Vultures	X	X		
Bengal Florican	X	X		
Sarus Crane		X		
Lesser Adjutant Stork	X			
Grassland Birds		X	X	
Gharial	X	X	X	
Mugger Crocodiles			X	
Fishes/Community		X	X	

Considerations and guidelines to assess Subunits for Climate Change projections:

The TAL has globally important populations of Tiger, Rhinoceros, Swamp deer, Gangetic dolphins, Bengal Florican, and Gharial. Although the tiger is a habitat generalist, climate-related changes could affect its prey species if grasslands succeed into forests, or become too dry and parched or flooded to sustain large populations of ungulates. The tiger populationsin the low-lying Terai protected areas are vulnerable to both floods and to extended droughts, when tigers could lose important water sources. Since tigers are territorial, the loss of water sources in specific areas could result in conflicts between individual tigers affecting their ecology, territorial structure, and demographics.

Some species are habitat specialists that require grasslands. These include Rhinoceros, Swamp deer, and Bengal Florican. There are also smaller birds that specialize in grassland habitats(BCN and DNPWC 2011). Several grassland species require specific communities of grass. For instance, rhinoceros prefer *Saccharum spontaneum* grasses as a food plant (Jnawali 1995). These grasses grow best in moist riparian habitats. Swamp deer prefer shorter grasses, with *Imperata cylindrica* as a primary food plant. They also require swampy areas with aquatic vegetation as a source of minerals (Qureshi, Sawarkar, and Mathur 1994). Several grassland bird species depend on habitat types that vary in structure and composition. Bengal Florican and several other grassland bird species require open grasslands. The carnivorous Lesser Adjutant stork and vultures require open savannas where they can hunt small animals and carrion as food but where there are scattered large trees for roosting.

However, the grasslands are dynamic systems that are highly sensitive to precipitation and moisture (Peet et al. 1999). Since they occur in flood plains, grasslands are susceptible to floods and river cutting, and to fire during long dry seasons. Therefore, the habitats for these species are vulnerable, both temporally and spatially to climate change(BCN and DNPWC 2011).

The Gangetic dolphin, Gharial, and Mugger crocodiles are habitat specialist species that require continuous flowing water in rivers. The Gharial and crocodiles are physiologically susceptible to temperature changes because the sex of these species is determined by the nest incubation temperature, not by chromosomes (Lang and Andrews 1994). Thus, the loss of suitable nesting sites with proper temperature regimes could disrupt the population demographics of both species. Changes in river flow regimes could also disrupt their ecology, habitat use, and behavior.

The Great Pied hornbill (*Buceros bicornis*) requires large, mature trees for nesting and roosting, and fruit trees for foraging (James and Kannan 2009). These birds play an important role in the structure of the forest community because they disperse the trees' seeds (Kitamura 2011). The hornbills are affected if large trees are lost or their fruiting and seasonal cycles are disrupted by changing climate conditions, creating a feedback loop affecting forest structure and composition.

The fish community in rivers and streams requires sustained flows, but several fish species have narrow ecological and physiological ranges including high water flows, clean oxygenated water, and specific water temperatures. Changes in river hydrology and water temperature affect the survival of these species. The Mahseer, one of the largest freshwater fish in South Asia, is an example and indicator species for these conditions.

Land cover and land use Subunits

Conservation areas

The TAL has several natural ecosystems—forests, savanna and grasslands, wetlands, rivers and streams, and natural springs—that are vital habitats for endangered and irreplaceable species and that sustain ecological services and processes. Changes in temperature and rainfall influence these ecological communities, and projections suggest that some lowland vegetation types are vulnerable to the impacts of climate change (Thapa et al. 2015).

Most remaining natural habitats are within protected areas and their buffer zones, Ramsar sites, TAL corridors, and watershed conservation areas along the Churia range. Many important community-managed forests are also part of the TAL corridor system. Therefore, the workshops assessed the following as Subunits of natural land cover:

1. Chitwan National Park
2. Bardia National Park
3. Banke National Park
4. Shuklaphanta Wildlife Reserve
5. Parsa Wildlife Reserve
6. Khairapur Blackbuck Conservation Area
7. Lumbini Wetland
8. Ghodaghodi Lake Area
9. Mohana Laljhadi Corridor
10. Basanta Corridor
11. Khata Corridor
12. Churia Forest Corridors

Considerations and guidelines to assess Subunits for Climate Change projections:

Figures 17 and 18 show the flood vulnerable conservation units. All protected areas and corridors are in flood-vulnerable districts. The northern part of Chitwan National Park, western Bardia National Park, and Shuklaphanta Wildlife Reserve lie in flood prone areas. However, floods maintain alluvial grasslands, which are attractive wildlife habitats. Thus, flood mitigation projects should maintain some degree of annual flooding in these areas. Bardia NP and Shuklaphanta WR are also in districts vulnerable to drought (Figure 19).

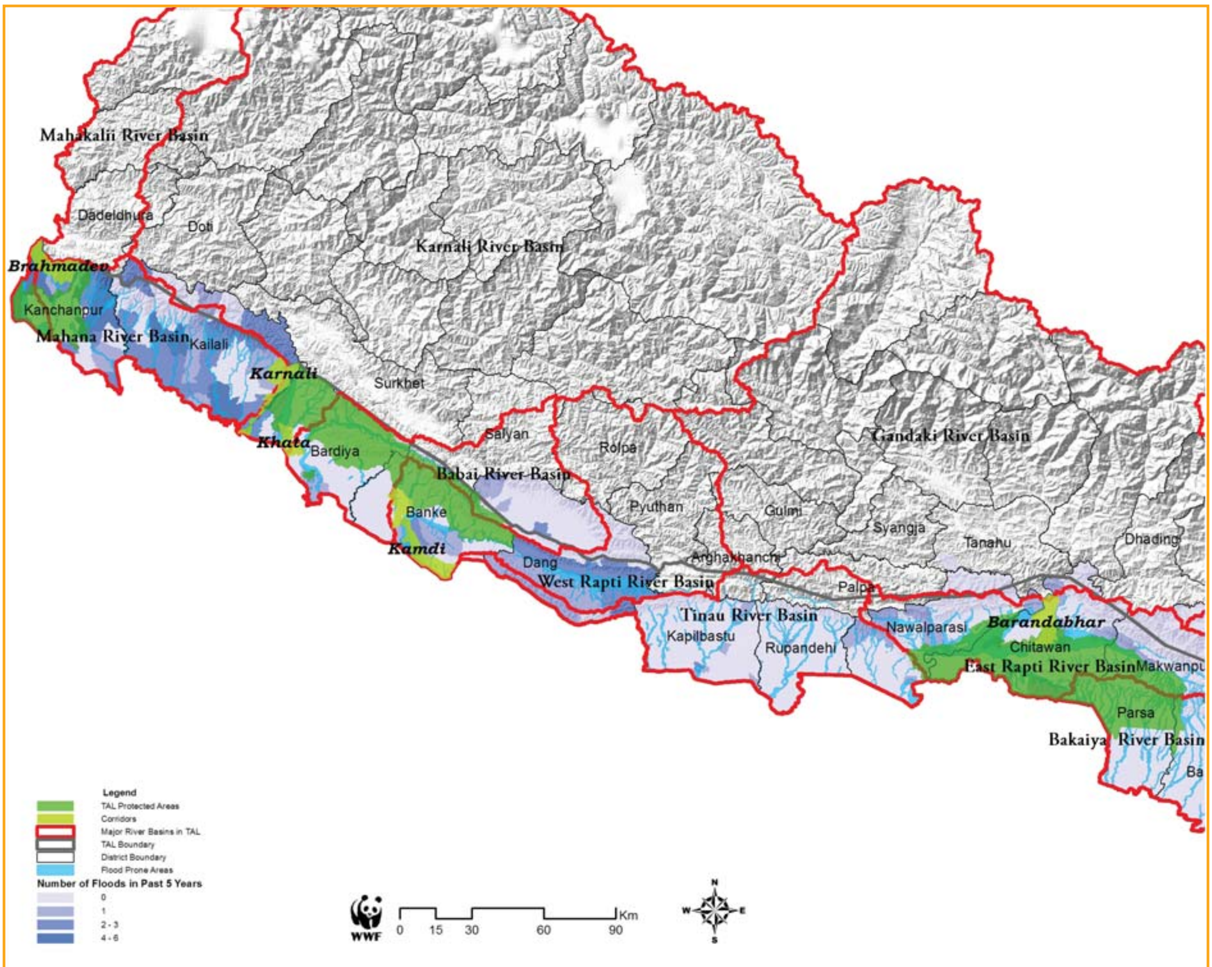


Figure 17: *Protected areas and priority wildlife corridors of the Terai Arc Landscape. Most protected areas have experienced several flood events over the past five years.*

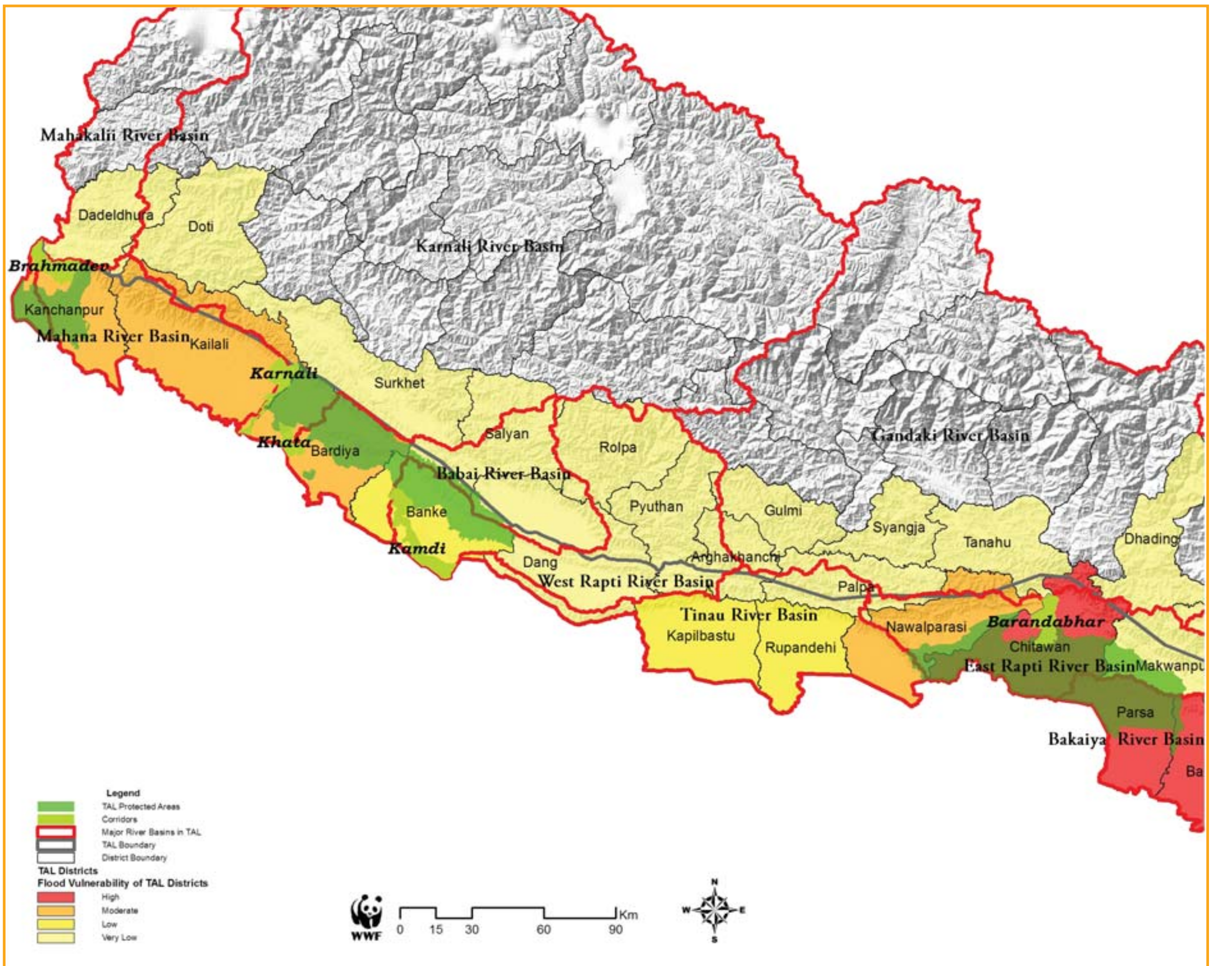


Figure 18: *Protected areas and corridors of the Terai Arc Landscape. The protected areas lie in flood vulnerable districts.*

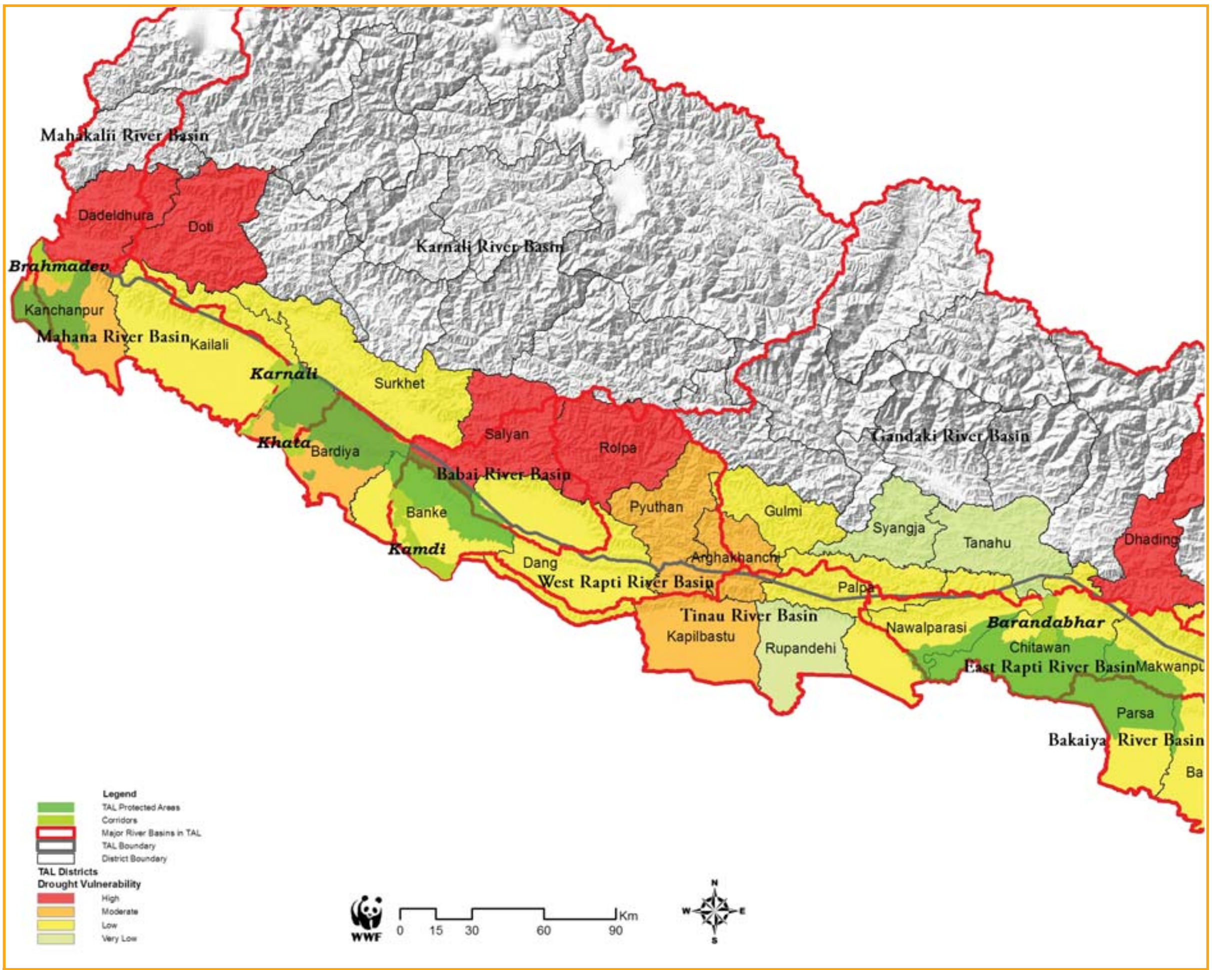


Figure 19: *Protected areas and corridors of the Terai Arc Landscape and projected drought vulnerable districts.*

The analysis of climate impacts on forest and vegetation change shows that resilient forest types will endure along the Churia ranges in the Babai, West Rapti, Tinau, East Rapti, Bakaiya, and Bagmati river basins (Thapa et al. 2015). The East Rapti and Bakaiya basin areas are highly vulnerable to floods, but less vulnerable to drought. However, Kapilvastu district in Tinau basin, Bardia district in the Karnali basin, and Rautahat district in the Bakaiya basin are moderately vulnerable to drought (Figure 20 and 21).

