Climate Change Vulnerabilities and Ecosystem-based Adaptation

ATLAS OF THE PANCHASE MOUNTAIN ECOLOGICAL REGION, NEPAL

IMPLEMENTING AGENCY

Ministry of Forest and Soil Conservation, Department of Forests

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IUCN

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ATLAS

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Government of Nepal
Ministry of Forest and Soil Conservation
Department of Forestry

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Partner Organization

ISET-N

Preface

This atlas is one outcome of Mountain EbA Project, Nepal that examined climate change-related vulnerabilities of ecosystems in the Panchase Mountain Ecological Region (PMER), a part of the mosaic of ecosystems in Nepal's Western Development Region (WDR). It presents details about the climate, ecosystem, vulnerability and adaptation options in the PMER as well as the key findings of the study. The project, Ecosystem based Adaptation in Mountain Ecosystems in Nepal, is being implemented by the Government of Nepal (GoN) through the Ministry of Forest and Soil Conservation (MoFSC) and is coordinated by the Ministry of Science, Technology and Environment (MoSTE). The United Nations Environment Programme (UNEP), the United Nations Development Programme (UNDP) and the International Union for Conservation of Nature (IUCN) are key partners together with the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB).

Nepal, Peru and Uganda are the three national sites located in three continents where the mountain ecosystems pilot project has been implemented. The project aims to conserve ecosystems and enhance ecosystem services in order to make ecosystems and dependent communities resilient to the increasingly adverse impact of climate change. In order to reduce human vulnerability to the impacts of climate change local institutions and communities are assisted to manage their ecosystems and services and Ecosystem-based Adaptation (EbA) options are promoted.

Data collected at ward level is presented in maps that show important areas, features and systems. By depicting locations of the EbA options, the maps help visualize useful scenarios for decisions on fund allocations and assessing the impact of the decisions. The PMER base map is based on geographical information system (GIS) platforms developed by the Department of Survey of the GoN. The base map was used to prepare vulnerability maps of wards, village development committees (VDCs) and sub-watersheds. These maps do not, however, show the changes in the landscape caused by differences in elevation and the differences in vulnerability are not as distinct as shown by the maps. Although data available at the VDC and ward levels are not precise, these maps can help support policy decisions. Both maps and the atlas are a useful reference for understanding the challenges of climate change, adaptation to it and EbA.

Acknowledgement

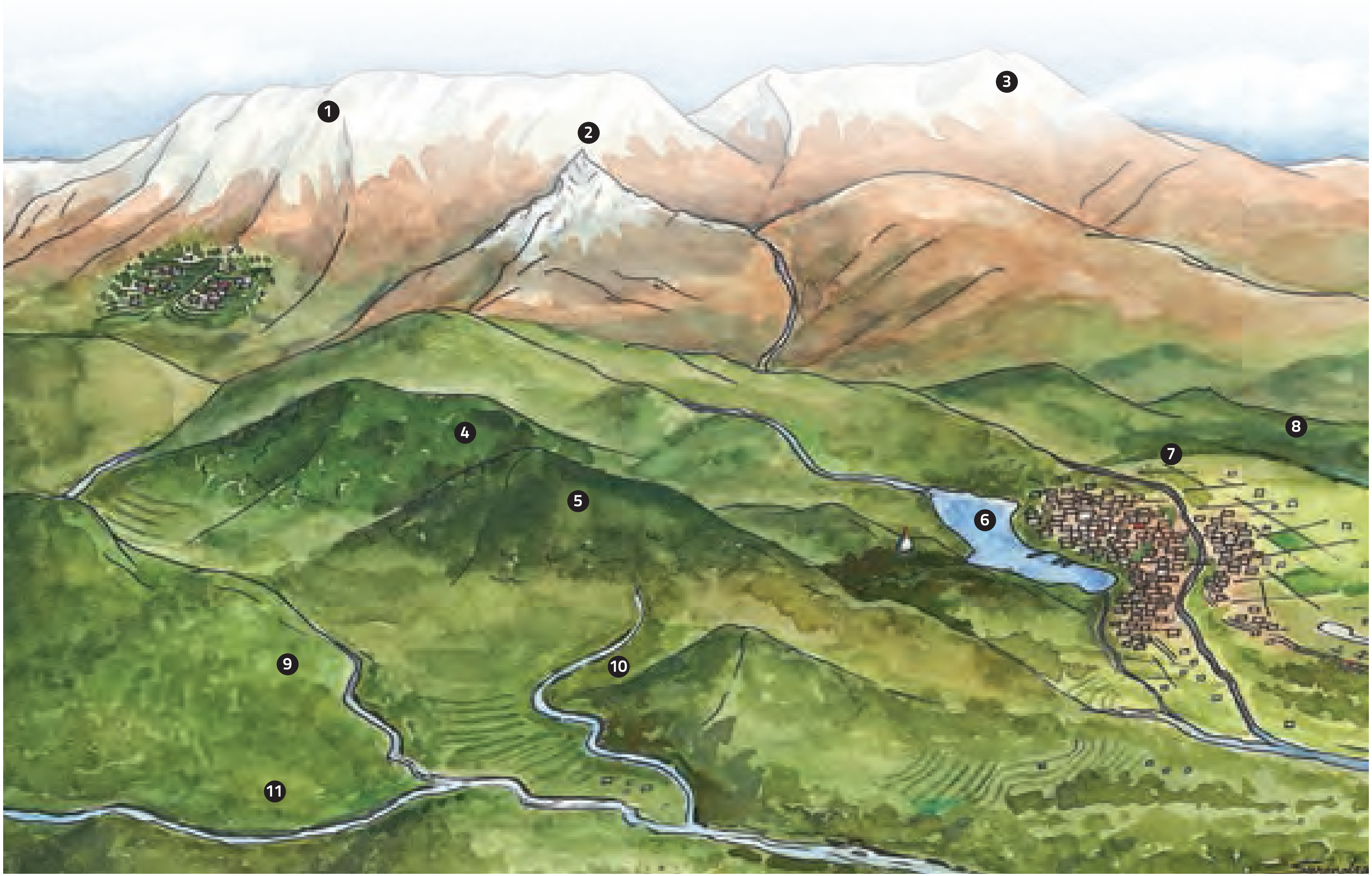
The preparation of this atlas has benefitted from the support of many individuals. I thank all those who helped in completing this study and the atlas. I am grateful to Mr. Mozaharul Alam of the UNEP Regional Office for Asia Pacific and to Dr. Robert Munroe and Charlotte Hicks from the United Nations Environment Programme World Conservation Monitoring Centre, Cambridge, United Kingdom, for their support and input. Preparation of the atlas has benefited from their input at different stages. Valuable support was also provided by Director General of Department of Forests, Dr. Rajan Kumar Pokharel (Former Regional Forest Director of Western Region), Deputy Director General of Department of Forests, Mr. Gauri Shankar Timala; Mr. Vijaya P. Singh, Assistant Country Director and Mr. Vijay Prasad Kesari, Program Analysts of UNDP Nepal; Mr. Rajendra Khanal, Program Coordinator and Ms. Anu Adhikari of IUCN Nepal; Dr. Akhileshwar Lal Karna, Regional Director, Western Regional Forest Directorate, GoN, Ms. Moon Shrestha, Mr. Pragyajan Y. Rai and all the staff of EbA Project in Kathmandu. I also thank Dr. Dinesh Bhuju for his help. I am grateful to local participants of Panchase region, Mr. Gopal Gurung and other colleagues for their support. I also thank Marcus Moench and Michelle Fox of ISET-International, Seema Bhatt of ISET-India, Gehendra Gurung of Practical Action, Praveen Man Singh of Oxfam, Aarjan Dixit of CARE International, Professor Ashutosh Shukla and Professor Kedar Rijal for their input. Perry Thapa has provided much needed editorial support. Thanks also to Mr. Surendra Pradhan for preparing the sketches.

Yogendra Subedi, Kanchan Mani Dixit, Yubaraj Satyal, Ratnadeep Lohani, Shobha Kumari Yadav, Sristi Silwal, Rabi Wenju, Sravan Shrestha, and Anustha Shrestha, researchers at ISET-N, conducted various Shared Learning Dialogues (SLDs) in the Panchase Mountain Ecological Region as well as provided input on the content at different stages. Kamal Thapa, who has moved on from ISET-N, provided much needed input in the initial stages of the study. Suresh Shrestha of Digiscan designed the layout of this atlas with support from Narayanshree Adhikari, Gita Bhomi and Ganga Shrestha of ISET-N.

Table of content

List of acronyms

BMUB	Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
CBO	Community-Based Organization
CRF	Climate Resilience Framework
DoS	Department of Survey
EbA	Ecosystem-based Adaptation
GCM	Global Circulation Model
GDP	Gross Domestic Product
GIS	Geographic Information System
GO	Government Organization
GoN	Government of Nepal
GPS	Global Positioning System
ICIMOD	International Centre for Integrated Mountain Development
IPCC	Intergovernmental Panel on Climate Change
ISET	Institute for Social and Environmental Transition
ISET-N	Institute for Social and Environmental Transition- Nepal
IUCN	International Union for Conservation of Nature
LAPA	Local Adaptation Plan for Action
LDC	Least Developed Country
MASL	Meter Above Sea Level
MDO	Machapuchhre Development Organization
MoFSC	Ministry of Forest and Soil Conservation
MoSTE	Ministry of Science Technology and Environment
NCVST	Nepal Climate Vulnerability Study Team
NGO	Non Governmental Organization
ODI	Overseas Development Institute
PMER	Panchase Mountain Ecological Region
SLD	Shared Learning Dialogue
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
VDC	Village Development Committee

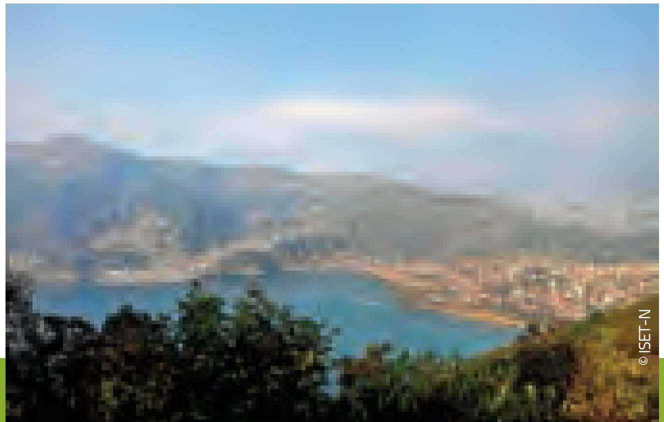


1 Dhaulagiri
2 Machhapuchhre
3 Annapurna range
4 Panchase Mountain Ecological Region
5 Panchase Peak (2,517 masl)
6 Phewa Lake
7 Lakeside settlements of Pokhara with hotels and restaurants
8 Seti River
9 Modi Khola
10 Aandhi Khola
11 Kali Gandaki River

Panchase Lake helps maintain inherent quality of the local ecosystem.

Vegetation on Panchase slopes is diverse.

The temples and stupas in Panchase are popular pilgrimage sites.



The Phewa lakeside settlement and Pokhara municipality, seen from the Panchase region.

Objectives

This atlas depicts Ecosystem-based Adaptation (EbA) in the Panchase Mountain Ecological Region (PMER) in western Nepal, which joins the Annapurna Himalaya range. It is derived from a study that had four aims:

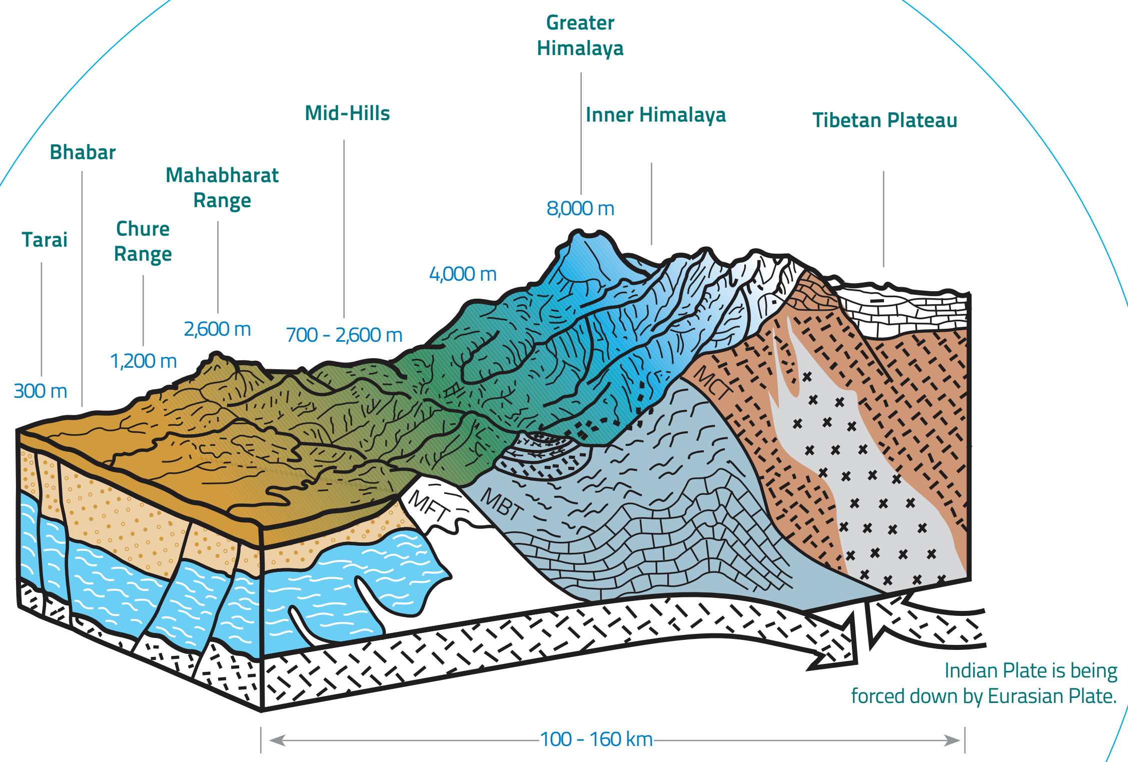
(a) Assess the PMER's vulnerability to climate change and related hazards;
(b) Develop a climate change scenario for the PMER based on historical climate trends, scientific projections and local perceptions;
(c) Develop a picture of future vulnerability to hazards associated with the new climate as envisioned in (b); and
(d) Identify EbA options to enhance resilience.

EbA has the potential to reduce the vulnerability of ecosystems and humans to both climatic and non-climatic risks. It aims to optimize the benefits of ecosystem services, minimize vulnerabilities stemming from the interaction between human and ecological systems and obtain feedback on that type of interaction. Enhanced ecosystem resilience will minimize the vulnerability of local communities to climate change.

Introduction

Nepal is categorized by the United Nations as a least developed country (LDC) and is highly vulnerable to climate change. Several global assessments place it among countries most vulnerable to climate change and related disasters.[1] This vulnerability is a result of many factors, including the country's vastly diverse topography, ranging from plains located at less than 100 m above sea level in the Tarai region bordering India, to Himalayan peaks in the north soaring to altitudes of more than 8 000 m. Nepal's vulnerability to climate change is also heightened by the country's low level of economic development and limited institutional capacity and resources for disaster relief. Climate change-induced vulnerability has serious consequences for human wellbeing because it threatens the ecosystems and their services that sustain local communities. It is very likely that livelihoods, resources, opportunities and gains in poverty reduction and social service provision will be undermined. The interaction between the different components of an ecosystem must sustain the flow of its benefits. An EbA approach can minimize vulnerability related to climatic exposure and maintain, if not enhance social wellbeing.

1 See Maplecroft (2010), Harmeling and Eckstein (2012) and Shepard et al. (2013) for details. The assessments use different indicators to compare the vulnerability of one country with that of others. Different indicators with different assumptions give different category of risks and vulnerabilities.



MCT - Main Central Thrust

MBT - Main Boundary Thrust

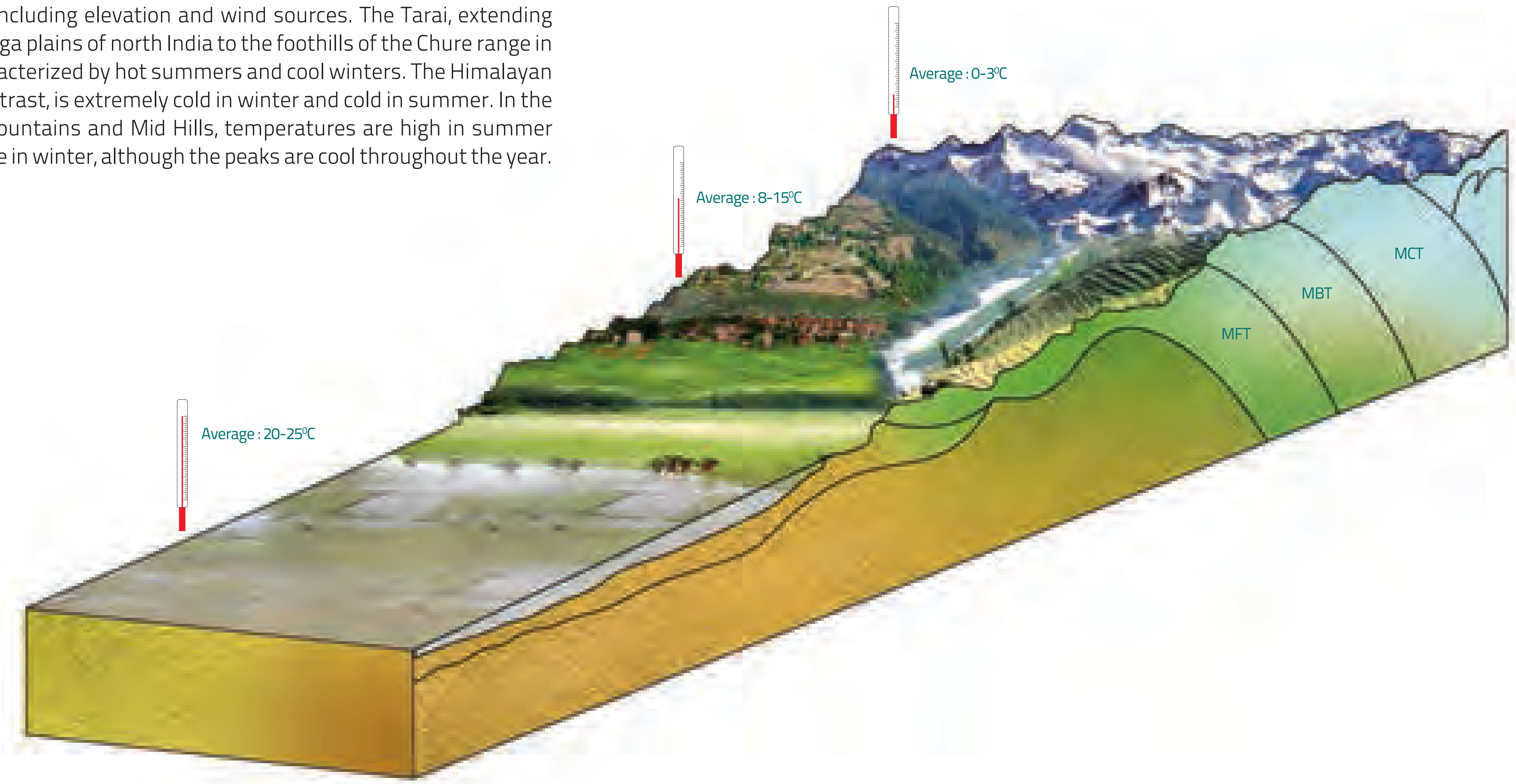
MFT - Main Frontal Thrust

Source: Hagen (1998)

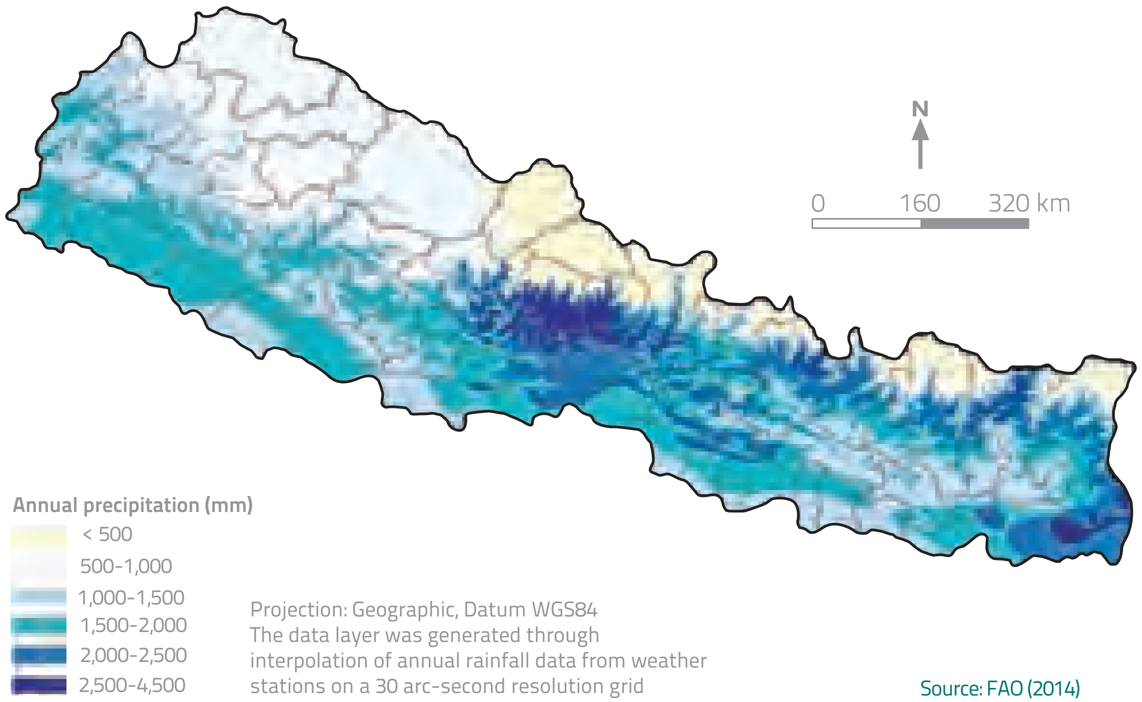
Climate characteristic

TEMPERATURE

The temperatures in Nepal are influenced by the macro level interaction between Indian Ocean currents and the Asian landmass as well as topography including elevation and wind sources. The Tarai, extending from the Ganga plains of north India to the foothills of the Chure range in Nepal is characterized by hot summers and cool winters. The Himalayan region, in contrast, is extremely cold in winter and cold in summer. In the lower Mid Mountains and Mid Hills, temperatures are high in summer and moderate in winter, although the peaks are cool throughout the year.



Adapted from Hagen (1998)



Projection: Geographic, Datum WGS84
The data layer was generated through interpolation of annual rainfall data from weather stations on a 30 arc-second resolution grid

Source: FAO (2014)

PRECIPITATION

The 30-year average for annual rainfall over Nepal, measured at 166 stations across the country between 1976 and 2005, was 1 857 mm (Practical Action 2009). Eighty per cent of the rainfall occurs during the four monsoon months of June, July, August and September. Some of the other months can be rainless. The country has four distinct seasons: spring, summer, autumn and winter. The high elevation regions of Nepal receive snowfall, which is sparsely monitored. Over the last three decades, frost occurrence in Nepal has significantly reduced (Dixit 2010).

Spring (March-May) :
Dry and hot, with occasional thunder and hail.

Summer (June-September):
Rainy, very hot and humid in the low land, with about 80 per cent of annual rainfall.