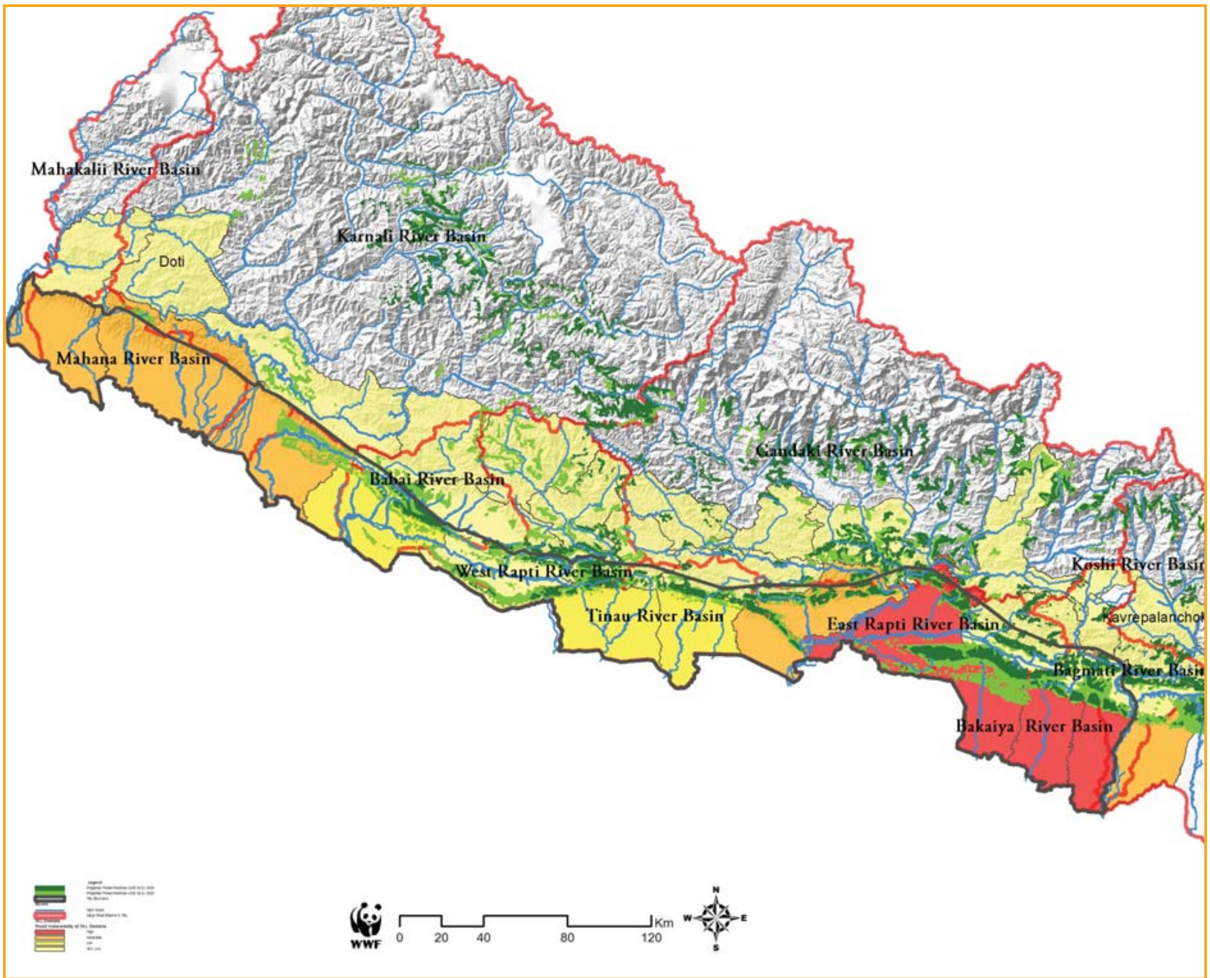


Figure 20: *Projected climate resilient forest communities, with projected flood vulnerability districts of the Terai Arc Landscape. Forest resilience projections are from Thapa et al. 2015.*

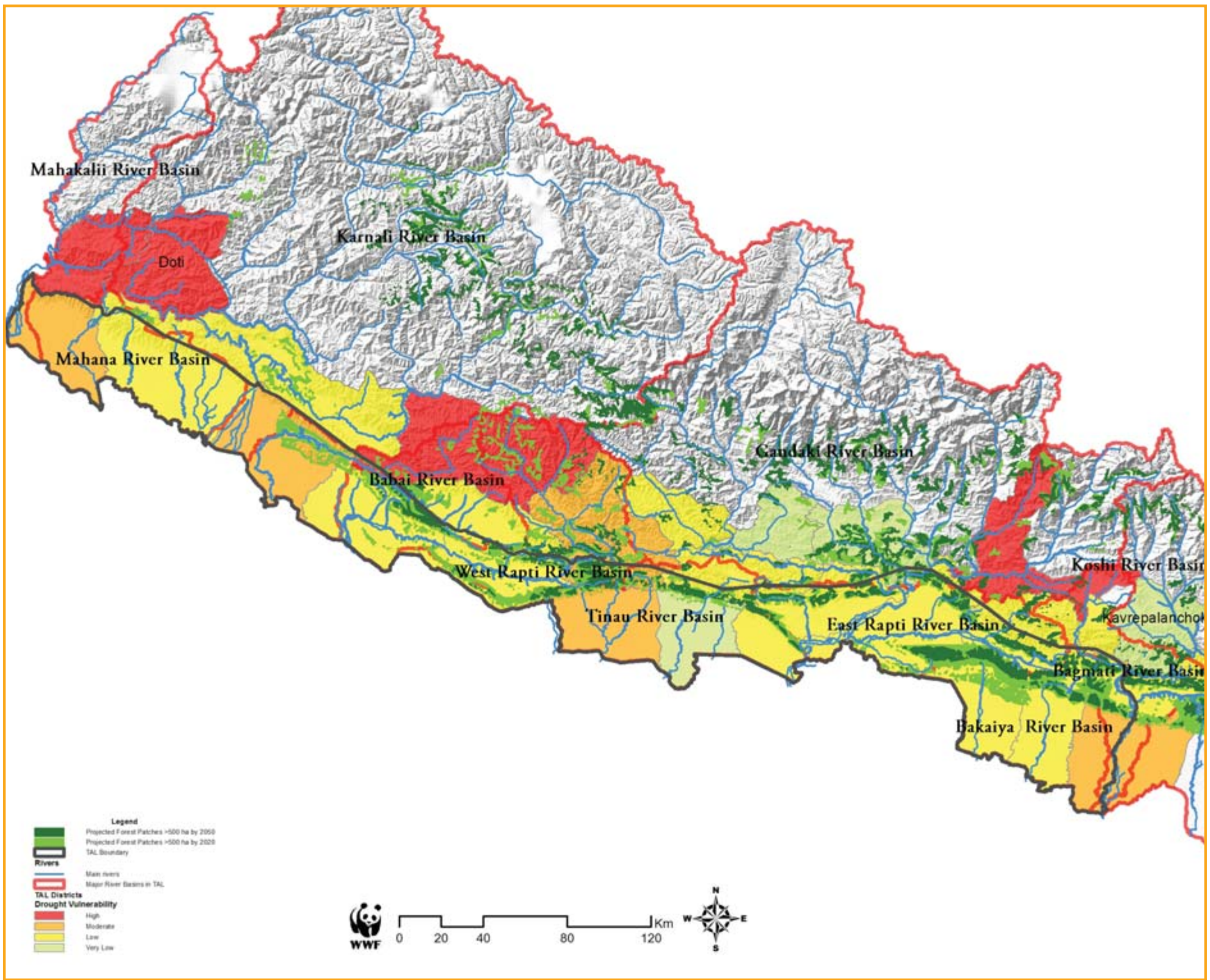


Figure 21: *Projected climate resilient forest communities, with projected drought vulnerability districts of the Terai Arc Landscape. Forest resilience projections are from Thapa et al. 2015.*

Human land use areas

The three major types of human land use areas (other than built areas) in the TAL that support livelihoods and economic development are Subunits:

1. Land under agriculture
2. Plantations
3. Livestock grazing areas

Considerations and guidelines to assess Subunits for Climate Change projections:

The Terai is the 'rice bowl' or granary of Nepal because of its high productivity and extensive rice-growing areas. Climate change can have serious impacts on agriculture as floods can inundate crop fields for extended periods or droughts can parch them. Either condition will result in crop loss or a decline in crop productivity. Since the Terai is the source of staple foods items that support the national market, the loss of these agricultural crops and dairy products could affect people across Nepal. Thus, it is important to implement interventions to reduce climate vulnerability.

Changes in temperature and rainfall may result in a proliferation of pests and diseases that could destroy crops and affect livestock (NCVST 2009, Practical Action 2010). Invasions by new species of pests or new strains of diseases are predicted.Random and unpredictable rainfall patterns can result in uncertainties of when to begin ploughing, sowing, or even harvesting crops.

In the TAL, the districts producing the most rice are Bara, Kailali, Rupandehi, and Kapilvastu, followed by

Kanchanpur, Bardia, Nawalparasi, Parsa, Rautahat, Dang, Banke, and Chitwan(Figures 22 and 23; Table 6).Kailali, Bara, Bardia, Nawalparasi, Rautahat districts also produce pulses (Table 6).

Table 6: *Agriculture, livestock and human parameters and climate projections in the TAL districts. The flood and drought vulnerability index is coded from Very High=Red > Orange>Yellow> Green=Low. The colour codes for the agriculture, livestock, and human parameters are based on natural cutoffs for the data distribution using five categories.*

Data from Statistical information on Nepalese agriculture. 2011/2012 (2068/069). Statistics Section, Agri-Business Promotion and Statistics Division, Ministry of Agricultural Development, Government of Nepal.

FLOOD VULNERABILITY	Paddy Area (ha)	Pulse crop Area (ha)	Irrigated Areas (ha)	Cattle and Buffalo	Households	Population	DROUGHT VULNERABILITY
Arghakhanchi	8,189	1,034	2,914	145,117	48,354	200,446	Arghakhanchi
Palpa	8,750	2,000	4,026	189,973	62,967	269,372	Palpa
Makwanpur	11,110	2,370	3,507	208,938	89,550	427,494	Makwanpur
Chitwan	29,655	6,543	30,679	206,382	132,838	566,661	Chitwan
Banke	36,462	16,256	19,002	236,568	96,330	493,017	Banke
Dang	38,300	29,332	40,212	232,326	122,614	557,852	Dang
Rautahat	40,650	20,766	57,653	191,375	109,976	696,221	Rautahat
Parsa	44,360	8,325	29,986	125,198	108,341	601,701	Parsa
Nawalparasi	44,890	11,344	41,563	299,250	131,651	635,793	Nawalparasi
Bardiya	45,500	19,252	42,895	230,100	84,207	426,946	Bardiya
Kanchanpur	46,655	4,814	30,788	252,208	83,042	444,315	Kanchanpur
Bara	52,700	14,246	55,455	188,764	114,691	701,037	Bara
Kailali	65,500	23,205	58,029	298,398	146,431	770,279	Kailali
Rupandehi	70,500	6,429	81,158	221,471	170,077	886,706	Rupandehi
Kapilvastu	71,500	7,432	32,786	232,113	94,571	570,612	Kapilvastu

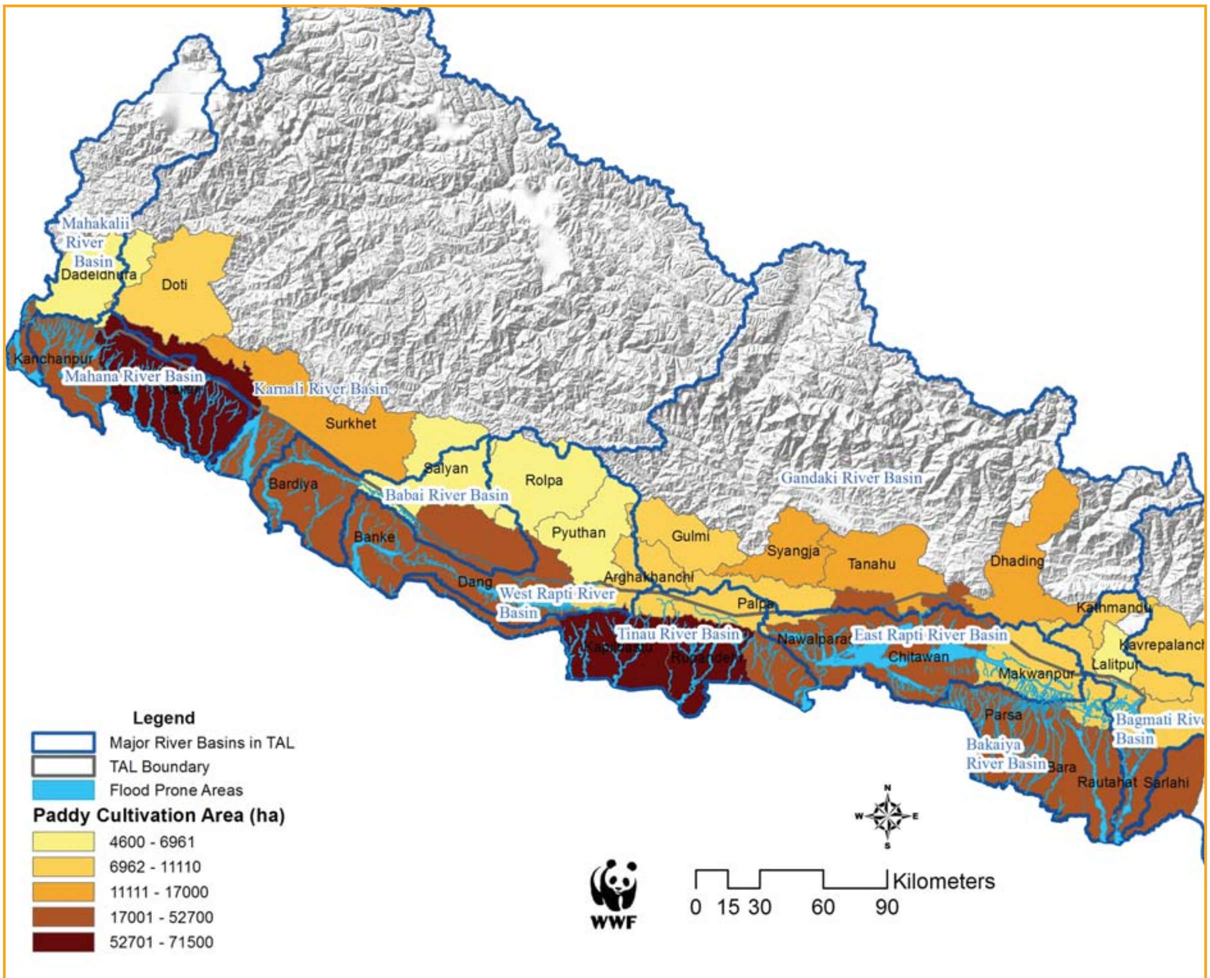


Figure 22: *Extent of rice paddy areas in the Terai Arc Landscape districts. The map can be compared to the flood and drought vulnerability maps, and the irrigation and human density maps to assess the potential climate impacts on agricultural productivity and livelihoods. Data source: GoN 2012.*

Of these districts, Bara, Rautahat,Parsa, Kailali, Kanchanpur, Bardia, and Nawalparasi are highly vulnerable to floods (Table 6, Figure 14), while Kapilvastu, Kanchanpur, Bardia, and Rautahat are vulnerable to droughts (Table 6, Figure 13).

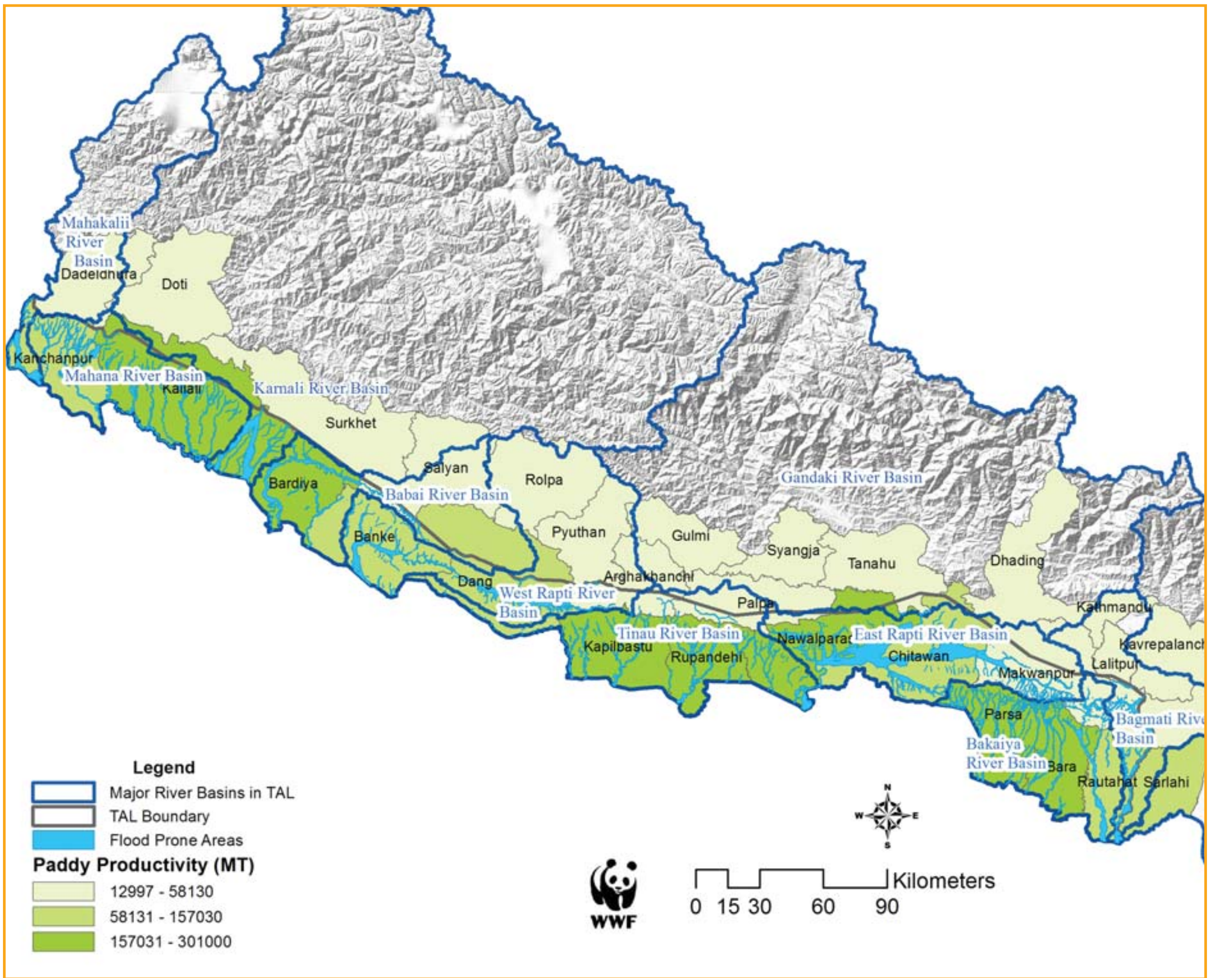


Figure 23: *Rice paddy productivity in the Terai Arc Landscape districts. The map can be compared to the flood and drought vulnerability maps, and the irrigation and human density maps to assess the potential climate impacts on agricultural productivity and livelihoods. Data source: GoN 2012.*

Loss of productivity in agricultural areas or a loss of land to river cutting and landslides may prompt people to clear additional forestlands and drain wetlands for agriculture. Since people have already cleared most natural habitat, further clearing will encroach into conservation areas, affecting biodiversity and ecological services. As well, most people free graze their livestock in forests (Karkee 2004), and the added stress from heavy grazing can affect forest regeneration. The TAL districts have a high density of livestock (Figure 24).

Several districts are vulnerable to extreme, increased flooding, and extended droughts (Table 6; Figures 13, 14, 15). If these conditions occur, livestock could be lost during floods as could forage and fodder.

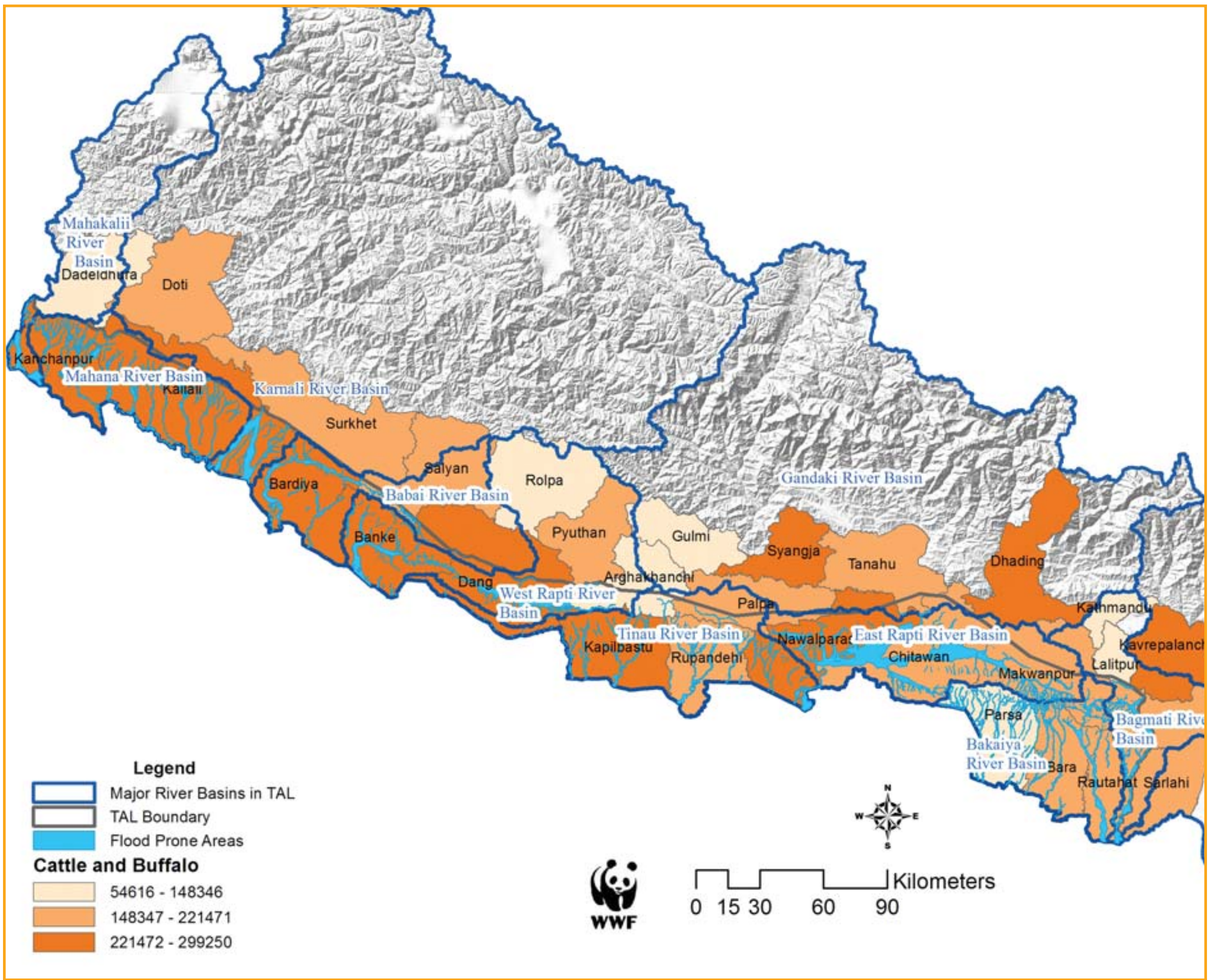


Figure 24: *Livestock (cattle and buffalo) density in the Terai Arc Landscape districts. People depend heavily on livestock to support their livelihoods. Livestock are in turn supported from forest resources for fodder and graze. The map can be compared to flood and drought vulnerability maps to assess the potential climate impacts on livelihoods. Data source: GoN 2012.*

Infrastructure Subunits

The infrastructure in the TAL region includes large cities that are commercial hubs, several airports, and major highways that provide access, mobility, social and economic connectivity, and communication networks. The frequent and intense natural disasters expected with climate change conditions will increase the vulnerability of the infrastructure. If roads, airports, and communication systems are destroyed, social linkages and commerce will be lost or disrupted, resulting in socio-economic hardship and losses. Thus, the following Subunits were assessed for the socio-economic impacts of climate change on infrastructure.

1. Cities (urban settlements)
2. Rural settlements and communities
3. Airports
4. National roads
5. District roads
6. Local roads
7. Irrigation systems
8. Hydro/mini hydro

Considerations and guidelines to assess Subunits for Climate Change projections:

Linear infrastructure, such as roads (existing, under construction, or planned), planned railroads, and power transmission lines, run from east to west through several flood pronedistricts (Figure 11).

Site-based infrastructure, such as airports, factories, and commercial centers, are in flood prone areas. Lately, floods washed away infrastructure disrupting mobility and causing economic and livelihood related hardships and losses, especially in the western districts where floods have been relatively common in recent years (Figure 25).

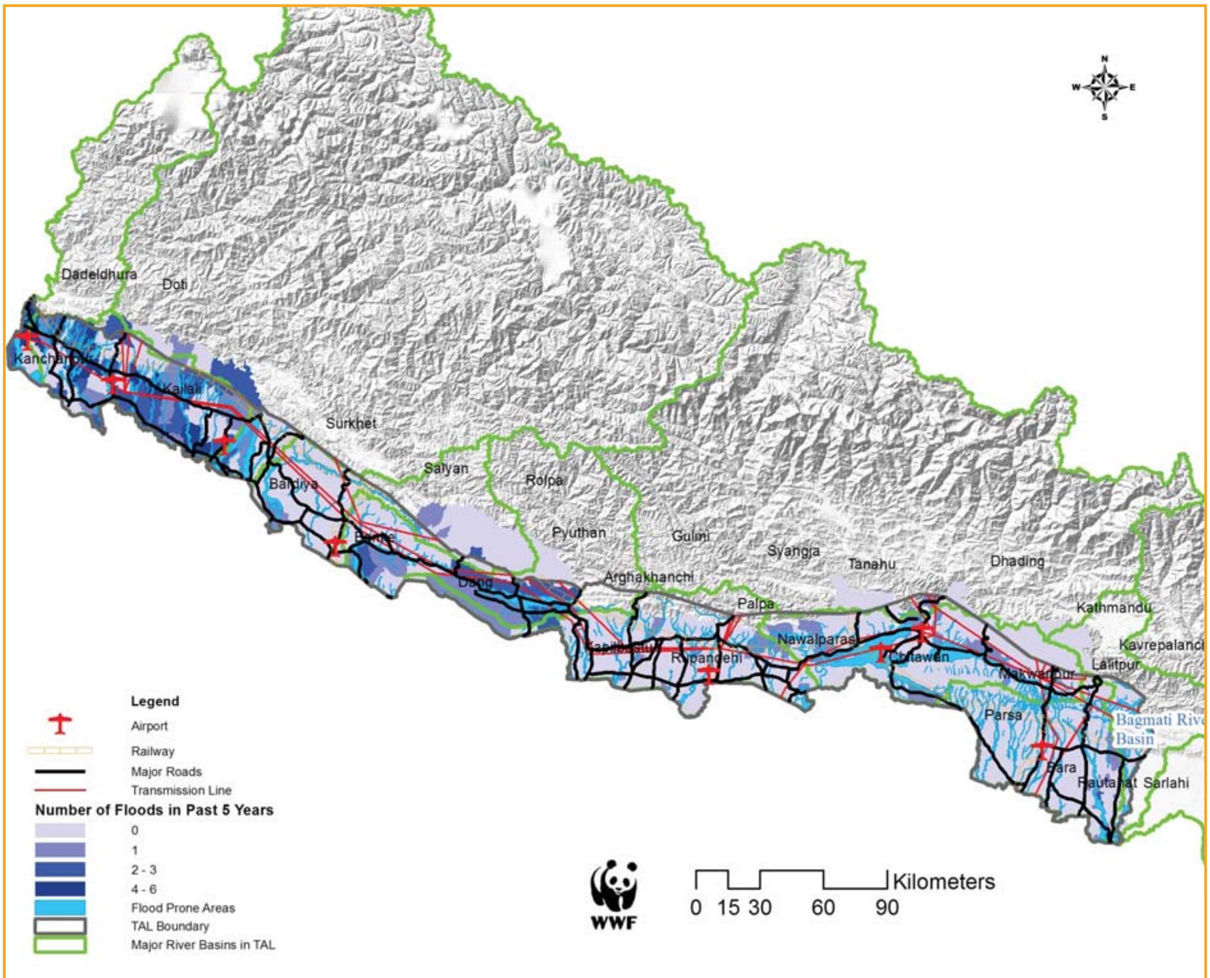


Figure 25: *Major infrastructure in the Terai Arc Landscape. Many of these structures have been subjected to severe floods during the past five years.*

Since climate projections advise that floods will become more frequent and more severe in the future, infrastructure will be even more vulnerable to these disasters. Districts where considerable new infrastructure has been planned - Chitwan, Parsa, Bara, and Rautahat - maybe very vulnerable to floods in the future (Figure 14, 15). Therefore, infrastructure planned for these areas should have engineering designs to make them climate resilient.