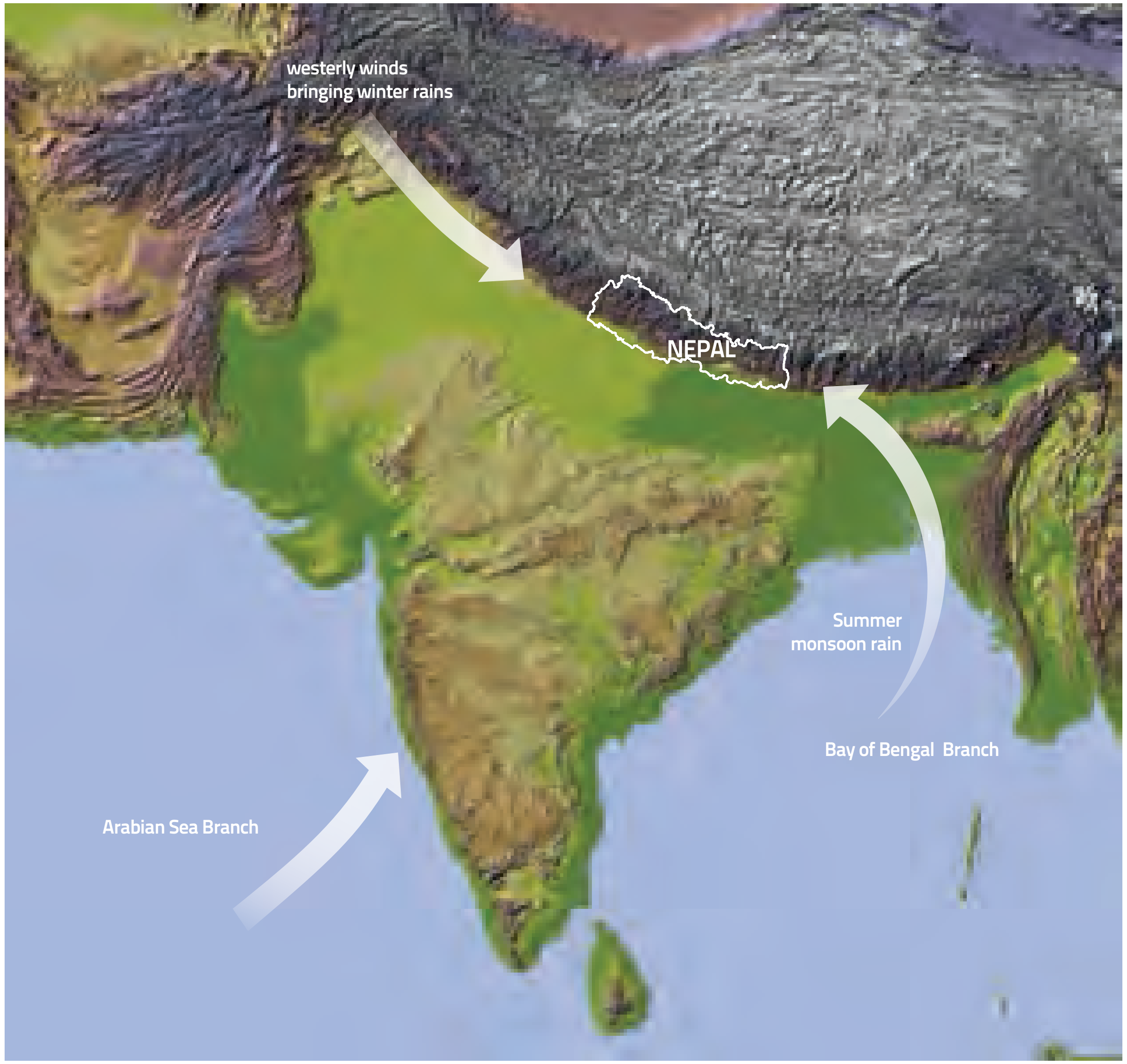
Autumn (October-November):
Moderately hot in low land cold in higher elevations

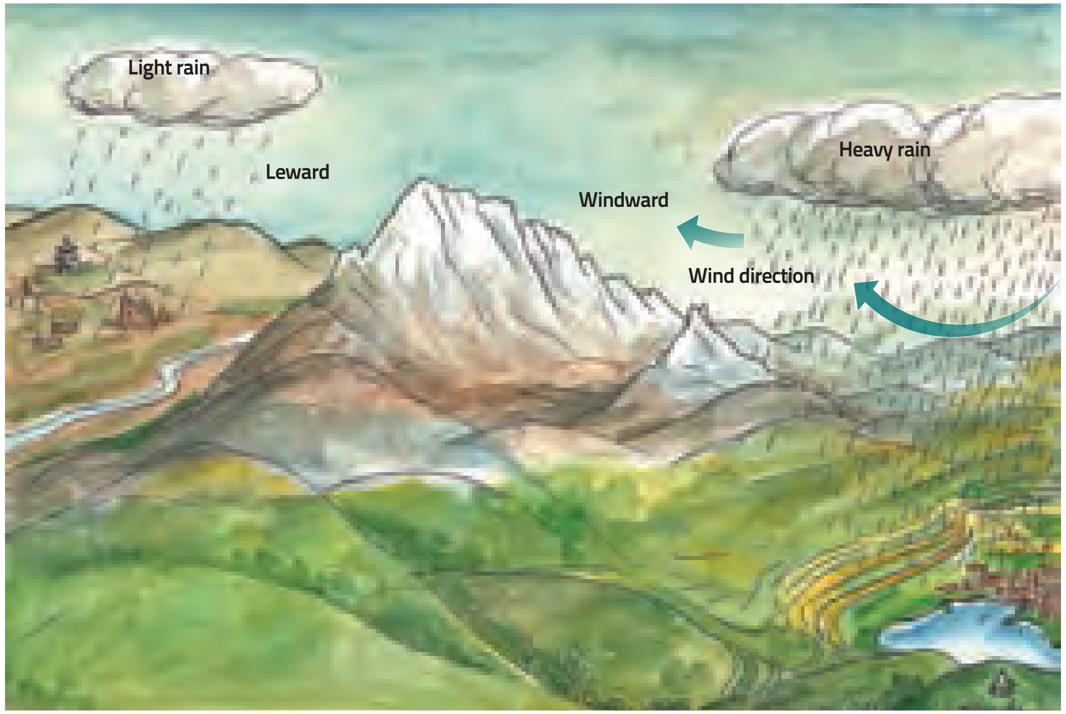
Winter (December-February):
Cold and dry with occasional rains due to the westerly winds.

Rain-carrying winds

The monsoon winds in summer and westerly winds in winter are the main sources of precipitation in Nepal. Winds blowing from the Indian Ocean to the South Asian land mass bring rain to most parts of the Indian subcontinent, including Nepal. Near the southernmost section of the Indian Peninsula, the monsoon winds divide into the Arabian Sea branch and the Bay of Bengal branch. The latter brings the main summer monsoon rainfall to Nepal. The summer monsoon is crucial for the economic wellbeing of South Asia where rain-fed agriculture is the livelihood of hundreds of millions of people.

The summer monsoon reaches eastern Nepal in the early weeks of June and gradually moves westward across the country. It retreats in the reverse order, usually exiting the country by late September. The eastern part of the country gets more rain than the western part. In contrast, the west gets more precipitation, often as snowfall, when westerly winds from sub-polar Asia, ladened with moisture from the Mediterranean Sea, reach the country in December and January. The westerly winds are sometimes enhanced by winds from the Arabian Sea.

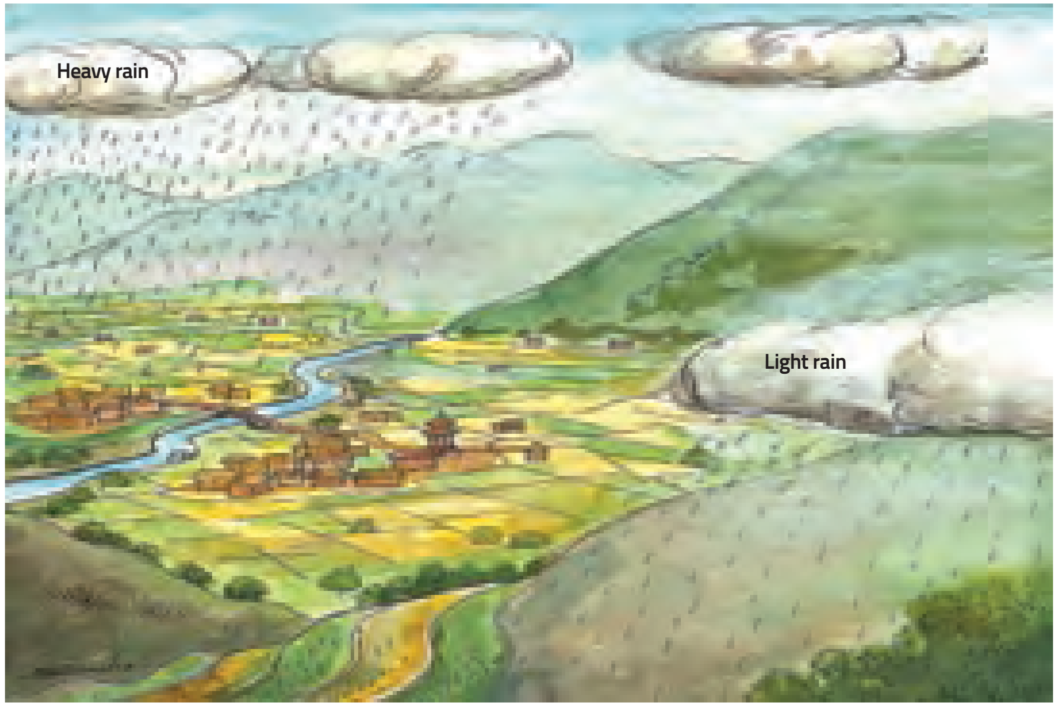




Meso-scale variation. Regions on the wind ward of mountain ranges are wetter than those on leeward side

The Himalayan range has a dramatic effect on the meso-scale characteristics of rainfall in Nepal. While certain regions of the country like Kaski District south of the Annapurna and Dhaulagiri ranges, have much higher levels of rainfall than the national average of 1 857 mm, other regions have much less. Lumle in Kaski District gets 5 411 mm of rain annually while Jomsom in Mustang District gets just 400 mm annually. These leeward and windward effects are also apparent in many other places in the Mid Hills.

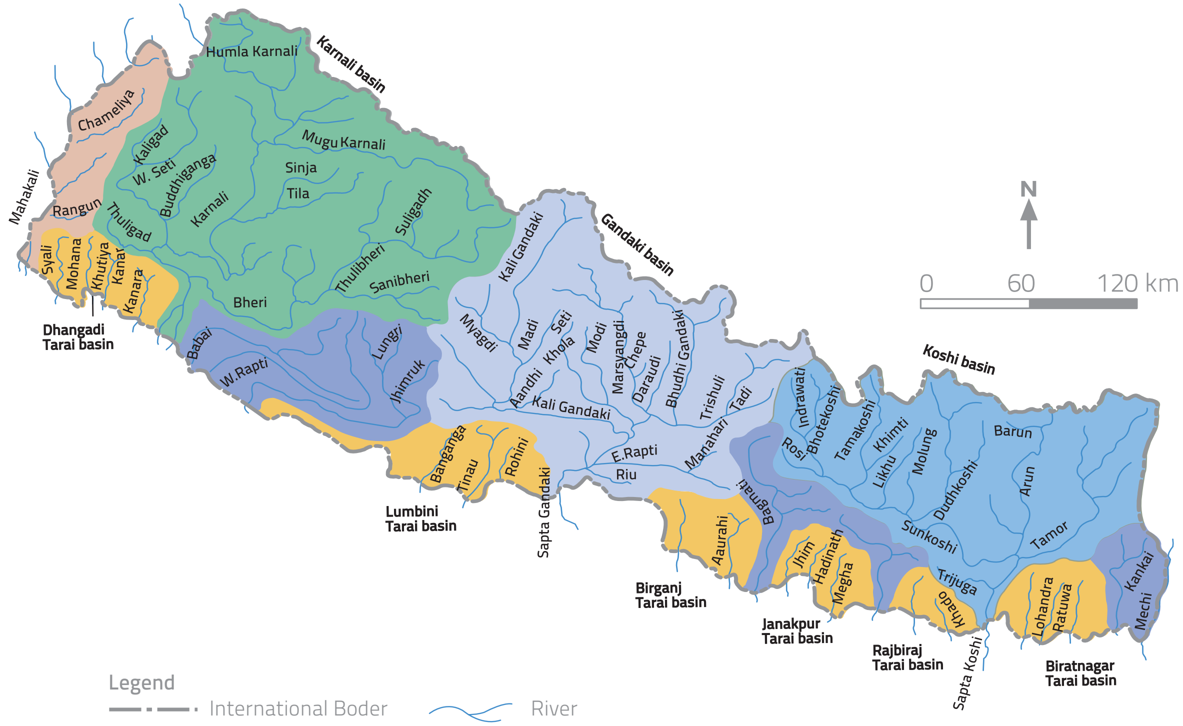
Micro-level variations in rainfall are also found within Nepal. Rainfall across the valley floor and surrounding hills vary dramatically due to rapidly rising rain clouds with no correlation to elevation. Within a single day the variations within a watershed can be extreme. This orographic effect also results in adjacent watersheds recording vastly different amounts of daily and annual rainfall.