Human population density is high in the TAL districts, especially in Kanchanpur, Kapilvastu, Rupandehi, Nawalparasi, Parsa, Bara, Chitwan, Rautahat, and Sarlahi (Table 6, Figure 6, 7). The urban and rural settlements in these districts are vulnerable to floods. Frequent flooding already affects some rural settlements, especially in the far western districts (Figure 26).

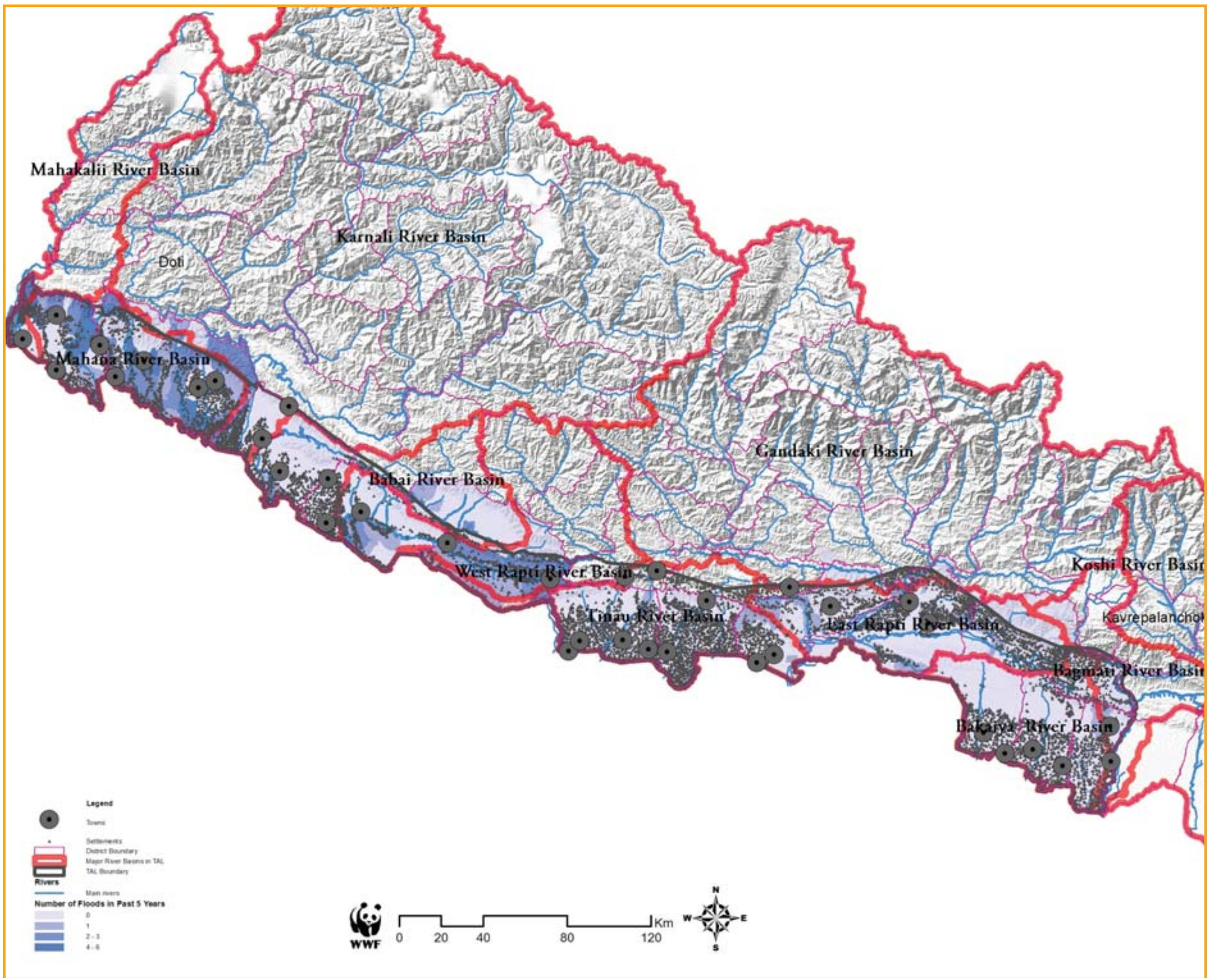


Figure 26: Distribution of rural and urban settlements areas that have experienced severe flood events during the past five years.

Climate projections show that in the East Rapti and Tinau river basins, some densely settled districts -Parsa, Nawalparasi, and Bara -are extremely vulnerable to floods (Figure 26 and 27), while other districts -Rautahat, Kanchanpur, Kapilvastu, and Sarlahi- are vulnerable to extended droughts (Figure 28).

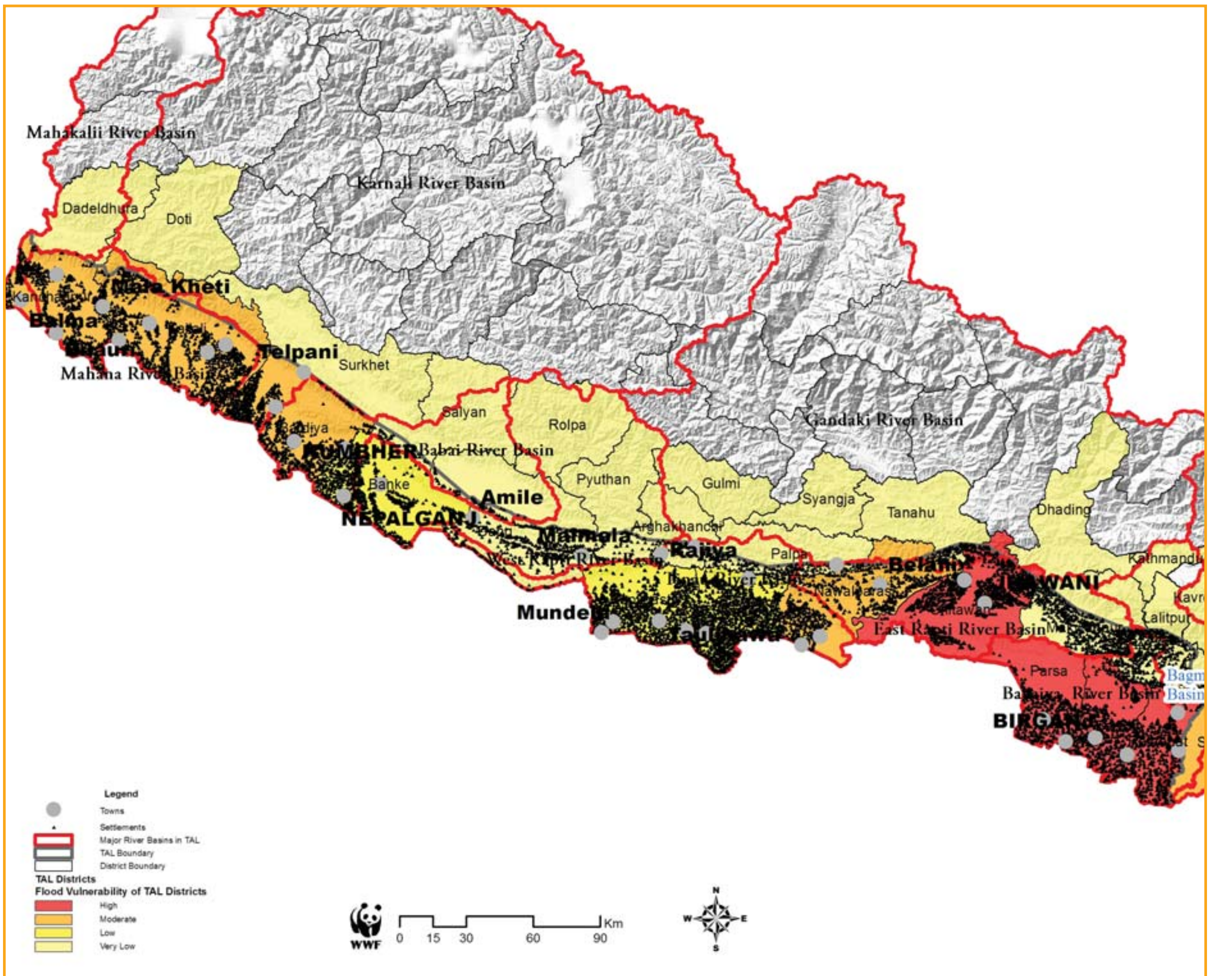


Figure 27: *Distribution of rural and urban settlements in districts with projected flood vulnerability. Data source: GoN 2012*

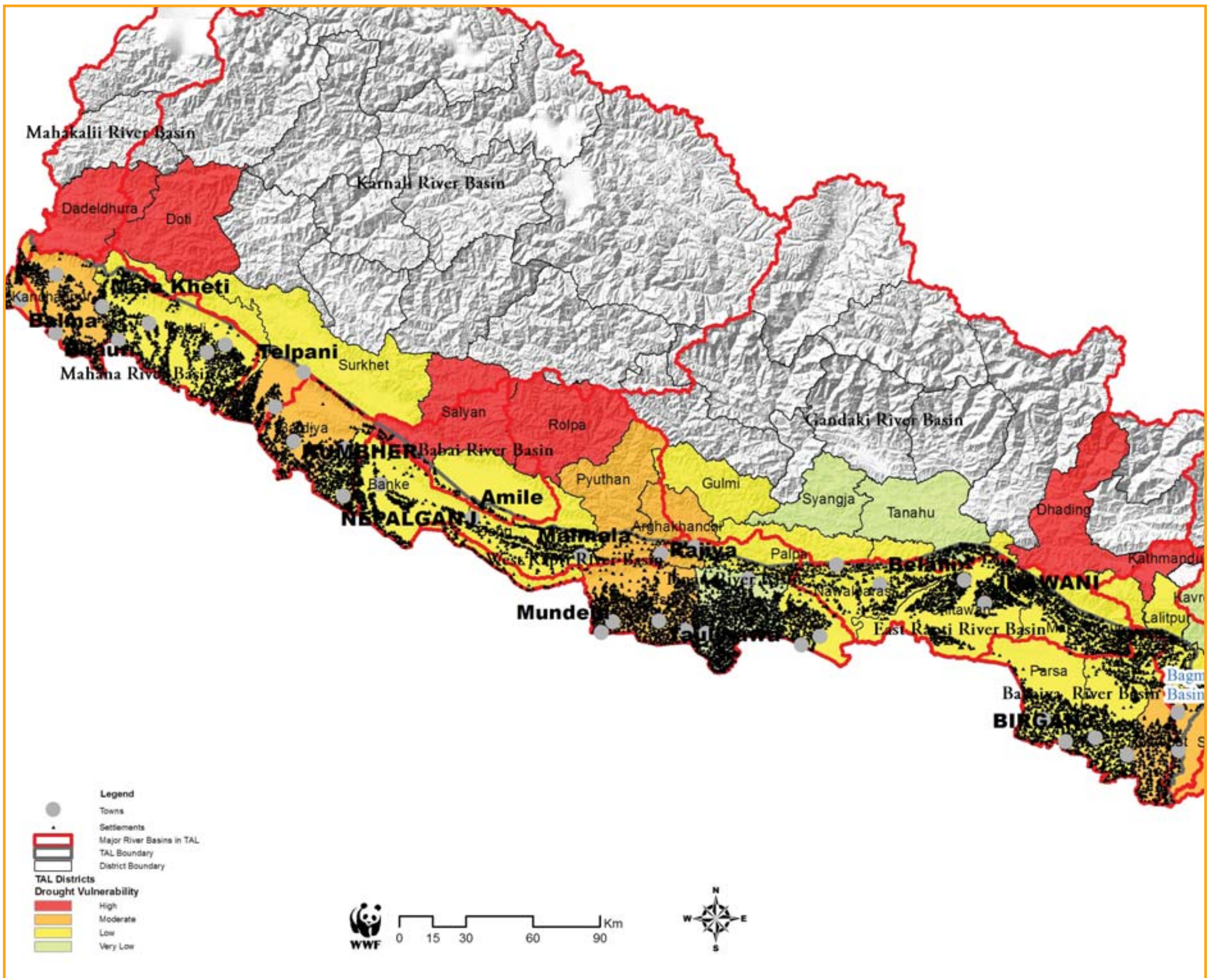


Figure 28: *Distribution of rural and urban settlements in districts with projected drought vulnerability. Data source: GoN 2012*

4.3 Supporting policies and enabling conditions

Nepal has prepared a National Adaptation Programme of Action, NAPA (GoN 2010) to address vulnerabilities to climate change through strategic, systematic adaptation measures. The NAPA promotes a watershed or landscape-scale approach, comparable to the Flowing Forward approach.

There are seven focal areas for climate change policy:

1. climate friendly natural resource management;
2. climate adaptation, disaster and risk reduction;
3. technology development, transfer and utilization;
4. study and research;
5. capacity building, people's participation and empowerment;
6. low carbon development and climate resilience; and
7. access to financial resources and utilization

The NAPA has identified six Thematic Working Groups: Agriculture and Food Security, Climate-Induced Disaster, Urban Settlement and Infrastructure, Public Health, Forests and Biodiversity, and Water Resources and Energy. The mandates of these thematic groups are aligned with the plans set forth in Nepal's 10th Plan for national development, which emphasizes green development and climate-adaptation. In addition to these groups, there are two crosscutting themes: Livelihoods and Governance, and Gender and Social Inclusion.

The following institutions and policies are relevant to each thematic group.