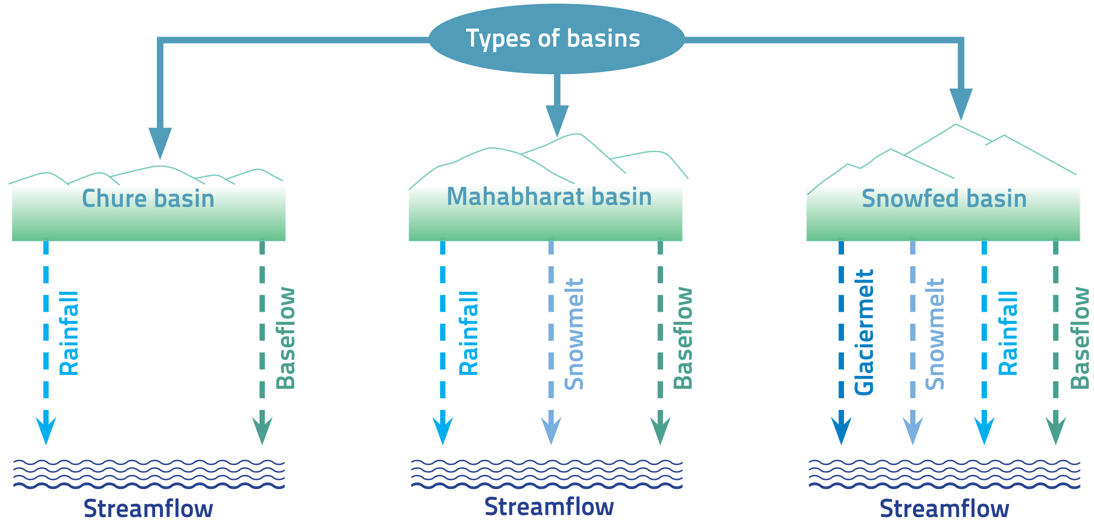


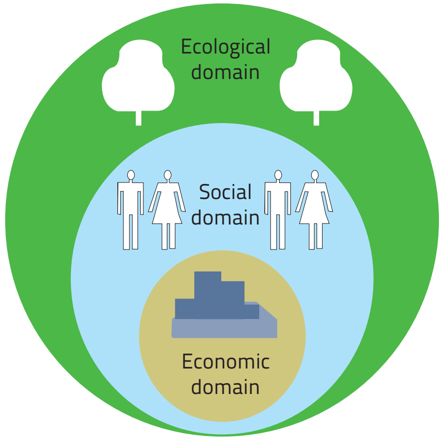
Micro-scale variation. Whether floor or hills of a single valley get more rain at any one rainfall event is impossible to predict

Nepal's river systems

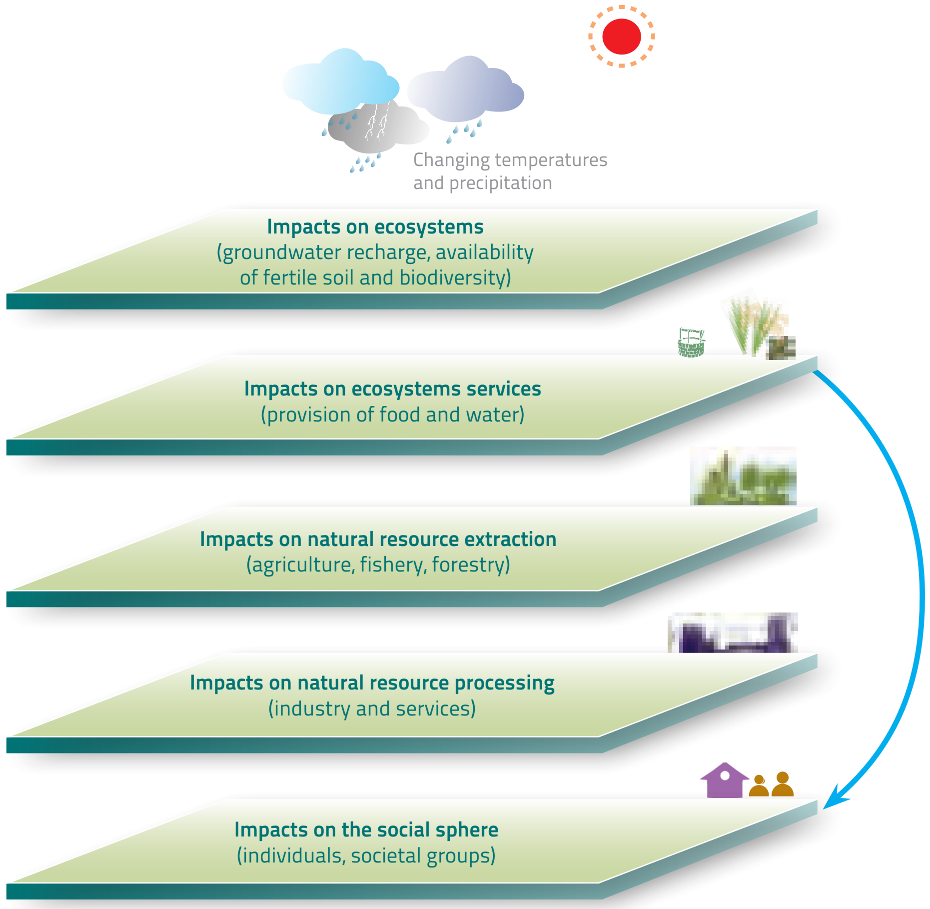
The interdependence of climate, elevation and geology has given rise to thousands of rivers in Nepal. The country has more than 6 000 rivers with a collective annual water yield of about 200 billion m³. Almost 80 per cent of the river flow occurs in the four monsoon months when the rivers carry high sediment loads created by erosion, landslides and mass movements. Nepal's rivers can be classified into 'Himalayan", 'Mahabharat" and 'Chure" types on the basis of their origin. Himalayan rivers originate in the snow-capped mountains and are fed by melting snow and glaciers and rainfall, with sustained dry season flows. Mahabharat rivers originate in the Mid Hills and are mostly fed by rainfall and a limited amount of snow-melt, with low dry season flows. Chure rivers originate in the southern face of the Mahabharat and Chure Hills. These rivers are flashy in nature and rainfall in the catchment may lead to instantaneous peak flows. The upper sections of the Chure rivers are braided and the rivers meander as they flow southwards along Nepal's Tarai into the northern and eastern Indian States of Uttar Pradesh, Bihar and West Bengal.







Source: LPR (2014)



Source: Fritzsche et al, (2014)/EURAC (2014)

Nested ecological, social and economic systems

River ecosystem elements such as flow channel, floodplain, land and land use types in the riparian areas directly link rivers with human habitats, agricultural lands, forests, grasslands, wetlands and plant and animal biodiversity. Rivers provide many ecosystem services and support local livelihoods. Hydrological (water flow and distribution), geological (erosion and sedimentation), biochemical (disintegration and synthesis: nutrient recycling) and biological (conversion of water, nutrients and energy into food) processes govern the supply of services to social and economic systems embedded within the larger ecosystem. The impact of rising temperature and changing precipitation will be felt across interdependent natural and social systems. Both climatic and non-climatic factors affect ecosystems and the services they generate and have social and economic implications.

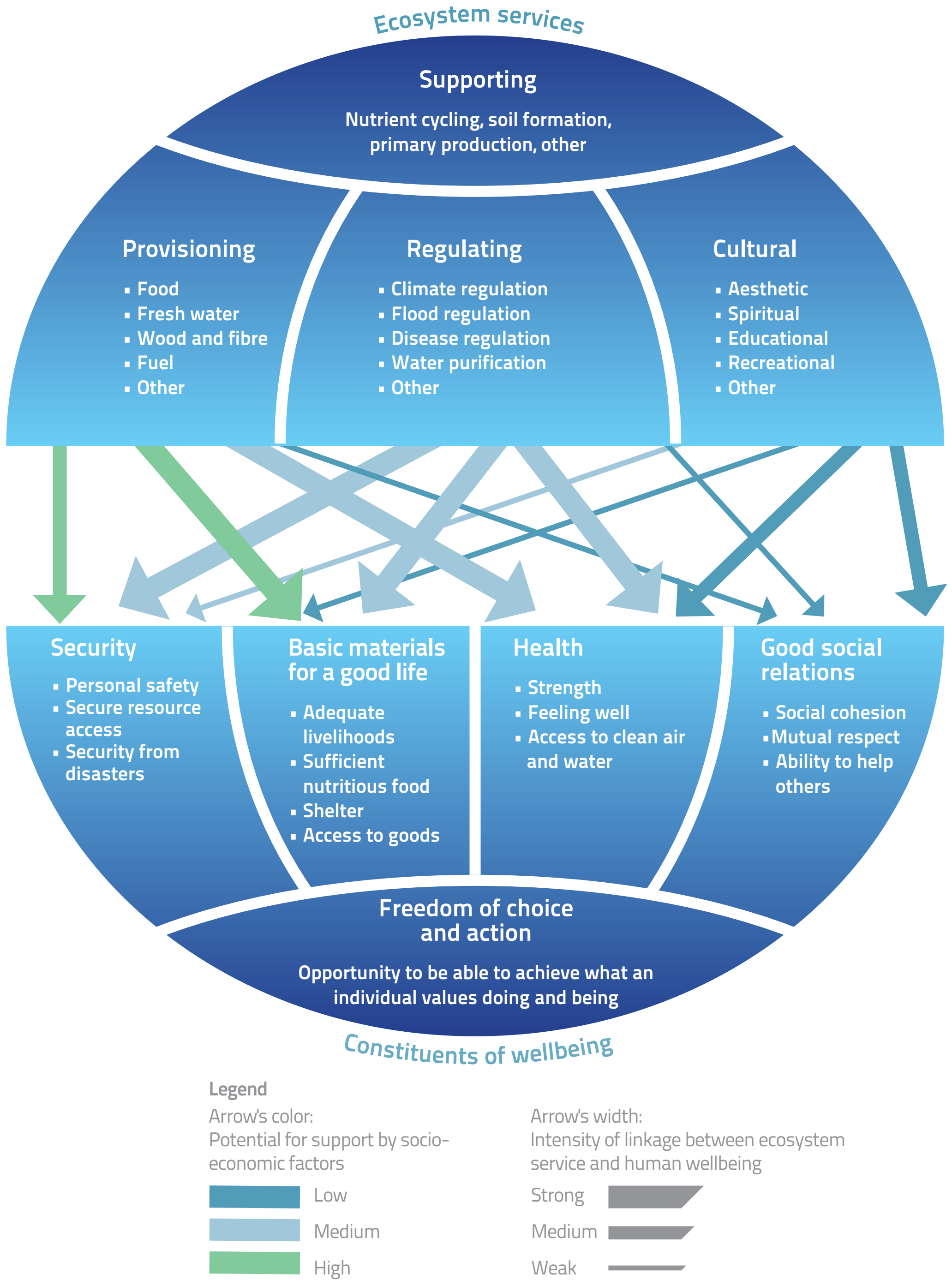
Ecosystem services and human wellbeing

Ecosystems produce services of national, regional and global value. They are defined by the Millennium Ecosystem Assessment (MEA) as 'provisioning services such as food and water, dynamic complexes of plant, animal, and micro-organism communities and the non-living environment, interacting as a functional unit" (MEA 2005). Ecosystems help regulate floods, drought, land degradation and diseases and provide support services such as soil formation and nutrient recycling as well as recreational, spiritual and religious services and other non-material benefits (MEA, 2005). Ecosystem health determines the wellbeing of most of Nepal's population as well as that of the northern Ganga plains of India.

General ecosystem services in Nepal

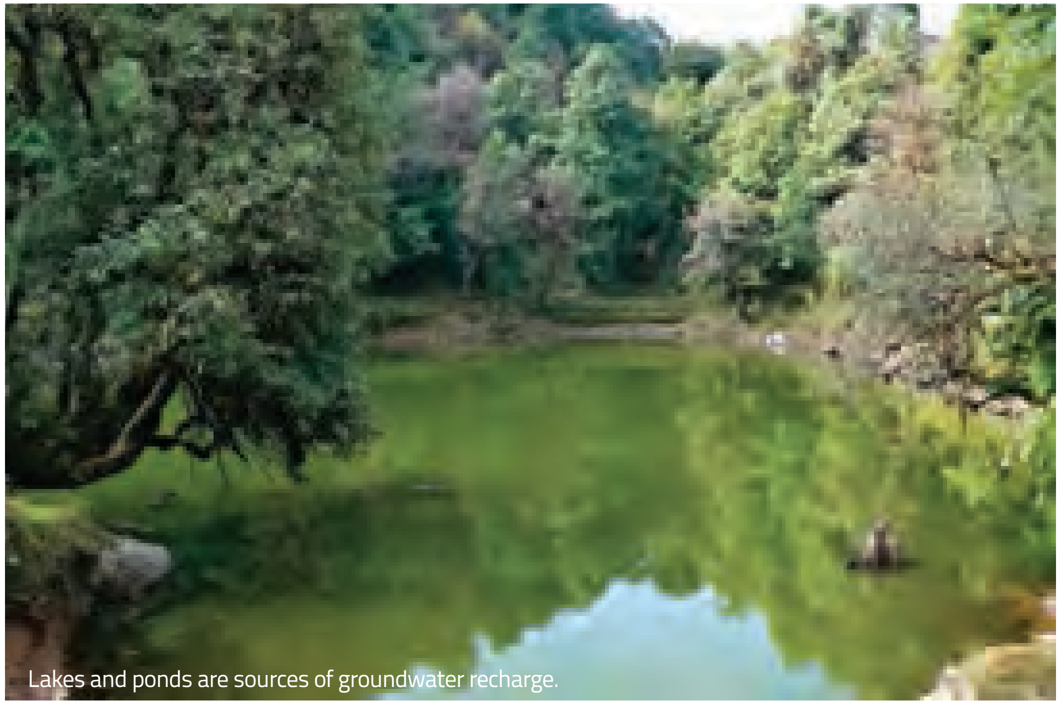
Provisioning	Regulating	Cultural	Supporting
▪ Food, fodder, fuel ▪ Fresh water ▪ Minerals ▪ Industrial raw materials ▪ Pollination ▪ Genetic resources	▪ Climate regulation ▪ Precipitation ▪ Water regulation ▪ Biological control	▪ Recreation ▪ Traditional knowledge ▪ Conservation practices ▪ Agro-biodiversity	▪ Recharging groundwater ▪ Soil formation ▪ Erosion control ▪ Water retention ▪ Nutrient recycling and movement.

Adapted from Rasul, G. (Undated)



Source: MEA (2005)

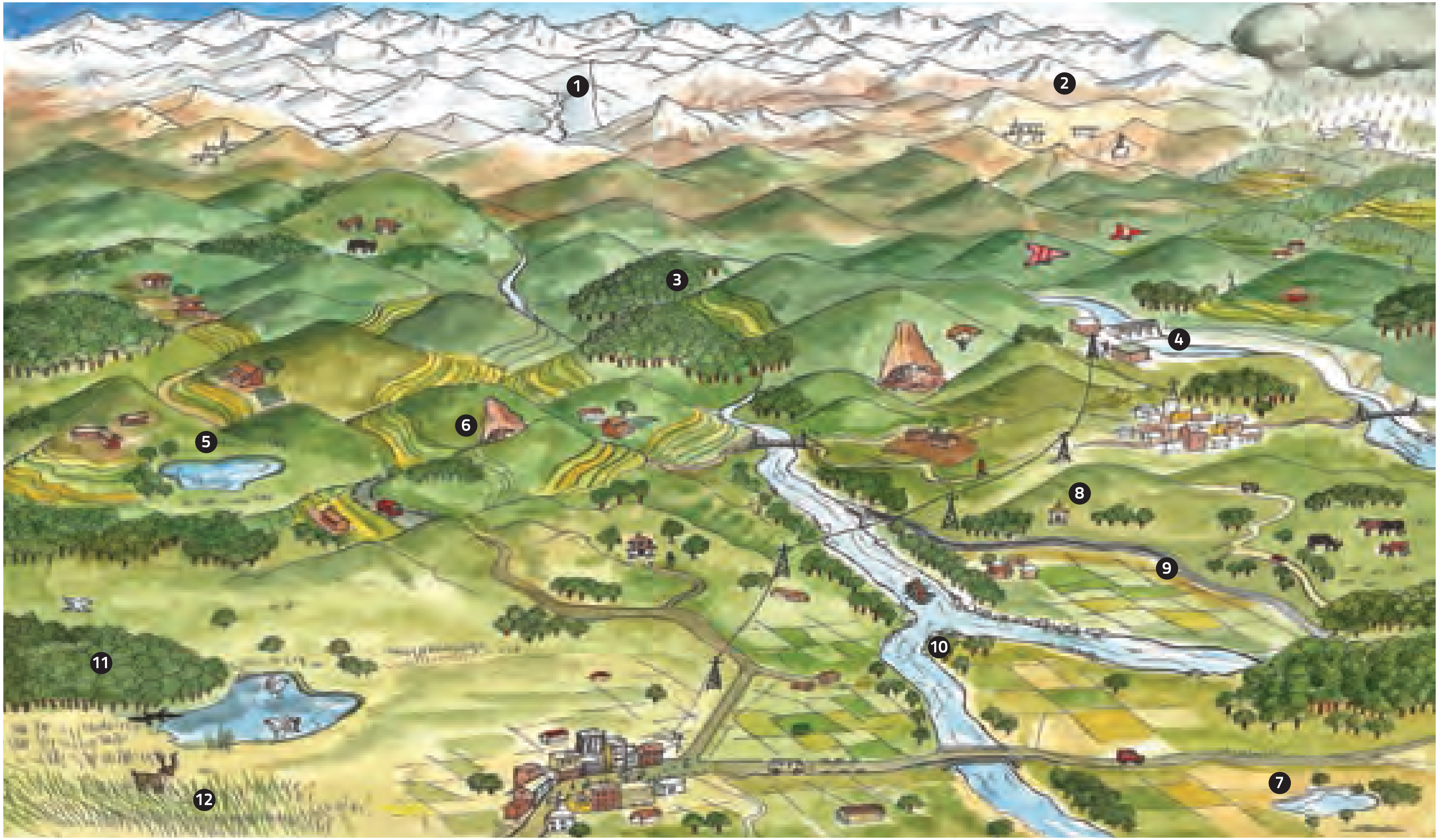

Farming is a labour-intensive activity.


Lakes and ponds are sources of groundwater recharge.


Community participation is an important strategy.

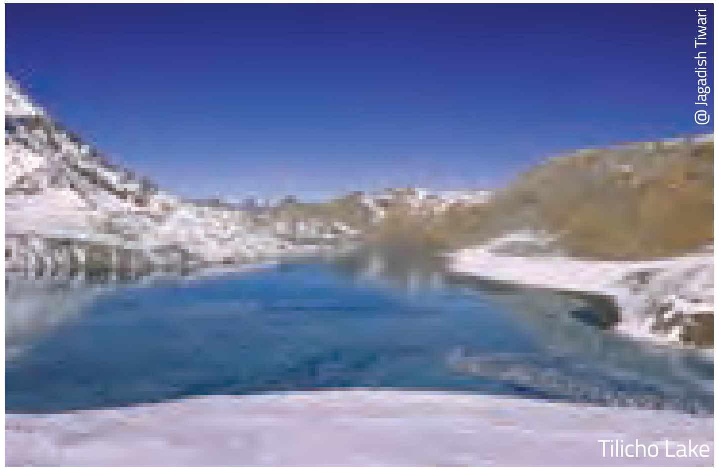

Temples and shrines

Schematic presentation of ecosystem services in Nepal

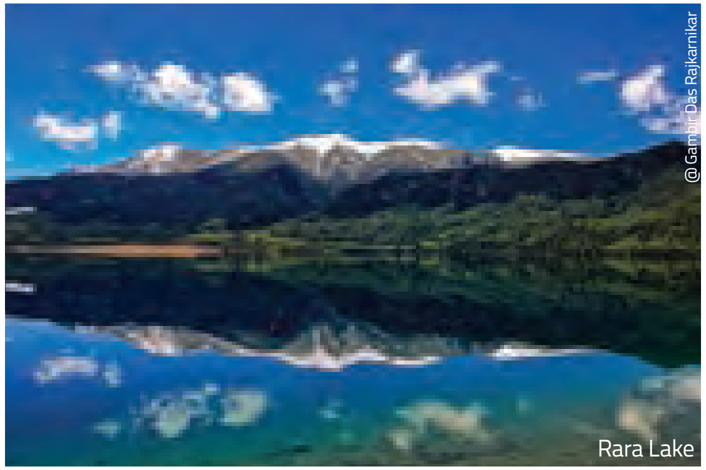


1. The gradual release of water stored in glaciers, glacial lakes and snow packs sustains flows of the perennial snow-fed river and supports downstream communities.
2. The Himalayan range and peaks attract large numbers of back-packers, group trekkers, mountaineers, and pilgrims.
3. Forests produce timber, fuelwoods, fodder, herbs, and medicinal plants; regulate the climate; and help recharge groundwater in hilly micro-watersheds.
4. River water generates the hydroelectric power that supports socio-economic development.
5. Ponds help recharge the springs that feed the thousands of community-based systems that supply drinking water to rural households.
6. Landslides are sources of sediment and can threaten ecosystems, crops and assets. They can occur naturally or be triggered by indiscriminate human actions.
7. Lakes and ponds possess value in their ability to maintain ecosystem integrity.
8. Temples, shrines, and stupas offer religious and spiritual satisfaction, which also offer opportunities for promoting tourism.
9. Both farmer- and agency-built irrigation systems support agriculture, enhance crop production, and help ensure food security.
10. Rivers, where rafting and canoeing are popular, are sources of recreation, jobs, and revenue. They sustain aquatic ecosystems and local communities, which depend on river water for irrigation and livelihoods. Rivers also provide religious and cultural services, including providing a venue for cremations and ritual baths.
11. Tarai forests that are home to rhinoceroses and royal Bengal tigers provide the opportunity to offer safaris to domestic and international tourists.
12. Tarai wetlands support diverse aquatic life forms and livelihoods, including fishing.