Agriculture and food security

Institutions:

- Ministry of Agricultural Development
- Ministry of Land Reform and Management
- Ministry of Livestock Development
- Department of Agriculture,
- Department of Livestock Services
- National Agricultural Research Council
- Agriculture Input Company Limited
- Regional Directorates of Agriculture
- Research centers (5 regions)

Supporting policies:

- Agriculture Policy 2061
- Rangeland Policy, 2012
- Agricultural Development Strategy (ADS), 2015-2035
- Agricultural Perspective Plan (APP) (1995-2015)
- Nepal's Accession to World Trade Organisation

Forest and biodiversity

Institutions:

- Department of Forests
- Department of National Parks and Wildlife Conservation
- Department of Soil Conservation and Watershed Management
- REDD Forestry and Climate Change cell
- Regional Directorate

Supporting policies:

- Forestry Sector Policy 2000/ 2014
- Forestry Sector Strategy
- Forest Fire Strategy 2012
- Landscape Level Conservation Strategy 2004
- Nepal Biodiversity Strategy 2002-2014
- Nepal Biodiversity Strategy and Action Plan 2014-2020.
- Strategy and Action Plan 2015-2025, Terai Arc Landscape
- Nepal State Party to legally binding International conventions; CITES, CBD, RAMSAR,
- Churia conservation strategy

Water resources and energy

Institutions:

- Ministry of Energy
- Ministry of Irrigation
- Department of Irrigation
- Department of Electricity Development
- Water and Energy Commission Secretariat
- Inter sectoral Coordination bodies
- Parastatals (Alternate Energy Promotion Centre)
- Nepal Electricity Authority (NEA)

Supporting policies:

- Hydropower Development Policy 2001
- Water Resources Policy 1992/200
- Water Resource strategy 2002
- National Water Plan 2005
- Rural energy Policy 2006
- National Transport Policy 2005
- Environment Protection Act 1997 and Environment Protection Rules 1997
- Electricity Act 2049
- Local Self Governance Act 1999

Climate induced disasters

Institutions:

- Ministry of Home Affairs
- Prime Minister's Fund for Disaster Relief
- Department of Water Induced Disaster Prevention

- Department of Hydrology and Meteorology
- Nepal Centre for Disaster Management
- Nepal Red Cross Society

Supporting policies:

- National Strategy for Disaster Management 2009
- Guidance note: Disaster Preparedness and response Planning 2011
- Local Disaster Risk Management Planning Guideline 2011
- Local Self-governance Act and Regulations
- Land Acquisition Act, 2034 and Regulations/ guidelines

Public health

Institutions:

- Department of Health
- Inter sectoral Coordination bodies
- Nepal Red Cross Society
- National Public Health Lab
- Regional Hubs

Supporting policies:

- National Health Policy, 1991
- National Health Sector Plan -IP 2002-2003
- Local Self-Governance Act
- National Drug Policy 1995
- National Ayurveda Health Policy 1996
- Water Supply Policy 1996
- Rural Water Supply and Sanitation Policy 2004
- National Water Supply and Sanitation Sector Policy 2014
- Birth, Death and other Personal Events Registration Act 1976

Urban settlement and infrastructure

Institutions:

- Ministry of Urban Development
- Ministry of Physical Infrastructure and Transport management
- Department of Road
- Department of Transportation management
- Department of Urban Development and Building Construction

Supporting policies:

- Local Self-Governance Act and Regulations
- Public Road Act, 2031
- Land Acquisition Act, 2034 and regulations/ guidelines

4.4 Flowing forward workshop outputs

Climate impacts by basin

For each Unit or basin, the workshops considered and assessed the impacts on the Subunits in possible climatic change scenarios. The resilience, exposure, and vulnerability scores for each Subunit in the respective basins (Units) in the TAL are described below. The color codes for the resilience, exposure, and vulnerability scores provided in Tables 7-16 are as follows:

Babai River Basin

Increasing temperatures, and erratic and high rainfall that leads to severe floods can cause habitat loss and degradation, especially for key species that require active conservation attention. More frequent

forest fires and the spread of invasive species can cause changes to habitat and food scarcities, especially for those focal species with specialized habitat and food requirements. People affected by droughts or displaced by floods may place pressure on protected areas. The species most exposed include the rhinoceros, tiger, gharial, Lesser Adjutant stork, and vultures.

The productivity of the agricultural areas and livestock grazing areas may decrease due to flash floods during heavy rainfall alternating with times of drought that cause water sources to dry up and increase the frequency of forest fires. The habitats in Bardia National Park are expected to change, resulting in loss of species diversity, and requiring more adaptive conservation management. The forest composition in national forests and other community-managed forests, including in the Churia could also change, with degradation of forest quality and productivity.

These climatic disasters could affect major infrastructure in the basin. Roads (Telpani-Bhurigaun road), irrigation schemes (Bheri-Babai diversion), and bridgesmay be damaged or destroyed.Rural and urban settlements will be affected by a loss of livelihoods and socio-economic connectivity.

***Table 7:** Resilience, exposure, and vulnerability scores of Subunits in the Babai River basin.*

Subunit		Resilience	Exposure	Vulnerability
Species				
	Greater One-horned Rhinoceros	1.67	4.67	4.28
	Tiger	2.33	4.00	3.56
	Gharial	1.67	4.33	4.11
	Python	3.00	3.00	2.67
	Great Pied Hornbill	3.17	3.00	2.61
	Vultures	2.50	4.67	4.00
	Lesser Adjutant Stork	2.00	3.33	3.17
	Grassland Birds	3.83	2.33	1.89
	Mugger Crocodiles	3.00	2.33	2.17
	Fishes/Fish Community	3.17	3.33	2.94
LULC				
	Agricultural areas	2.67	3.67	3.11
	Bardia National Park	2.83	3.33	3.06
	Community managed forests	2.50	3.67	3.00
	Livestock grazing areas	2.33	3.00	3.06
	National forests	2.50	3.00	3.17
	Churia	3.83	2.67	2.39
Infrastructure				
	Rural settlements	2.50	3.67	3.50
	Irrigation systems	2.75	3.33	3.08
	Urban areas	2.50	3.67	3.33
	National roads	3.25	1.67	1.75
	District roads	3.25	1.67	1.75
	Local roads	3.25	1.00	1.42

Karnali River Basin

Excessive extraction of sand and gravel from the Karnali River and its tributaries could change the river profile, causing the river to shift course, especially with expected high rainfall and resulting floods. Decreasing water levels in the Geruwa River could make less water available for aquatic species and wildlife in Bardia National Park. These changes may especially affect Gangetic dolphins, in about half the area they occupy in the Karnali river system, and Gharial. The rhinoceros' population in Bardia National Park will also have less water available, especially in the Geruwa River during the dry periods.

Some land use and land cover Subunits will be exposed to increasing temperatures and erratic rainfall, causing deforestation and degradation of forest areas and grasslands. These conditions could create favorable environments for invasive plant species to spread and replace the existing vegetation, thus changing the forest composition in community managed forests and national forests.

If these changes occur, the local communities will lose forest products they use every day to support their livelihoods. Loss of grasslands and grazing grounds will affect livestock. Wildlife species with specific habitat, food plants, and host plants will lose these resources, causing populations to decline and even local extirpations of core populations. Corridors will lose their ecological function. However, agricultural areas and plantations are not expected to be severely affected.

The heavy rainfall expected during the rainy seasons can carry heavy silt loads that could block rivers causing flashfloods, which destroy rural settlements. Damage to bridges, local and district roads will sever socio-economic connectivity. People unable to move out of flood affected areas will be more vulnerable. The planned railroad system could be affected by floods. Irrigation canals will be blocked or damaged, making them non-functional. Floods can also damage electric fences erected to prevent human-wildlife conflict, causing conflict levels to intensify.

Table 8: *Resilience, exposure, and vulnerability scores of Subunits in the Karnali River basin.*

Subunit	Resilience	Exposure	Vulnerability
Species			
Gangetic Dolphins	4.00	3.67	3.00
Gharial	2.33	2.33	2.56
Fishes/Fish Community	4.67	1.33	0.94
Greater One-horned Rhinoceros	4.17	1.67	1.44
Tiger	5.00	1.00	0.67
Swamp Deer	4.50	1.00	0.83
Great Pied Hornbill	5.00	1.00	0.67
Vultures	3.67	1.00	1.11
Grassland Birds	5.00	1.00	0.67
LULC			
Livestock grazing areas	2.00	3.67	3.67
Community managed forests	4.50	2.67	2.00
Corridors	4.33	3.67	2.72
National Park	4.83	2.33	1.56
Agricultural areas	4.17	1.00	0.94
Plantations (sugarcane)	2.50	1.00	1.50
Infrastructure			
Irrigation systems	1.50	4.00	3.83
National roads	2.25	1.00	1.58
Rural settlements	2.75	4.00	3.58
District roads	3.75	3.00	2.75
Local roads	4.25	3.00	2.58
Airports	1.33	1.67	2.39
Railroad	1.00	2.67	3.33

Bagmati River Basin

Erratic, high rainfall can cause flashfloods in the Terai and landslides in the Churia. Increasing demand for land and forest products by people, including flood refugees moving into sensitive areas,could exacerbate degradation of forests and grasslands. These climate-related impacts are expected to increase exposure of focal species, especially tigers, elephants, hornbills, and vultures.

Increasing temperatures and changing rainfall patterns could affect the viability of agricultural areas, causing farmers to change their traditional farming practices. To escape frequent floods, some may move to higher elevation lands, especially in the Churia, where they would clear and cultivate steeply sloping land using maladaptive farming techniques. Thus, the risk of soil erosion, siltation, and rivercutting could increase. The consequences would be felt in the Churia and Terai areas and beyond. Changing climatic conditions will affect the species compositions of national forests, including community managed forests, and plantations. With increasing and erratic rainfall, the eroding Churia slopes and downstream siltation can cause flashfloods, affecting infrastructure, especially rural settlements, and national and district roads in the basin. The settlements will have less water in winter.

***Table 9:** Resilience, exposure, and vulnerability scores of Subunits in the Bagmati River basin.*

Subunit		Resilience	Exposure	Vulnerability
Species				
	Tiger	2.33	4.67	4.06
	Wild Elephant	2.00	4.67	4.17
	Deer and Blue Bull	4.00	4.00	3.00
	Great Pied Hornbill	1.17	4.67	4.44
	Vultures	1.00	4.67	4.50
LULC				
	Agricultural areas	2.83	3.00	3.06
	National forests	3.17	3.00	2.78
	Community managed forests	3.00	3.00	2.67
Infrastructure				
	Rural settlements	2.50	2.33	2.67
	National roads	2.67	3.00	2.94
	District roads	2.67	3.00	2.94

East Rapti River Basin

Heavy rainfall will cause extensive floods and flashfloods in the Rapti River, trapping and killing wildlife. Fish, Gharial, and mugger crocodiles could be washed downstream or displaced into flood plain areas. Terrestrial species, such as tigers and vultures, will face food scarcity as prey populations are lost.

The productivity of forests and agricultural areas will be affected by high siltation due to floods and hotter dry periods. The forests and grasslands could become susceptible to invasive species; more frequent forest fires could change the vegetation compositions. Thus, the protected areas (including Chitwan and Parsa), the Barandabar corridor, and the community-managed forests could be exposed more to impacts from climate change.

Agricultural land could be lost to settlements and urbanization. Servicing a growing human population will increase development activities in the basin. However, the roads, irrigation systems, and rural and urban settlements need climate-resilient engineering designs and more systematic planning. Otherwise, this infrastructure will be very exposed to climate change impacts.

Table 10: Resilience, exposure, and culnerability scores of Subunits in the East Rapti River basin.			
Subunit	**Resilience**	**Exposure**	**Vulnerability**
Species			
Vultures	2.33	5.00	4.22
Tiger	3.67	3.33	2.78
Gharial	1.00	5.00	4.67
Mugger Crocodiles	3.67	5.00	3.78
Fishes/Fish Community	3.83	4.00	3.22
LULC			
Corridors	2.33	5.00	4.22
Agricultural areas	4.67	4.00	2.94
Community managed forests	3.67	4.00	3.28
Leasehold forests	2.50	5.00	4.17
Chitwan NP	3.33	5.00	3.89
Parsa WR	2.67	5.00	4.11
Infrastructure			
Large Cities	2.25	5.00	4.25
Rural settlements	2.00	5.00	4.33
Airports	1.50	1.00	1.83
National roads	2.25	5.00	4.25
District roads	2.25	3.67	3.58
Hydropower	1.75	1.67	2.42
Irrigation systems	2.00	2.33	2.33

Mahakali River Basin

Floods and prolonged dry seasons will exacerbate problems of soil erosion, water scarcities, lowering water tables, and land use changes, especially those changes due to human uses in the Churia range. Too little or too much water (i.e., flood conditions) could affect wildlife populations, including flagship species like tigers, swamp deer, rhinoceros, and fish communities in the rivers. The composition of the forests and grasslands could change, even in protected areas, namely Shuklaphanta WR and Mohana Laljhadi and Brahmadev corridors. For instance, increasing temperatures could cause the disappearance of *Sati Sal* and *Bijay Sal* from forests and cause vegetation to be replaced or dominated by invasive species. The corridors will be susceptible to encroachment by people displaced throughthe natural disasters induced by climate change.

Both upstream and downstream in the basin, the remaining forests will be fragmented, even community-managed forests. Wetlands could be dry. Changing weather patterns could compel farmers to change patterns of agricultural cropping, including switching to different crops. For instance, farmers would begin growing maize instead of rice.

Natural disasters such as floods, landslides, and droughts will be more severe and prevalent, causing human disasters, especially in the rural settlements. Landslides and floods will destroy infrastructure such as rural roads and irrigation systems.

Table 11: *Resilience, exposure, and vulnerability scores of Subunits in the Mahakali River basin.*

Subunit	Resilience	Exposure	Vulnerability
Species			
Tiger	2.67	2.67	2.44
Swamp Deer	2.83	3.67	3.22
Greater One-horned Rhinoceros	2.17	3.00	3.11
Fishes/Fish Community	3.00	2.33	2.17
Bees	3.33	2.00	1.89
LULC			
Shuklaphanta WR	3.17	3.00	2.78
Mohana Laljhadi corridor	3.33	4.33	3.39
Brahamdev corridor	3.17	3.00	2.78
Churia forest	3.20	4.67	3.77
Agricultural areas	3.00	4.33	3.50
Community managed forests	3.60	2.00	1.80
Wetland	3.67	3.67	2.94
Infrastructure			
Rural settlements	2.50	4.33	3.67
Local roads	2.67	4.33	3.61
Irrigation systems	3.00	3.33	2.83

Mohana River Basin

Higher temperatures and changes in rainfall pattern may lead to changes in the species in wildlife habitat because invasive species will spread and replace native food plants and other tree species. Bijay Sal, an important timber species that dominates the Terai forests, will be especially vulnerable. The high silt loads that rivers carry down from the Churia will adversely affect key riverine habitats for wildlife species in the Terai, including for tigers and their prey species. With increased silt loads,changes in river flows and water quality will affect aquatic species, such as the Gangetic dolphin, crocodiles, and fish communities. Limited water availability can affect Sarus cranes and Lesser Adjutant storks if there is not enough water to maintain wetlands. Localizing water holes will increase the risk of poaching.

Increasing temperatures can encourage the emergence and spread of pests and diseases in agricultural areas, decreasing agriculture productivity. Flashfloods will destroy agricultural lands. Silt and sand from eroding lands will be deposited in these agricultural fields, making them uncultivable. Flashfloods will also destroy small-scale irrigation systems. The species composition of forests—including national and community managed forests—will change with changing climatic conditions. Basanta and the Mohana Laljhadi corridors are vulnerable to forest change and degradation, especially if people displaced by floods settle in these forests.