Some of Nepal's various ecosystems



Tilicho Lake

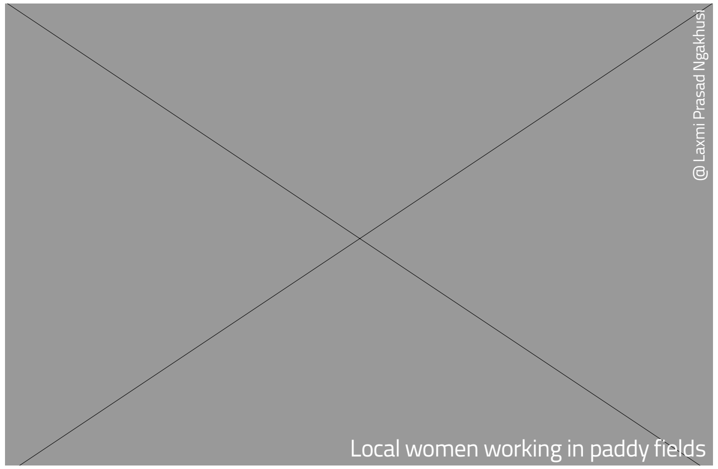

Rara Lake

Begnas Lake

Mid-Hill region with settlements and maize field

Tarai wetland

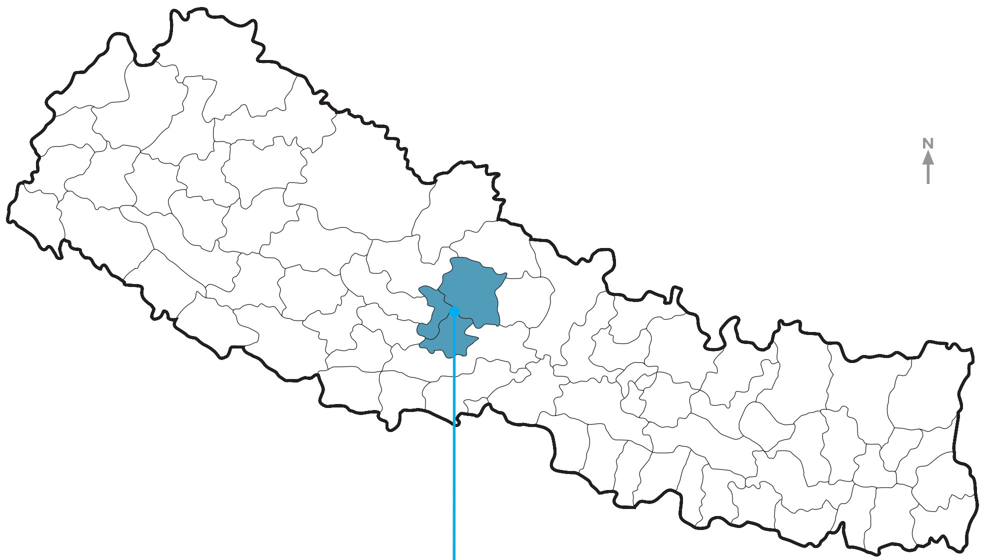

Tarai forest and grass land



Local women working in paddy fields

Mid-Hill river valley


Group of women go fishing in Tarai



The Panchase Mountain Ecological Region

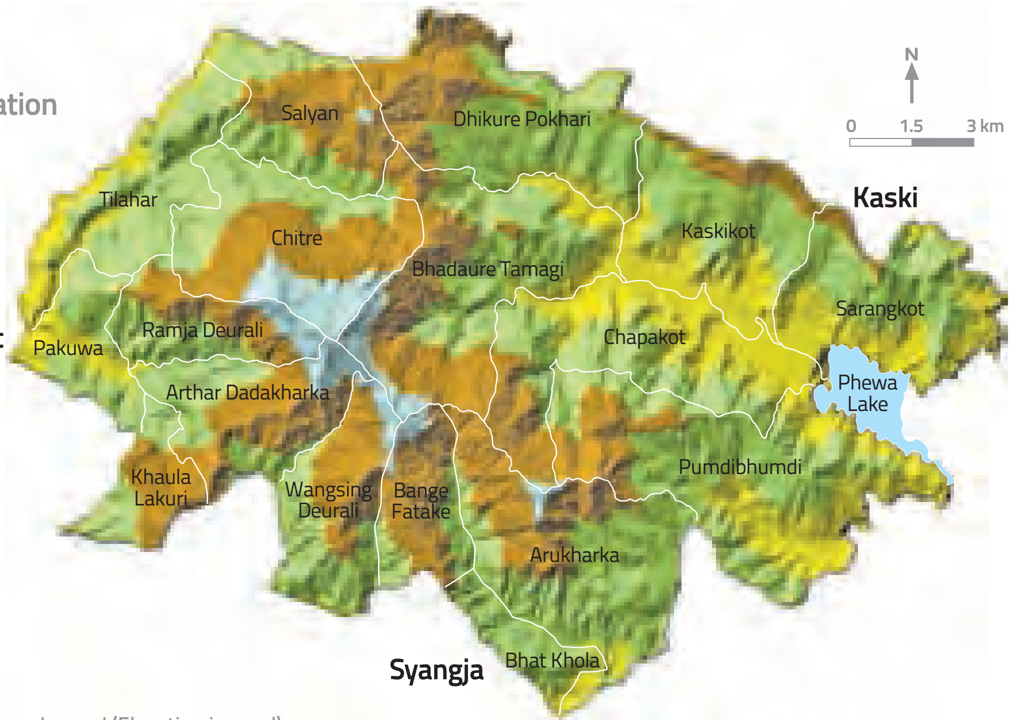
Straddling the three districts of Kaski, Syangja and Parbat in western Nepal, the PMER covers an area of 283 km^2 spread across 17 Village Development Communities (VDCs), the lowest levels of governance in the country.

Degree of slope

Legend (Slope in degrees)

0-15 | 16-30 | 31-45 | 46-60 | 61-90

Elevation



Legend (Elevation in masl)

2,500-2,000 | 2,000-1,500 | 1,500-1,000 | Less than 1,000

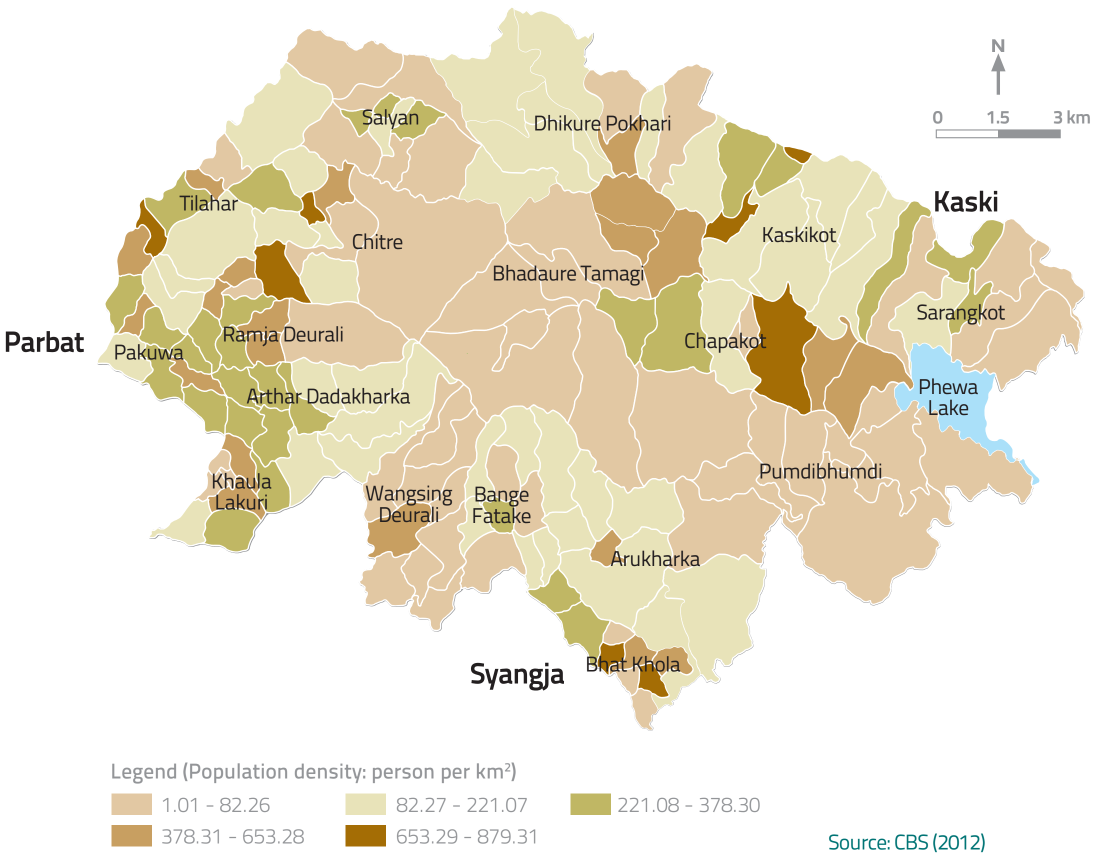
Slope and elevation

The PMER elevation ranges from 742 m above sea level along Phewa Lake to 2 517 m at Panchase Peak. Almost 79 per cent of the area (223.57 km^2) is situated at altitudes ranging between 1 000 and 2 000 m, with only four per cent (11.32 km^2) having a higher elevation and the remaining 17 per cent (48.11 km^2) at lower altitudes. A significant proportion of the land lies on steep or extremely steep slopes near Panchase Peak. Areas nearer the valley floors are either flat or gently or moderately sloping. The landscape comprizes alternating ridges and valleys.

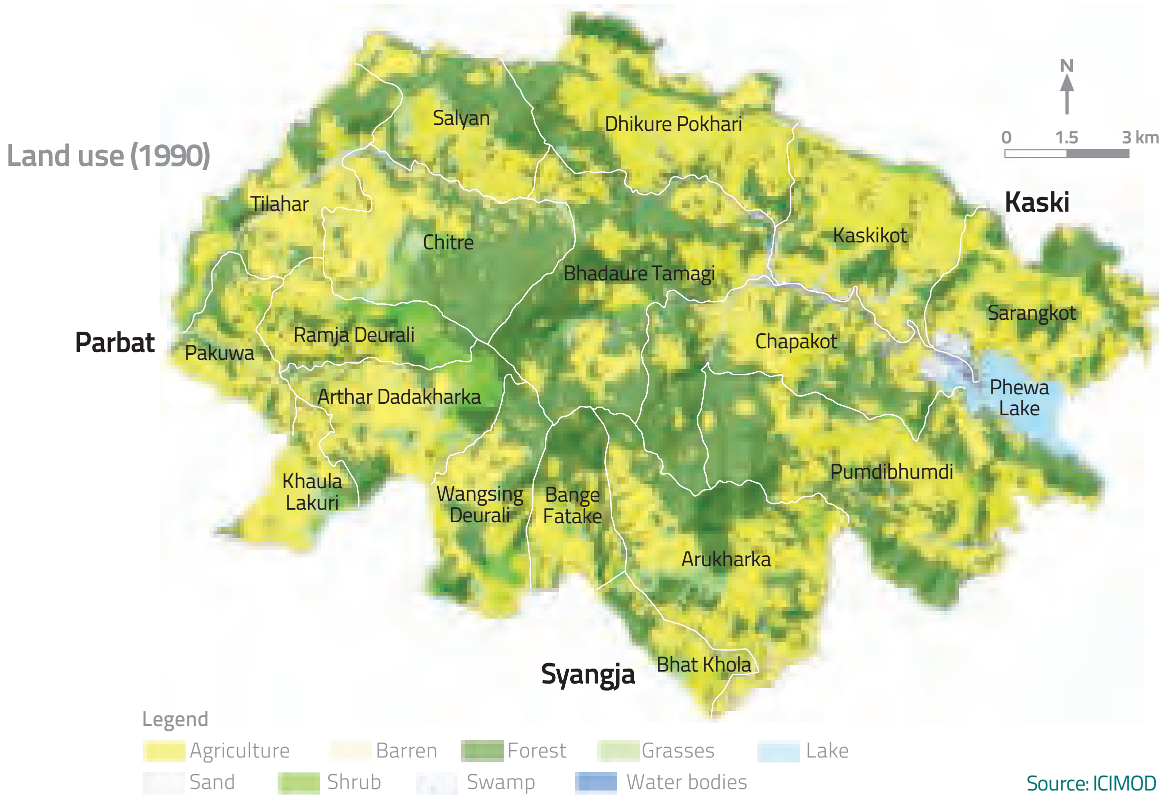
Population and livelihood

The VDCs located in the PMER are home to 62 000 people, 56 per cent of them women. Young men and women are migrating out of the region, creating a demographic shift that is changing the socio-economic context of the PMER. More than two-thirds of PMER households have one or more members employed in Southeast Asian or Gulf countries. Local communities depend on natural resources for sustenance. The region is sparsely populated, with settlements located in the middle elevation region. According to the 2011 national census, the PMER is home to 15 caste and ethnic groups and the average household size is 4.7. Agricultural activities including crop farming and livestock rearing, together with nature-based livelihoods are the main sources of income. Some households make a living from beekeeping and coffee and vegetable farming. PMER residents also work as teachers, civil servants and wage labourers.