Infrastructure will be negatively affected by landslides, floods, and riverbeds rising due to depositions of sand and silt. National, district, and local roads, such as the *Hulaki Sadak* (postal road) and Mahakali highway will all be affected. Bridges, irrigation canals, and the power transmission lines are also vulnerable, diminishing their capacity to provide essential services. Floods and prolonged inundation of rural and urban settlements can cause the spread of diseases and scarcities of drinking water, compromising the health and well-being of people.

Table 12: Resilience, exposure, and vulnerability scores of Subunits in the Mohana River basin.			
Subunit	**Resilience**	**Exposure**	**Vulnerability**
Species			
Tiger	4.2	2.7	2.1
Gangetic Dolphins	1.3	4.3	4.2
Great Pied Hornbill	3.2	1.7	1.6
Sarus Crane	2.2	4.0	3.4
Lesser Adjutant Stork	2.2	2.7	2.3
Grassland Birds	3.8	4.3	3.2
Bijayasal	1.7	3.7	3.8
Mugger Crocodiles	1.5	2.7	2.5
Fishes/Fish Community	2.2	4.3	3.9
LULC			
Agricultural areas	1.7	3.7	3.6
Irrigation systems	2.0	4.3	4.0
Corridors	3.2	4.0	3.4
Protection forest (Basanta and Mohana Laljhadi)	1.7	3.7	3.6
Community managed forests	3.7	3.3	2.8
Infrastructure			
Large cities	1.8	3.3	3.4
Rural settlements	2.3	4.7	4.1
Airports	2.0	1.0	1.5
National roads	2.5	3.3	3.2
District roads	2.5	3.3	3.2
Local roads	2.5	4.3	3.8
Irrigation systems	2.0	4.7	4.2

Bakaiya River Basin

Rising temperatures will lead to changes in the composition of tree species in forests and the vegetation composition of wildlife habitat. Native plants could be replaced by invasive species, some of which are unpalatable to herbivores, including prey species for tigers. Therefore, declining population of prey species will affect tiger population. Development and increasing human population will begin to fragment forests, affecting elephant population as their ranging movements become constrained. Loss of large nesting trees will affect the vulture population. Periods of droughts and low water flows in rivers can affect the fish communities.

Erratic and heavy rainfall can result in flashfloods. Silt and sand deposition in agricultural lands, community managed forests, and plantations will diminish productivity. Changing river courses will remove or change composition in forests and grasslands, including habitats in wildlife corridors.

Prolonged inundation from severe floods and flash floods can damage road networks and bridges, and destroy rural settlements.

Table 13: Resilience, exposure, and vulnerability scores of Subunits in the Bakaiya River basin.

Subunit	Resilience	Exposure	Vulnerability
Species			
Vultures	2.00	4.67	4.17
Tiger	1.17	2.67	3.44
Elephant	2.00	4.00	3.83
Fishes/Fish Community	1.17	3.67	3.78
LULC			
Protected areas	3.50	1.33	1.50
Corridors	3.00	3.00	2.67
Agricultural areas	2.67	2.67	2.78
Plantations	2.33	2.00	2.22
Livestock grazing areas	2.83	1.67	1.89
Community managed forests	2.17	2.00	2.28
Infrastructure			
Rural settlements	2.83	3.67	3.22
National roads	3.50	3.00	2.33
District roads	3.25	2.67	2.25
Local roads	1.75	4.33	3.92
High tension line	2.50	1.00	1.50
Irrigation systems	3.17	1.33	1.61
Railroad	2.75	1.67	1.92

Tinau River Basin

Increasing temperatures will affect the phenology (seasonal cycles) of plants, resulting in a loss of resources, especially for those animal species that are adapted to feed on certain fruits, leaves, and other plant material, or to nest and reproduce during a certain time of the year, in synchrony with the host plant phenology. The cascading ecological links could affect other ecological processes, and species. The impacts on these species and their habitats will intensify with the loss of habitat due to encroachment into natural forests and grasslands by increasing numbers of people displaced by climate change. Species such as vultures, Sarus crane, Lesser Adjutant stork, and the grassland birds will be especially affected in this basin, which does not have large protected areas that can provide core refuge, especially for large mammal populations.

Increasing temperatures and changing rainfall patterns could also result in changes to agricultural cropping patterns, affecting productivity. Natural catastrophes such as floods, landslides, and droughts, and extensive erosion will change the status of land cover, especially affecting the quality of habitat in wildlife corridors and the forest composition of the community-managed forests and watershed protection forests.

Natural disasters triggered by severe rainfall and consequent floods will pose challenges to infrastructure, necessitating the need for designs adapted to potential changes in the climate. Local, district, and national roads will especially be affected. Large cities and rural settlements will be vulnerable to the climatic extremes of floods and droughts.

Table 14: *Resilience, exposure, and vulnerability scores of Subunits in the Tinau River basin.*

Subunit	Resilience	Exposure	Vulnerability
Species			
Vultures	1.00	4.33	4.33
Sarus Crane	3.83	3.67	3.06
Lesser Adjutant stork	1.00	3.67	4.00
Grassland Birds	3.67	3.33	2.94
Fishes/Fish Community	4.00	3.00	2.50
Common Leopard	3.00	2.67	2.33
Barking Deer	3.00	2.67	2.33
Jackal	4.50	2.33	1.50
Other	1.00	3.67	4.00
LULC			
Corridors	2.67	2.33	2.61
Agricultural areas	2.00	4.00	3.83
Plantations	2.67	1.67	1.94
Watershed protection forests	1.83	3.00	3.06
Community managed forests	3.33	3.00	2.56
Infrastructure			
Large Cities	2.67	2.67	2.78
Rural settlements	2.33	2.67	2.56
Airports	3.33	1.00	1.22
National roads	2.33	3.00	3.06
District roads	2.33	3.00	3.06
Local roads	2.33	4.33	3.89
Hydropower	1.33	1.67	2.56

Narayani River Basin

Flash floods from climate change and an increasing human population are expected to affect most wildlife species, especially tigers, rhinoceros, gharial and crocodiles. The species compositions of large areas of habitat in the protected areas, wildlife corridors, and community managed forests are expected change in the next five years.

Agricultural productivity could decline because of climate change. Invasive species could spread in agricultural areas, plantations, and the watershed protection forests. Large cities and rural settlements may be affected by floods, creating health problems and food shortages. National, district, and rural roads could be destroyed by floods. Irrigation systems have high exposure and vulnerability.

Table 15: Resilience, exposure, and vulnerability scores of Subunits in the Narayani River basin.			
Subunit	**Resilience**	**Exposure**	**Vulnerability**
Species			
Tiger	4.83	4.33	2.89
Greater One-horned Rhinoceros	3.83	3.33	2.72
Gharial	3.67	3.33	2.78
Mugger Crocodiles	4.33	3.33	2.56
Indian Monitor Lizard	3.50	3.33	2.83
LULC			
Protected areas	3.50	4.67	3.50
Corridors	3.00	4.67	3.67
Agricultural areas	3.83	4.67	3.39
Plantations	4.33	4.00	2.89
Watershed protection forests	3.00	4.33	3.50
Community managed forests	4.17	4.33	3.11
Infrastructure			
Large cities	4.50	4.00	2.83
Rural settlements	4.50	4.00	2.83
Airports	4.50	3.33	2.50
National roads	3.50	3.33	2.83
District roads	3.50	3.33	2.83
Local roads	3.50	3.33	2.83
Irrigation systems	3.50	4.67	3.50
Railroad	3.50	4.67	3.50

West Rapti River Basin

Erratic rainfall and increasing temperatures could cause changes to the species composition of wildlife habitat, including the spread of invasive species. There is a possibility of extirpation (local extinction) of some species -tigers, vultures, crocodiles, and Sal (*Shorea*) are especially at risk.

Accelerating changes to land use and species compositions in forests could also affect the ecological integrity of protected areas (Banke National Park), corridors (Kamdi and Lamahi), wetlands, community-managed forests and plantations. Productivity of agricultural areas will decline and be lost, especially along the river banks and flood prone areas.

Major infrastructure in this Unit would be exposed to floods that could wash it away causing loss of lives. The large cities, national, district, and rural roads, and irrigation systems are especially exposed.

Table 16: *Resilience, exposure, and vulnerability scores of Subunits in the West Rapti River basin.*

Subunit	Resilience	Exposure	Vulnerability
Species			
Tiger	1.67	2.00	2.61
Vultures	3.33	3.33	2.72
Mugger Crocodiles	1.83	2.00	2.56
Sal	2.67	2.33	2.28
Khair	2.67	2.00	2.28
Spotted Dear	4.17	3.00	2.44
Wild Boar	3.17	2.67	2.61
LULC			
Banke National Park	3.00	2.67	2.50
Kamdi corridor	2.83	4.33	3.56
Lamahi	3.00	4.33	3.50
Community managed forests	3.33	4.33	3.39
Wetlands	2.00	4.67	4.00
Agricultural areas	2.17	4.00	3.61
Infrastructure			
Large Cities	3.00	4.33	3.50
Rural settlements	2.67	2.67	2.78
National roads	2.00	3.67	3.67
District roads	2.00	3.67	3.67
Local roads	2.00	3.00	3.17
Hydropower	2.33	2.67	2.72
Irrigation systems	3.33	3.00	2.72
Railroad	1.33	1.67	2.39

4.5 Social adaptive capacity

Social adaptive capacity measures the readiness of the institutions, with effective enabling policy environments and the information required, to address the adverse impact of climate change and utilize opportunities from climate change and variability. Since the policies and institutional structures are similar across the TAL, the analyses for Subunits were conducted across all basins, instead of for each individual basin.

4.5.1 Species Subunit

The workshops assessed each major species Subunit (tiger, rhino, bengal florican, swamp deer, hornbill, elephant, *bijay sa*l, and grassland birds) for the institutional and policy support required for climate change integrated conservation in the TAL. The parameters considered include the capacity and readiness to monitor and manage fires, increased poaching, illegal trade in wildlife and plants, and human-wildlife conflict. It also considered the capacity to monitor species composition, population changes, vegetation shifts, and changes in phenology. The overall social adaptive capacity was highest in the East Rapti basin (Table 17).

Table 17: Social adaptive capacity analysis – species

River Basin	Information	Policies	Institutions	Average
Mahakali	2.75	2.75	2.93	2.81
Mohana	2.75	2.75	2.89	2.80
Karnali	2.75	2.75	2.89	2.80
Babai	2.75	2.75	2.84	2.78
W Rapti	2.75	2.75	2.80	2.77
Tinau	2.75	2.75	2.75	2.75
E Rapti	2.75	2.75	3.00	2.83
Bakaiya	2.75	2.75	2.84	2.78
Bagmati	2.75	2.75	2.75	2.75

Very High	High	Mid	Low	Very Low
>4	3 - 4	2.76 - 3	2 - 2.75	<2

Information: Overall, the values for information required and collected to monitor change for the species Subunits was similar across the basins (Table 17). The similar values for all basins (2.75) suggest that opportunities exist to diversify the type of information and its frequency of collection, andto improve data quality to improve adaptive capacity and resilience to climate change.

Policies: The analysis of the existing policies, rules, and regulations (listed in Part 4.3) that will be required, to create enabling environments to address vulnerabilities of species Subunits to climate change, did not differ (Table 17) because there are no basin specific policies. The low values for adaptive capacity (2.75) for all basins suggest opportunities for developing basin specific regulations in order to address the adverse and variable impact of climate change on specific species.

Institutions: Lists of institutions, from community to central levels, responsible for species conservation were prepared. Participants were asked to assess them in terms of their mandate and leadership in carrying out responsibilities efficiently and effectively, the resources available through these institutions, and their stakeholder consultation and coordination with relevant institutions. Social adaptive capacity analysis showed that there are institutions established for species conservation but their capacity needs to be enhanced to carry out responsibilities efficiently and effectively. The East Rapti basin has relatively higher adaptive institutional capacity, while Tinau and Bagmati have low adaptive institutional capacity.

4.5.2 Land use and land cover Subunit

Eleven LULC Subunits were prioritized in the TAL assessment. These included the natural land cover systems, such as protected areas, corridors, and wetlands, and human land-use systems, such as agricultural areas, industrial plantations, and designated livestock grazing areas (Table 4).

Social adaptive capacity for land use land cover was assessed in terms of information required, existing relevant policies and the institutional framework. Overall, the social adaptive capacity was highest in the Mahakali basin (Table 18).

Table 18: Social adaptive capacity - land use and land cover				
River Basin	**Information**	**Policies**	**Institutions**	**Average**
Mahakali	3.05	3.09	2.97	3.04
Mohana	3.05	2.88	2.93	2.95
Karnali	3.05	2.88	2.93	2.95
Babai	3.05	2.88	2.91	2.95
W Rapti	3.05	2.88	2.92	2.95
Tinau	3.05	2.88	2.90	2.61
E Rapti	3.05	2.88	2.97	2.97
Bakaiya	3.05	2.88	3.00	2.98
Bagmati	3.05	2.88	2.94	2.96

Very High	High	Mid	Low	Very Low
>4	3 - 4	2.76 - 3	2 - 2.75	<2

Information: Under LULC, information on agriculture, forests, wetlands, water bodies, and the builtup environments were considered in all the basins. Frequency of information collected, data processing and analysis, data quality, accessibility and communication were taken as criteria for assessment.

Social adaptive capacity values for all the river basins are high (3.05), meaning that information on land use and land cover is recorded. However, their access and communication is relatively weak. There are opportunities to improve the databases and data use for climate change related land management.

Policies: The policy documents included for assessment were: Land Use Policy, 2012; National Biodiversity Strategy, 2013; National Parks and Wildlife Conservation Act, 1973; Wetland Policy, 2010; Soil and Water Conservation Act, 1983; and Local Self Governance Act, 1999. Other ancillary and relevant policies such as the Hydropower Development Policy, 2001; Mines and Minerals Act, 1985; and the Public Roads Act, 1974 were also considered.

The analysis indicates that the Mahakali basin has relatively high adaptive capacity support through the policies considered. Since the Mahakali basin borders with India there are additional policy documents related to water use and withdrawal from the Mahakali river. All other river basins have average social adaptive capacity for policy aspects.

Institutions: The list of institutions responsible for LULC from community to central level was prepared and participants were asked to assess them in terms of social adaptive capacity. The results show that the capacities to carry out the responsibilities efficiently and effectively in these institutions have to be improved. The Bakaiya basin has the highest adaptive institutional capacity (3.00), whereas Babai, Tinau, and West Rapti basin have low adaptive institutional capacities (<2.92).

4.5.3 Infrastructure Subunit

Ten infrastructure Subunits were assessed in all river basins across the TAL. These include linear infrastructure, such as roads, the proposed railroad, and irrigation systems; major ‘point’ infrastructure, such as airports and cities with large human footprints; and smaller rural settlements.

Social adaptive capacity for infrastructure was assessed in terms of information required, existing relevant policies and institutional framework (Table 19). Overall, all river basins have low adaptive capacity (2.51 – 2.56) for infrastructure, while the values for Mohana and Karnali were marginally higher those for the Bakaiya and Tinau River basins were marginally lower.

Table 19: Social adaptive capacity – infrastructure

River Basin	Information	Policies	Institutions	Average
Mahakali	2.20	2.46	2.89	2.52
Mohana	2.20	2.46	3.03	2.56
Karnali	2.20	2.46	3.03	2.56
Babai	2.20	2.46	2.90	2.52
W Rapti	2.20	2.46	2.90	2.52
Tinau	2.20	2.46	2.88	2.51
E Rapti	2.20	2.46	2.97	2.54
Bakaiya	2.20	2.46	2.88	2.51
Bagmati	2.20	2.46	2.90	2.52

Very High	High	Mid	Low	Very Low
>4	3 - 4	2.76 - 3	2 - 2.75	<2

Information: Under the infrastructure Subunit, the location and type of infrastructure, stakeholder inventories, and provisions and necessity for effective Environmental Impact Assessments, Initial Environment Evaluations, and Social Impact Assessment were assessed in relation to climate change adaptation. Frequency of information required, data processing and analysis, quality and accessibility of the information were also additional criteria considered.

Social adaptive capacity on infrastructure information did not vary among the basins (Table 19), even though each river basin will have specific biological and physical characteristics

Policies: The main policy documents considered in the assessment were the Hydropower Development Policy, 2001; Mines and Minerals Act, 1985; and the Public Roads Act, 1974. Other ancillary policies considered were the Land Use Policy, 2012; National Biodiversity Strategy, 2013; National Parks and Wildlife Conservation Act, 1973; Wetland Policy, 2010; Soil and Water Conservation Act, 1983; and the Local Self Governance Act, 1999. The analysis shows that all the basins have low social adaptive capacity for policy (2.46) (Table 19).

Institutions: The institutions responsible for infrastructure development, from community to central level, were listed and participants were asked to assess them in terms of social adaptive institutional capacity. The analysis showed that the institutional capacity for carrying out responsibilities efficiently and effectively differs among river basins. The Mohana and Karnali basins have higher adaptive institutional capacity for infrastructure development than other rivers basins (Table 19).

4.6 Analysis and interpretation of workshop results

Climate change is expected to manifest as a general increase in temperature, with shifts in the relatively predictable seasonality of precipitation (MoE 2010). The change is expected to result in erratic and more intense rainfall alternating with longer dry periods, causing more severe and frequent floods and droughts. Predictions suggest that the East Rapti, Mohana, Karnali, Babai, Tinau, Bakaiya, and Bagmati river basins will experience more extreme rainfall, but the increase will be less pronounced in the Mahakali and West Rapti basins (Table 3). Thus, some river basins would be more vulnerable to the expected impacts of climate change than others (Figures 13, 14 and 15).

4.6.1 Species Subunits

Of the 14 species Subunits selected for assessment (Table 4), the workshop participants considered seven to be vulnerable to climate change at the landscape scale of the TAL (Table 17). Of these, the most vulnerable species Subunits are vultures, dolphins, and gharial. The vultures are vulnerable in five of the seven basins where they were selected as important Subunits for assessment (Table 20). The lower reaches of the Babai basin, with important vulture habitat, are less vulnerable to climate impacts than the upper reaches. All four other basins are clustered in the eastern part of the TAL, and are vulnerable to climate change.

Most threats to vultures would be from a loss of large roosting trees, combined with the continued and widespread use of Diclofenac, a veterinary drug used to treat livestock that is toxic to vultures and has been contributing to declines in vulture populations over the past several years (Prakash et al. 2012). If climate change begins to have debilitating effects on livestock, it is likely that owners may resort to using more Diclofenac (or similarly toxic drugs) to treat livestock, which could affect the vultures that feed on dead, disposed animals. Therefore, the use of Diclofenac and similarly toxic veterinary drugs should be totally banned. More vulture restaurants should be established to provide sources of food to restore populations. Climate-resistant forests with large trees, especially Bombax trees, should be identified and conserved for vultures to roost and nest.

Two of Nepal's most important flagship species, the tiger and rhinoceros, were not considered to be vulnerable to the impacts of climate change in the context of the TAL. However, tiger populations in the Bagmati, Babai, and Bakaiya basins are more vulnerable relative to the other basins (Table 20). The Bagmati is the eastern most extent of tiger distribution in Nepal, and does not include significant protected habitat for tigers, the Babai and Bakaiya basins include Bardia National Park (NP) and the Chitwan NP/Parsa Wildlife Reserve (WR) complex respectively. Both harbor important tiger populations.

Table 20: *Species Subunits considered to be most vulnerable to climate change in the TAL river basins.*

BASIN	Tiger	Rhinoceros	Elephants	Swamp Deer	Gangetic Dolphins	Great Pied Hornbill	Vultures	Sarus Crane	Lesser Adjutant Stork	Grassland Bird	Gharial	Mugger Crocodiles	Fishes/Fish Community	Bijay Sal
Babai	3.56	4.28				2.61	4.00		3.17	1.89	4.11	2.17	2.94	
Bagmati	4.06		4.17			4.44	4.50							
Bakaiya	3.44		3.83				4.17						3.78	
East Rapti	2.78						4.22				4.67	3.78	3.22	
Tinau							4.33	3.06	4.00	2.94			2.50	
Karnali	0.67	1.44		0.83	3.00	0.67	1.11			0.67	2.56		0.94	
Mahakali	2.44	3.11		3.22									2.17	
Mohana	2.11				4.22	1.61		3.44	2.28	3.22		2.50	3.94	3.78
Narayani	2.89	2.72	2.78									2.56		
West Rapti	2.62						2.72					2.56		2.28
AVG FOR ALL BASINS	2.73	2.89	3.59	20.3	3.61	2.33	3.58	3.25	3.15	2.18	3.78	2.71	2.78	3.03

Color Code for vulnerability scores:				
Least	Vulnerable			Most

In Babai, the tiger population was assessed to have low resilience and high exposure to climate change due to the potential for habitat fragmentation and loss of connectivity with other sub populations. The Babai river flows through the core area of Bardia NP, so the tiger population in the Babai valley could be isolated with no access to climate refugia (Table 7). Tiger prey populations could be affected by climate change impacts, causing population declines and depriving tigers of food. The Bakaiya basin is highly vulnerable to climate change, especially to severe floods, and the tiger populations in Parsa WR and the eastern parts of Chitwan NP could be isolated, with a lack of access to climate refugia.

The workshop participants assessed the rhino population in the Babai basin as vulnerable to climate impacts, but the population in the Mahakali basin to be less vulnerable (Table 20). Like the tiger population, the rhino population will be isolated in the Babai valley with no access to climate refugia. The rhinos in the Babai valley could be jeopardized by habitat degradation and a loss of palatable food plants due to the spread and displacement by invasive species—a trend already seen with the spread of Lantana. Since there are only three rhino populations in Nepal, the extirpation of rhinos from the Babai basin could have a significant negative impact on Nepal's rhino conservation program. The rhino population in Shuklaphanta WR is smaller, and only moderately vulnerable in the Mahakali basin. (The participants did not consider the rhinoceros as an important species Subunit in the Mohana basin, which includes the eastern part of Shuklaphanta WR). The rhino populations in the in the Karnali and Narayani basins were less vulnerable. In the Karnali river basin, the extent of impact from climate change (i.e., extension) was assessed to be low (~10%) taking up to ten years to manifest (Table 8), while in the Narayani the participants estimated it would take five years for impacts to manifest, but over a smaller area.

Translocations to augment existing populations in Bardia NP and Shuklaphanta WR to increase their viability were recommended, but only after appropriate analyses of climate impacts to habitat and after proper security is put in place. Climate change-integrated management plans, especially for grassland and wetland management are necessary. Climate refugia should be identified, including areas outside the protected areas. Connectivity to these refuge habitats should be maintained. For example, the potential of Barandabar as a climate refuge for rhinoceros should be assessed.

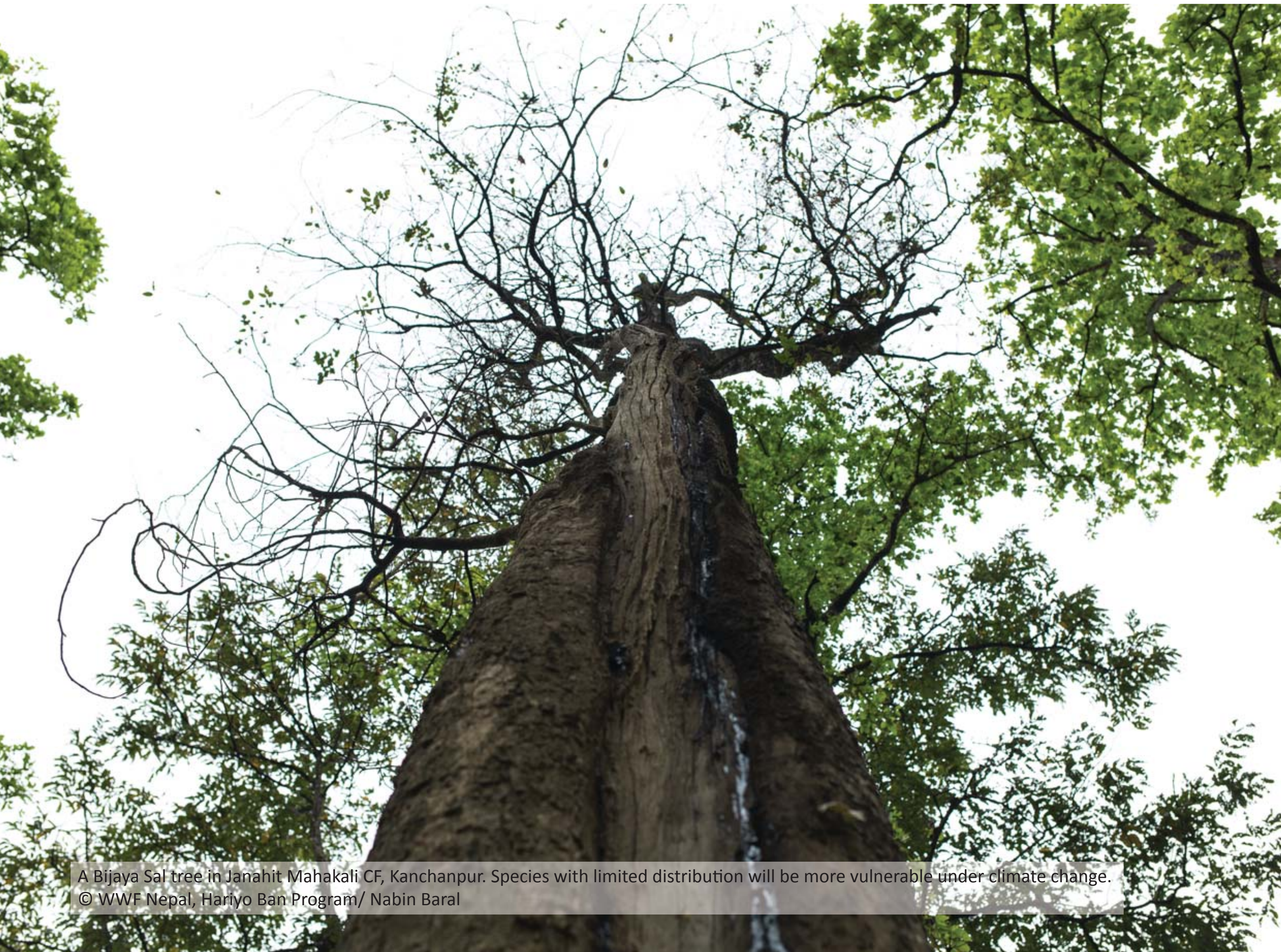
Gangetic dolphins were considered important in two river basins, the Mohana and Karnali, and vulnerable in both (Table 20). Instream barriers in the Karnali River break up connectivity, preventing the free movements of dolphins along the river. Changes to river flows could further impede and restrict movements of dolphins and their prey fish species. During floods, populations could be washed downriver. Animals swept downstream of barrages would be hindered from moving back up, if they have survived. Due to the small population size and low natural productivity of dolphins, the species is highly vulnerable to climate impacts.

Thus, a climate smart dolphin conservation strategy is necessary, and should include approaches to engage the communities depending on rivers as dolphin conservation stewards. Transboundary agreements are needed to incorporate engineering designs into instream barriers that permit dolphins and fishes to navigate through the barriers. Upstream watersheds must be conserved to prevent erosion and extreme river flows (both high and low) that can result in high floods and silt loads that affect water quality, or cause a lack of adequate water flows to support riverine ecology. The climate-adapted river conservation strategies for dolphins will help to conserve the integrity of river and stream ecosystems, including the watersheds. They will offer significant benefits to both natural and human communities.

Elephants were assessed as a species Subunit in three basins:Bagmati, Bakaiya, and Narayani. They were given high vulnerability rankings in the Bagmati and Bakaiya basins. In the Bakaiya basin, the populations could become isolated and confined to the protected areas or forest fragments, disrupting their movements and affecting their requirements for ecological space. Increasing temperatures could cause changes in the forest vegetation, with the loss of food plants that are outcompeted and displaced by unpalatable invasive plant species. This could force elephants (and other herbivores) to raid crops, resulting in increased human-elephant conflict. Thus, forest habitat and connectivity should be maintained for elephants to facilitate their movements to and within climate resistant forests that retain suitable habitat and food plants. Strategically placed electric fencing can be used to prevent elephants from entering agricultural areas to mitigate human elephant conflict.

Sarus cranes and Lesser Adjutant storks are very large birds requiring open grassy fields and wetlands with marshes and pools. Both species are good indicators of these habitats, and are experiencing population declines due to the conversion of habitat, especially into agriculture fields, and due to pesticides and other pollutants. Both are listed as Vulnerable by IUCN (BirdLife International 2012, 2013). While the Sarus cranes were assessed as moderately vulnerable to climate change impacts in the Tinau and Mohana basins, the Lesser Adjutant stork was vulnerable in the Babai and Tinau basins (Table 20).These bird populations can be affected and displaced if the remaining wetlands in these basins either dry up due to prolonged droughts from climate change, or are inundated for long periods due to extreme floods. The Lesser Adjutant storks are losing large nesting trees, so forests and woodlands with these trees should be conserved. Wetlands should be conserved and managed, especially in the lowland areas of the Tinau basin, to provide habitat for these species.

Gharial were assessed as an important species Subunit in three basins, and considered highly vulnerable in two; Babai and East Rapti. In addition to being Critically Endangered (Choudhury et al. 2013), Gharial is an indicator species of river ecosystem integrity. In both basins, river flows and temperature changes due to climate change are expected to impact gharial habitat, food availability, and reproductive capacity. Floods and droughts that affect river flows will affect the connectivity of the populations. Changing temperatures will affect nesting sites and thus the incubation temperatures, skewing the male to female ratio of populations. According to the assessment, large areas of the Gharial habitat will be severely affected in the basins. Therefore, active habitat management will be necessary, including strict control and regulation of gravel extraction from key areas identified for Gharial conservation.