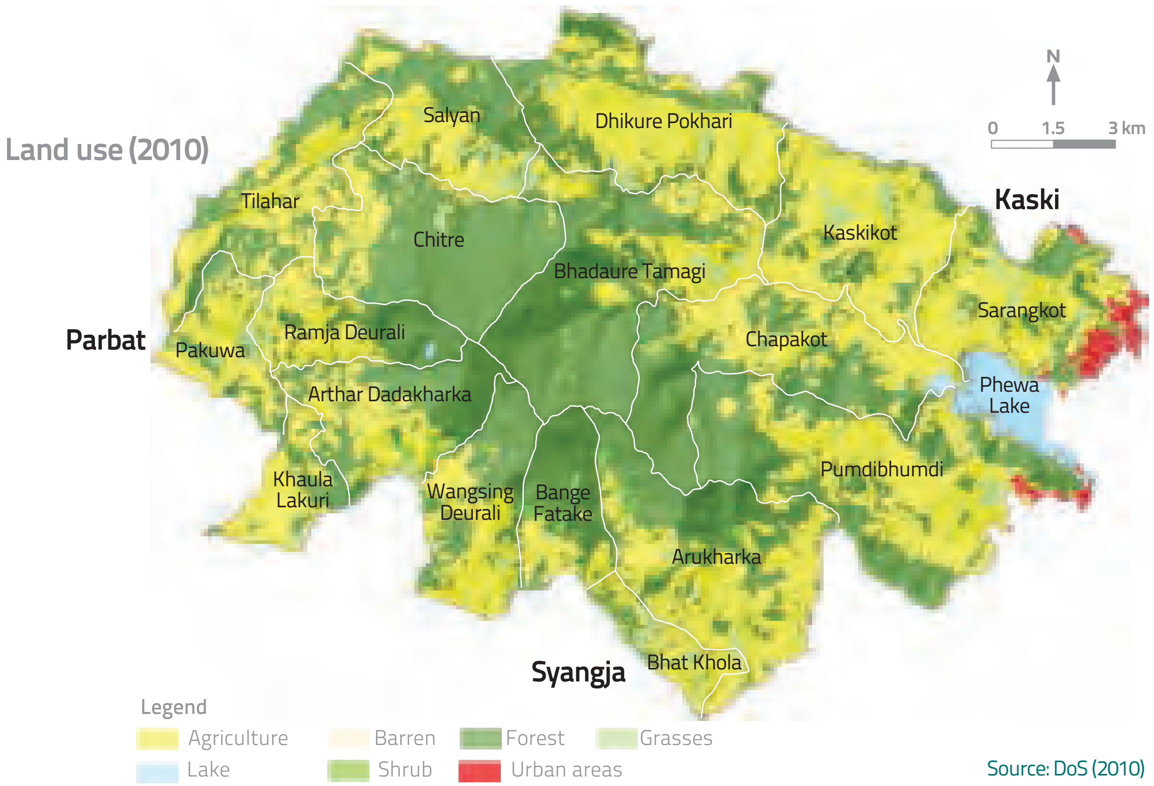
Population density



Source: CBS (2012)



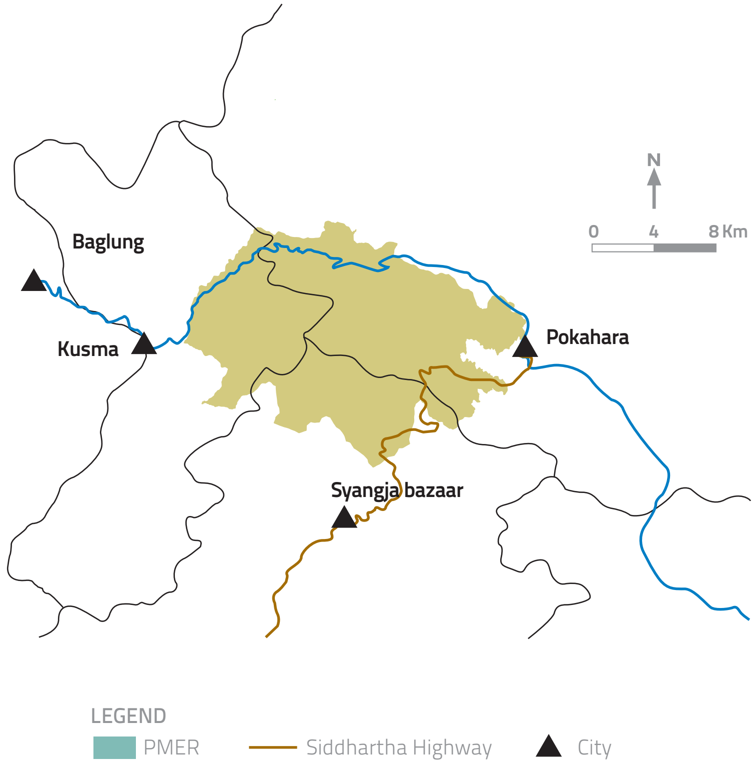
Source: ICIMOD



Source: DoS (2010)

Changes in land use

The PMER is close to the towns of Kusma in Parbat District, Baglung on the border of Myagdi and Parbat Districts and Putali Bazaar in Syangja District. While the population of these towns is declining, the population of Pokhara city is growing rapidly and is responsible for gradual changes in land use at low elevations in the PMER.

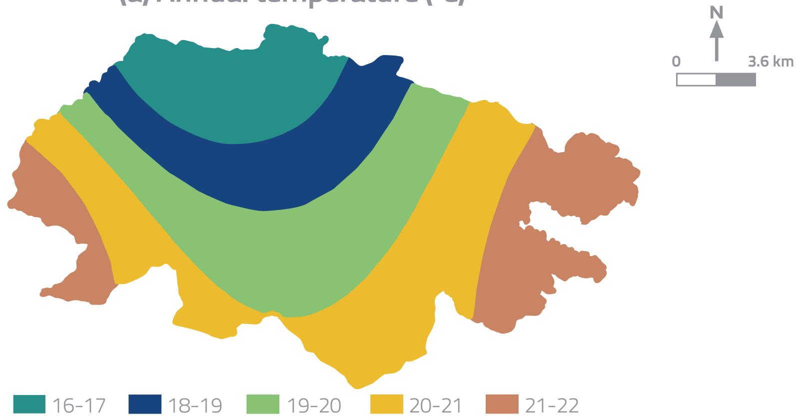


Climate monitoring stations in the Panchase

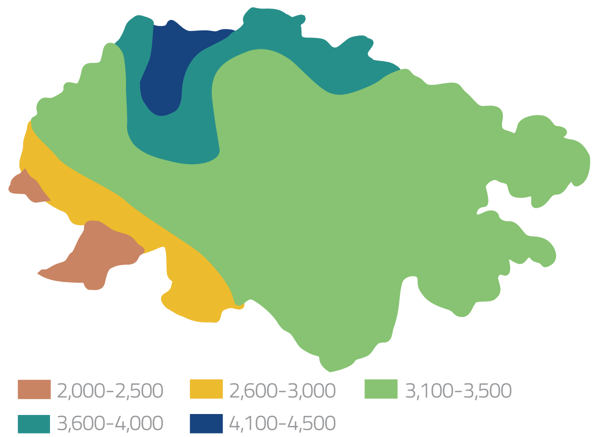
There are only a few meteorological stations in the PMER. While records are available for Lumle, a town located at a horizontal distance of 18 km northwest of the PMER, these do not capture the micro-scale characteristics of the PMER. The paucity of monitoring stations limits climate analysis and data from adjoining stations is used to extrapolate temperature and rainfall variations across the pre-monsoon, summer monsoon, post-monsoon and winter seasons.

Note: The numbers are the station designations assigned by the Department of Hydrology and Meteorology.

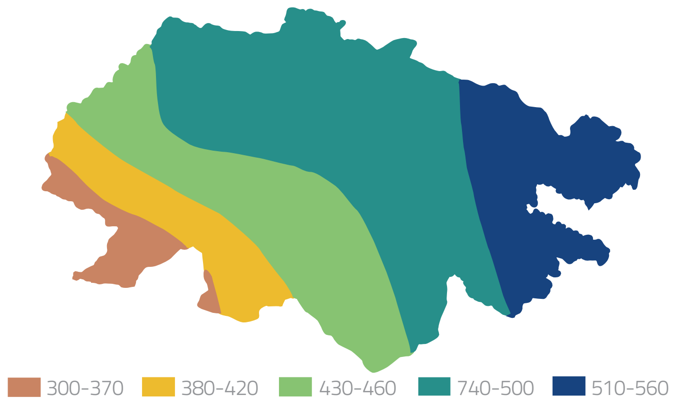
(a) Annual temperature (ºC)



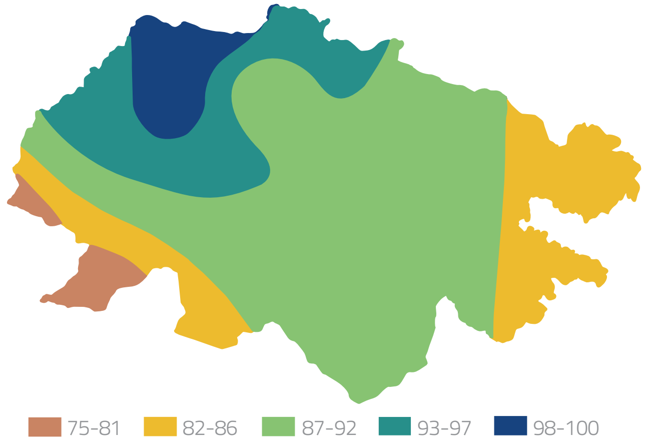
(c) Summer monsoon rainfall (mm)



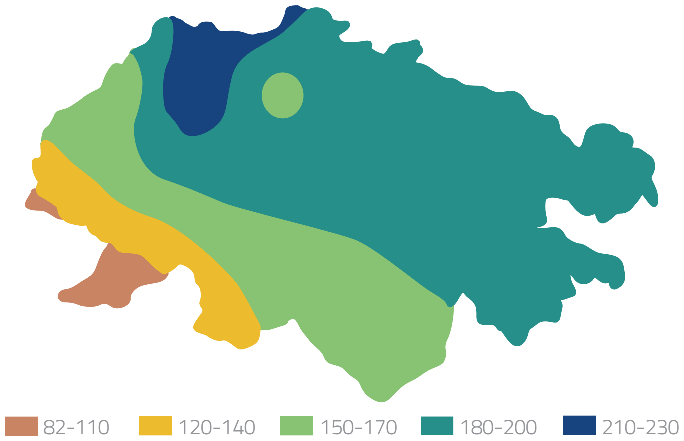
(b) Pre-monsoon rainfall (mm)



(d) Post-monsoon rainfall (mm)



(e) Winter monsoon rainfall (mm)



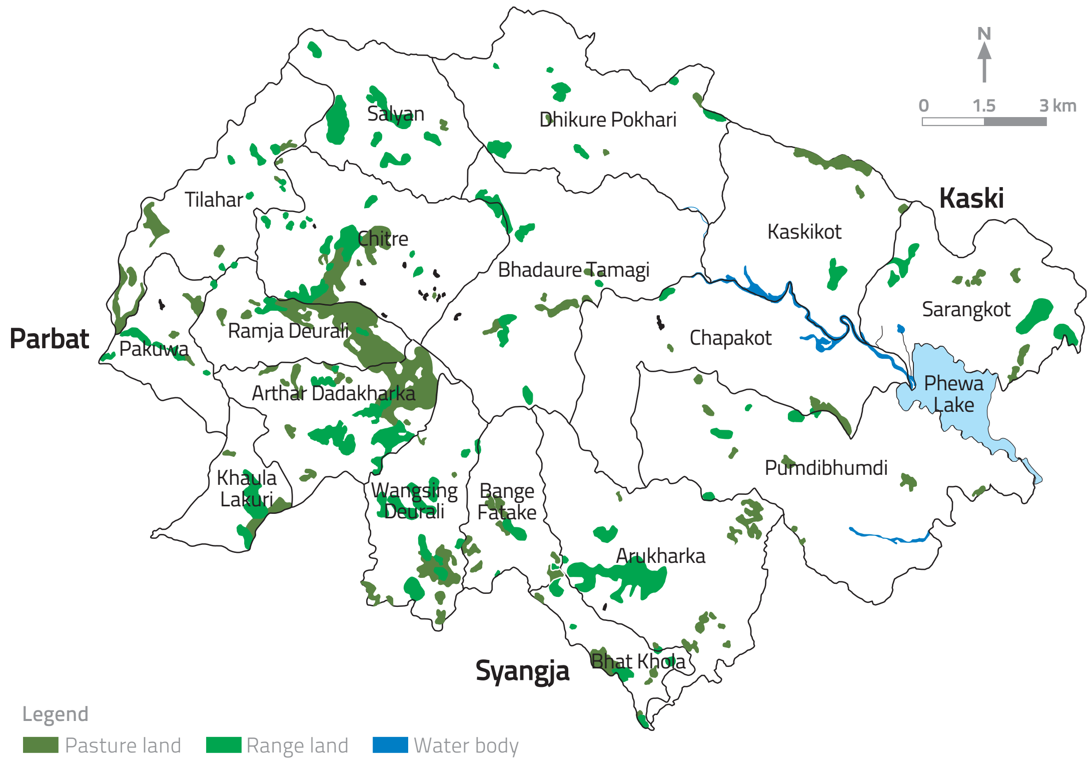
Rainfall and temperature in the Panchase

The PMER climate varies from sub-tropical to temperate. Summers are generally warm at low elevations but cold at high elevations. The annual average maximum temperature is 29.16°C and the average minimum temperature is 5.3°C. Based on data extrapolated from stations around the PMER, the mean annual rainfall is estimated to be 3 880 mm. However, Lumle station records 5 402 mm annual rainfall. On 10 June 2013, Pokhara Airport recorded 107.8 mm rainfall in one hour, the highest recorded hourly rainfall in Nepal's history.[5] The diagrams show temperatures and lines of equal rainfall in the PMER. Climate change will alter the existing seasonal rainfall pattern in the PMER, putting its ecosystems under stress and manifested in a decline in the quality of the goods and services generated by the ecosystems.