A Bijaya Sal tree in Janahit Mahakali CF, Kanchanpur. Species with limited distribution will be more vulnerable under climate change.
© WWF Nepal, Hariyo Ban Program/ Nabin Baral

Bijay Sal was assessed in two basins, and considered vulnerable in the Mohana, which is highly vulnerable to floods (Table20). Patches of *Bijay Sal* could disappear from this basin due to inundation from floods and heavy silt deposition. Climate resistant patches of *Bijay Sal* should be identified and conserved.

For better climate adaptation, the adaptive capacity of institutions -their policies, information availability, and ability to share information - requires improvement. While the policies and information are consistently low across all river basins, the institutional capacity and available resources in the East Rapti and Tinau basins were relatively higher (Table 17). Both basins had several climate vulnerable species, especially large birds (vultures, Sarus crane, and Lesser Adjutant storks). The two crocodilians (Gharial and mugger) were highly vulnerable in the East Rapti (Table 20). The greater institutional capacity to tackle climate change impacts in these two basins should help with adaptation.

4.6.2 LULC Subunits

Overall, 11 LULC Subunits were prioritized in the TAL assessment. These included natural land cover systems, such as protected areas and wetlands, and human land-use systems, such as agricultural areas, industrial plantations, and designated livestock grazing areas (Table 4).

Among the four major protected areas in the TAL, Parsa WR was considered as the most vulnerable to climate change. Parts of Bardia NP within the Babai basin, and of Chitwan NP in the East Rapti and Narayani basins were assessed as being moderately vulnerable (Table 21).

Table 21: *LULC Subunits considered to be most vulnerable to climate change in the TAL river basins.*

BASIN	Bardia NP	Chitwan Np	Parsa WR	Shuklaphanta WR	Banke NP	Corridors	Brahmadev Corridor	Kamdi Corridor	Lamahi Corridor	Laljhad Corridor	Wetlands	Agricultural Areas	Industrial Crop Plantations	Livestock Grazing Areas	National Forests	Churia	Community Managed Forests	Leasehold Forests	Watershed Protection Forests
Babai	3.06											3.11		3.06	3.17	2.39	3.00		
Bagmati												3.06			2.78		2.67		
Bakaiya		1.50				2.67						2.78	2.22	1.89			2.28		
East Rapti		3.89	4.11			4.22						2.94					3.28	4.17	
Tinau						2.61						3.83	1.94						3.06
Karnali	1.56					2.72						0.94	1.50					2.00	
Mahakali				2.78			2.78			3.39	2.94	3.50					3.77	1.80	
Mohana						3.61						3.61						2.78	
Narayani		3.50				3.67						3.39	2.89					3.11	3.50
West Rapti					2.50			3.56	3.50		4.00	3.81						3.39	
AVG FOR ALL BASINS	2.31	2.96	4.11	2.78	2.50	3.25	2.78	3.56	3.50	3.39	3.71	3.10	2.14	2.87	2.98	3.08	2.70	4.17	3.28

Color Code for vulnerability scores:					
Least	Vulnerable			Most	

In Parsa WR, the habitat in the East Rapti basin has already become subject to invasive plant species and more frequent forest fires. Climate change could exacerbate these changes. The East Rapti basin is highly vulnerable to the impacts of climate change (Figures 13, 14, 15 and 18, 19) especially to floods.

Chitwan NP, which forms a larger protected areas complex with Parsa WR, will be similarly impacted in the East Rapti basin and into the Narayani basin. In the East Rapti basin, alternating droughts and flash floods, heavy silt deposition, and higher temperatures are expected to expose Chitwan NP to more frequent forest fires, invasive plant species, and possibly encroachment by people. However, the southeast part of Chitwan NP in the Bakaiya river basin is less exposed, and the impact of climate change will only manifest in small areas. A management plan integrating climate change, as recommended for Chitwan NP, could guide active management and conservation of its important flora and fauna. Since Chitwan NP has Nepal's largest rhinoceros and tiger populations, habitat management for these species (and for tiger prey species) is an important goal, with interventions also covering the buffer zones and corridors that provide connectivity with other habitats in the TAL.

In Bardia NP, habitat change is already happening in the Babai basin, where invasive plants are replacing indigenous species, some of which have already disappeared. These changes are expected to take place across the entire park. Participatory conservation activities have been suggested as a more efficient, inclusive, and cost-effective way to manage the park, buffer zone, and the corridor forests.

In the Mahakali basin, the Shuklaphanta WR was assessed with relatively high exposure (Table 11). The water holes and wetlands are expected to become dry during drought periods; which is already happening.

The wildlife corridors of in the Mohana, Narayani, East and West Rapti, and Mahakali basins are considered to be vulnerable. These include the Kamdi, Lamahi, Barandabar, Khata, Basanta, and Mohana Laljhadi corridors. The exception is the Brahmadev corridor in the Mahakali basin (Table 21). The southern parts of the Basanta and Mohana Laljhadi corridors along the Mohana river have very low resilience, and, with the exception of the corridors in the Tinau basin, all other corridors have high exposure. The Barandabar corridor in the East Rapti basin is especially exposed to increasing temperatures, droughts, periods of exceptionally heavy rainfall with consequent floods, encroachment by people, and displacement of the natural vegetation by invasive exotic plant species. These changes will appear across a large area of the corridor. In both the Mohana and Karnali basins, the vegetation species composition of the Basanta and Khata transboundary corridors is expected to change extensively over the next one to five years. In the Mahakali basin, both the Brahmadev and Mohana Laljhadi corridors are very exposed to encroachment, grazing, fire, and floods in over 75% of the area. Some impacts are already appearing in this corridor. Similar impacts are expected in the Kamdi and Lamahi corridors in the West Rapti basin.

Wetlands were selected as priority Subunits only in the Mahakali and West Rapti basins, and are vulnerable to climate change in both (Table 21). Although wetlands were considered to be well connected and have functional redundancy, they have low adaptive capacity to climate change.

The agricultural areas in most basins are vulnerable to climate change with the exception of the Bakaiya, East Rapti, and Karnali basins (Table21). In all basins except in Bakaiya and Karnali, agricultural lands will be increasingly exposed to climate change. Bara and Rautahat districts in the Bakaiya basin, and Bardia district in the Karnali basin have some of the biggest areas of paddy lands and pulse crops with significant areas under irrigation (Table 6). Both districts in the Bakaiya basin are very vulnerable to floods due to climate change, while Bardia district is vulnerable to both floods and droughts (Figures 18, 19, 20 and 21). Some of the reasons for high exposure of agricultural lands are changes to river courses, floods, water scarcity during dry periods, and shifting settlement patterns that change land use. In the Karnali basin, these impacts are less pronounced, and in Bakaiya the impacts will only appear across about 10% of the agricultural areas after 5 years.Thus these Subunits received low vulnerability rankings. Suggested strategies to reduce vulnerability include restoration of the upper catchment areas and better soil and water management, including the use of small reservoirs to hold and regulate water release. Climate resistant crops and seed varieties should be introduced. Alternative income generation activities can diversify livelihoods and increase food security.

The industrial plantations are not vulnerable in all four basins in which they were assessed (Table 21). These plantations were judged to have low resilience against climate change, but relatively little exposure.

The designated livestock grazing areas were assessed in only three basins, and regarded as vulnerable in the Babai and Karnali basins (Table 21). The quality of forage in these grazing areas could be compromised by the spread of invasive species, and the extent of grazing areas could decrease if people encroach into these areas. To decrease vulnerability, recommendations include the rotation of grazing in these areas to prevent degradation from overgrazing and development of private forests for fodder production. Introducing improved livestock breeds can help reduce the quantities of fodder required.

Most 'managed' forests, from national forests to community and leasehold forests, are not considered to be vulnerable to climate change at the scale of the TAL. However, they are vulnerable in some basins (Table 21). Most of these forest lands have low resilience and are highly exposed to climate change. Expected impacts over large areas of these forested lands include encroachment into forest lands, possibly by people affected by floods; shifting and changing vegetation communities that will change the ecology of the forests; effects from floods and droughts; and erosion on steeply sloping areas that reduces soil quality and productivity. Therefore, degraded areas should be restored, based on a 'climate change-integrated land use plan'. The plan should include areas identified for resettlement of displaced people to prevent encroachment into important forest areas. It should also prioritize, for restoration and conservation of those corridors and watershed protection areas where climate-resistant forests will persist. The forests along the Churia range were assessed, but were not considered as vulnerable overall in any of the Churia river basins (Table 21).

The Mahakali basin had more social adaptation capacity for information and policies, while the Bakaiya basin had relatively more institutional capacity (Table 18). However, the capacity in all basins could be more developed overall, with priority given to East and West Rapti basins, which have the most climate vulnerable LULC Subunits (Table 21).

4.6.3 Infrastructure Subunits

Ten infrastructure Subunits were assessed across all river basins in the TAL. These include linear infrastructure, such as roads, the proposed railroad, and irrigation systems; and major 'point' infrastructure, such as airports and cities, and smaller rural settlements (Table 4). Some linear infrastructure, such as national highways, district roads, and the railroad span several basins.

Across the TAL, the most vulnerable infrastructure Subunits were urban areas, rural settlements, rural roads, and irrigation systems (Table 22). Almost all the infrastructure in all basins was assigned low resilience scores, with the exceptions being the local roads in the Karnali basin and the urban and rural settlements and airport in the Narayani basin.

Bridge on Karnali at Kothiaghat while under construction, such infrastructures can be under greater risk during increased flood events in the future.

Table 22: *Infrastructure Subunits considered to be most vulnerable to climate change in the TAL river basins.*

BASIN	Urban Areas	Rural Settlemetns	Airports	National Roads	District Roads	Local Roads	Irrigation Systems	RAilroad	Transmission Lines	Hydropower
Babai	3.33	3.50		1.75	1.75	1.42	3.08			
Bagmati		2.67		2.94	2.94					
Bakaiya		3.22		2.33	2.25	3.92	1.61	1.92	1.50	
East Rapti	4.25	4.33	1.83	4.25	3.58		2.33			2.42
Tinau	2.78	2.56	1.22	3.06	3.06	3.89				2.56
Karnali		3.58	2.39	1.58	2.75	2.58	3.83	3.33		
Mahakali		3.67				3.61	2.83			
Mohana	3.42	4.08	1.50	3.17	3.17	3.83	4.17			
Narayani	2.83	2.83	2.50	2.83	2.83	2.83	3.50	3.50		
West Rapti	3.50	2.78		3.67	3.67	3.17	2.72	2.39		2.72
AVG FOR ALL BASINS	3.35	3.32	1.89	2.84	3.16	3.16	3.01	2.79	1.50	2.57

Color Code for vulnerability scores:					
	Least	**Vulnerable**			Most

Most roads were assigned high exposure scores, with the exception of some roads in the Babai, Karnali, and Bakaiya basins. However, all three of these basins are considered to be flood vulnerable due to climate change (Figure 14, 18), which could increase the exposure of infrastructure to more frequent and severe floods in the future. The railroad planned to span the length of the TAL was considered as less vulnerable (Table 22) with little exposure to climate change impacts, but it will traverse several flood vulnerable areas, especially in the Bakaiya, East Rapti, Karnali and Babai basins. Climate-smart infrastructure designs with bioengineering and good drainage are recommended for roads and railroads. The Bhandara Malekhu road, *Hulaki Sadak* (postal road) and the Mahakali roads are especially vulnerable to floods, and are considered priorities for changes for climate-adapted design.

The irrigation systems in the Babai, Karnali, Mohana, and Narayani basins are vulnerable to climate change impacts (Table 22). Several districts in these basins (Bardia, Kailali, Kanchanpur) have some of the largest extents of irrigated agricultural land in the TAL, which are all vulnerable to floods and drought due to climate change (Table 6). Although the irrigation systems in the Bakaiya, East Rapti, and Mahakali basins were not considered vulnerable to climate change impacts they are flood vulnerable (Figure 14). In fact, the western river basins (Mahakali and Mohana, in particular) have recently had severe floods -infrastructure was destroyed, disrupting socio-economic connectivity and agriculture-based livelihoods.

Some districts in these basins (Parsa, Bara, Rautahat, Chitwan, Nawalparasi, and Kanchanpur) have large areas of agriculture that depend on irrigation systems. Therefore, the existing irrigation systems should be regularly cleaned of silt to ensure that water flows unimpeded, especially during rainy seasons when blocked canals could cause water to back-up and flood. The riparian areas should be maintained. Indigenous systems should be promoted as they have successfully managed irrigation systems, such as Rani Jamara in Kailali and *16-36 Mauja* in

Rupandehi. Irrigation systems that will be built in the future should incorporate engineering designs to make them climate-smart.

Except for settlements in the Tinau, Karnali, and Bagmati basins, all urban and rural settlements are vulnerable to climate change impacts (Table 22). The Tinau basin was not considered to be vulnerable to floods, but the lower reaches of both the Karnali and Bagmati basins can be vulnerable. The western part of Tinau basin and the lower reaches of Karnali and Bagmati basins are vulnerable to drought conditions due to climate change.The rural settlements in these vulnerable areas of the basins will be affected by periods of floods and drought, with severe impacts on livelihoods and lives, and disruption of the socio-economic-political fabric.

The Terai regions of the Mohana, Karnali, Babai, Tinau, and Bakaiya basins are densely populated with rural settlements so the impacts of climate change can affect large numbers of people (Figures 8, 28, 29). These settlements should be protected from floods with embankments and other climate-resilient engineering technology, including bioengineering designs that are generally more resilient, affordable, and thus, more effective. Better awareness programs on the potential disaster risks from climate change are needed to prepare people to deal with resulting impacts and minimize the potential risks and damage. Land use planning is necessary to identify areas that are climate vulnerable as well as the safe areas that can be used as climate refugia for people.

No airports, transmission lines, or hydropower infrastructure is vulnerable to climate change (Table 22). However, the airports in the East Rapti, Karnali, and Mohana basins are located in flood vulnerable areas (Figure 11, 14). Thus, more frequent and severe floods could damage these airports.

The social adaptive analysis showed that the capacity of institutions was greatest in the Mohana and Karnali basins (Table 19). Across all basins, the policies and capacities for information collection and sharing were consistently weak and should be improved, especially in the Mohana basin to improve climate change adaptation of rural settlements and irrigation systems, and in the East Rapti basin to improve adaptive capacity of urban areas, rural settlements, and national roads (Table 22).

Overall, the analysis indicates that several key socio-ecological indicators selected are vulnerable to impacts related to climate change. In a sense, they are indicators of change that can affect the survival and sustainability of biodiversity and human livelihoods, health, and lives in the Terai and Churia region of Nepal. The strategic interventions recommended are based on the vulnerabilities of these Subunits, but can build resilience and decrease vulnerability to climate impacts in both natural and human communities of the Terai Arc Landscape. These recommendations should be integrated into the strategic plan for landscape conservation management.

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WWF Nepal, Hariyo Ban Program
PO Box: 7660
Baluwatar, Kathmandu, Nepal
T: +977 1 4434820
F: +977 1 4438458
hariyobanprogram@wwfnepal.org
www.wwfnepal.org/hariyobanprogram