[5] The highest recorded rainfall before this was 70 mm per hour at Tistung Makawanpur, in 1993. The highest 24-hour rainfall recorded was 540 mm. See (NCVST 2009)

Ecosystems of the PMER

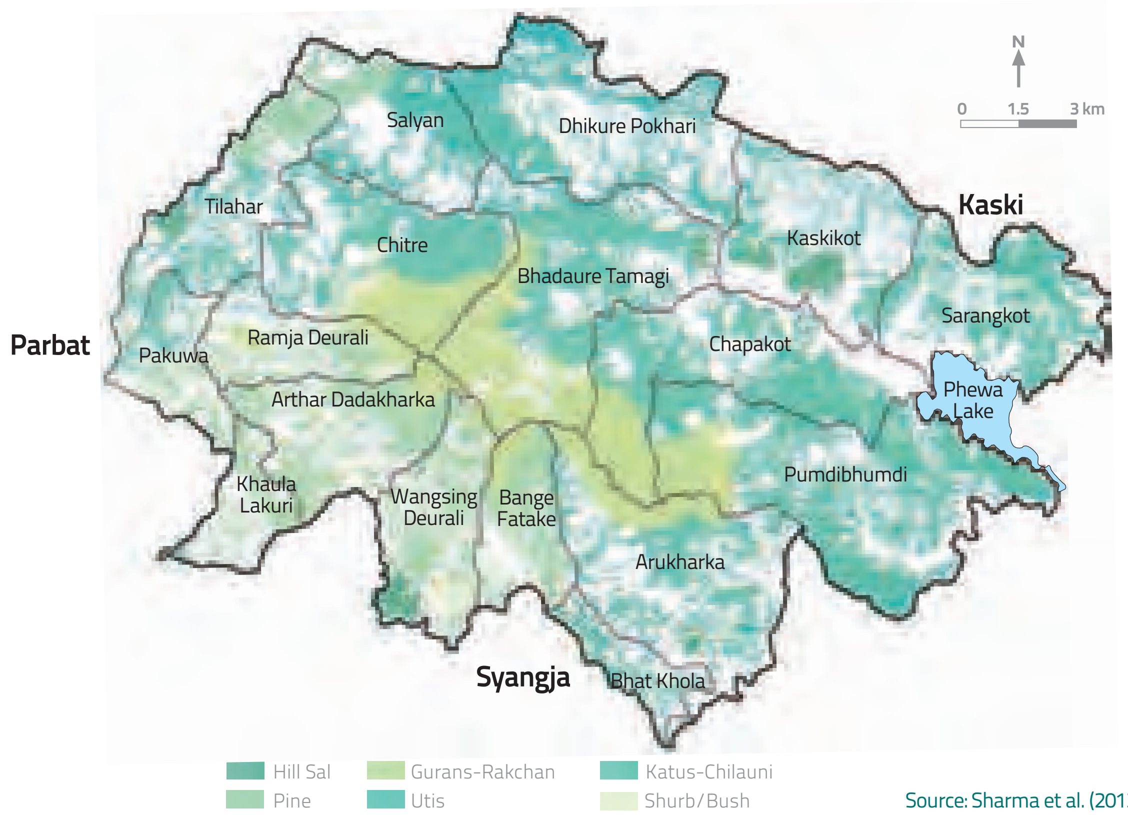
A variety of forests, different vegetation species like rhododendron and endemic orchids, wetlands, lakes, rivers, agricultural land, religious and cultural sites are found at different elevations across the PMER. These need to be conserved to ensure the integrity of the local biodiversity and ecosystem services.



Ecosystem types	Area (km²)	Per cent
Forest	170	61
Agricultural	95	34
Grassland	7.8	2.8
River	1.98	0.7
Wetland	1.20	0.4
Other	2.09	0.8

Source: MoFSC (2013)

Note: Based on Google Pro and land use maps.
The status and spatial extent of each ecosystem and land-holding and ownership patterns need to be further validated.



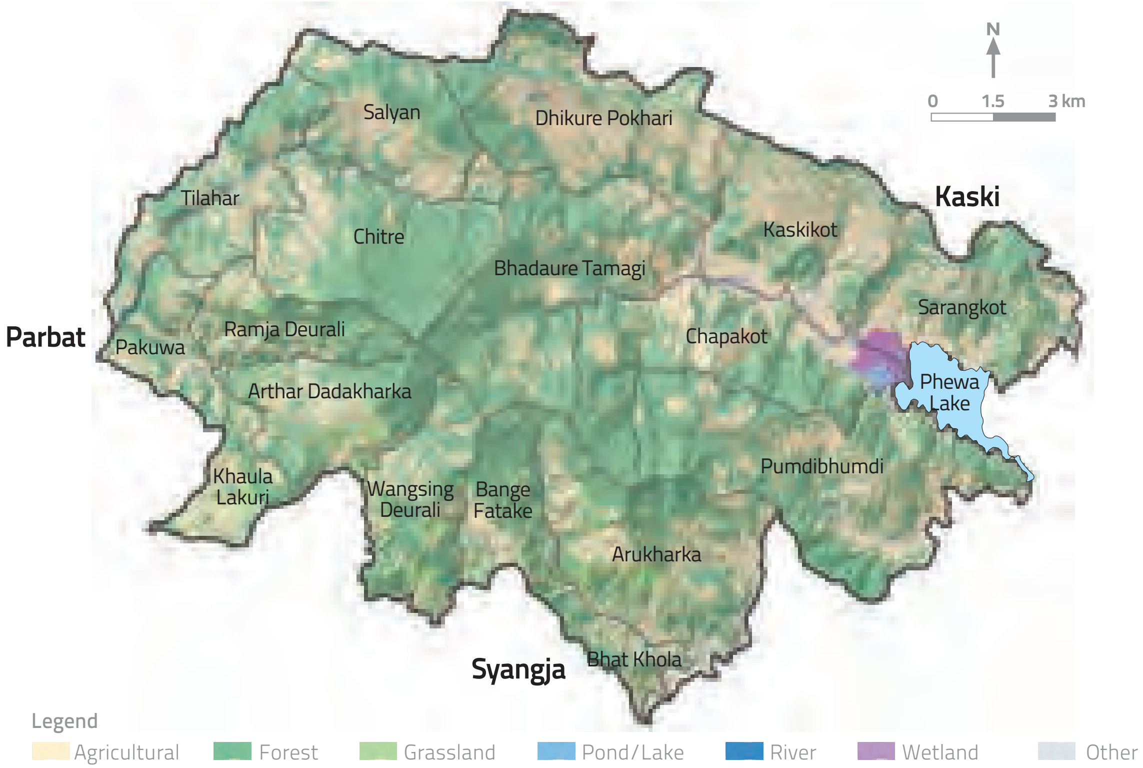
Source: Sharma et al. (2013)

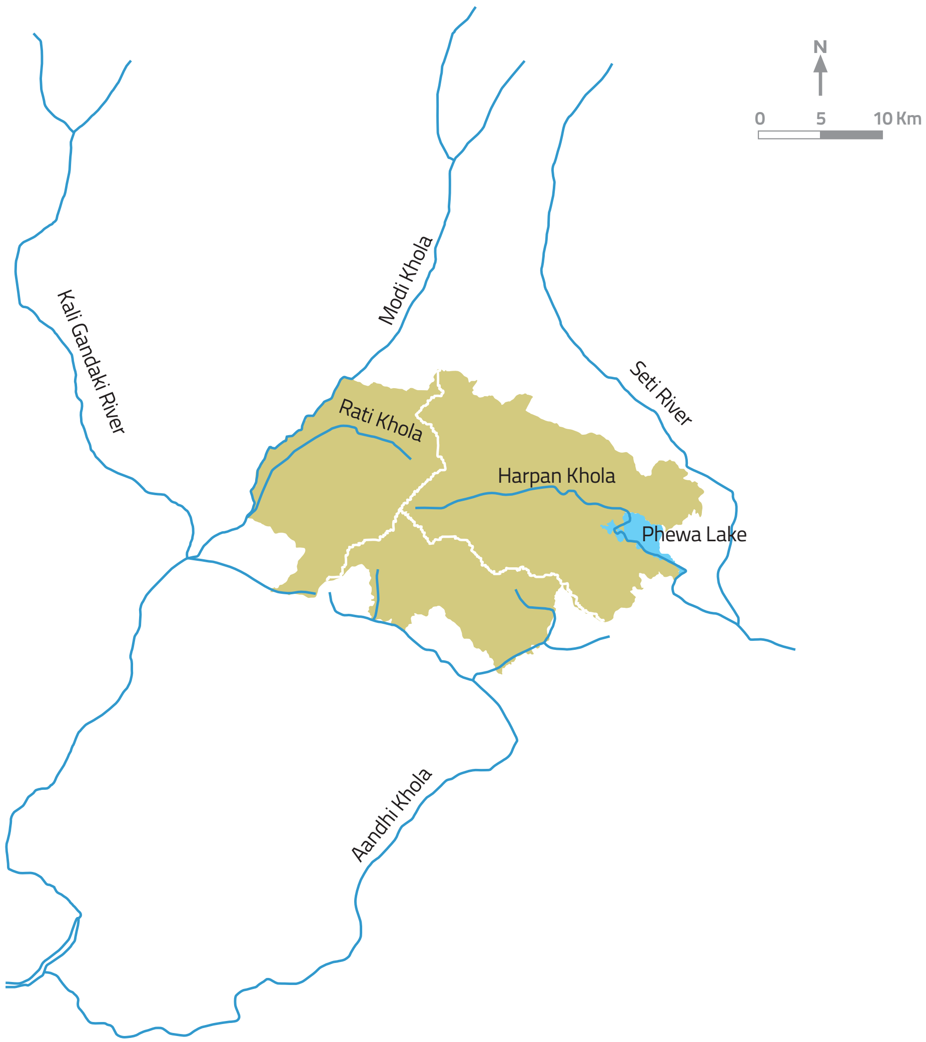
Forest ecosystem

The PMER has a wide variety of flora and fauna. Forests are not only important animal and plant habitats but also critical for local livelihoods.

Agricultural ecosystems

Subsistence-farming, dominated by food crops is the main livelihood in the PMER. Almost all farmers cultivate cereals (paddy, maize, wheat, barley, finger millet, naked barley and common buckwheat), legumes (soybeans, black gram and lentils), oil seeds (rapeseed and mustard), vegetables (potato, onion, cabbage and cauliflower), spices (ginger, turmeric and garlic) and horticultural crops on homesteads situated on either rain-fed uplands known locally as "bari" or irrigated lowlands known as "khet". As agriculture is mainly dependent on rainfall, it is sensitive to climate change.





River systems

The Seti, Modi Khola and Aandhi Khola rivers flank the PMER. The headwaters of the Aandhi Khola originate in the PMER as do the headwaters of Phewa Lake which is fed by the Harpan and the Rati/Jare rivers, also within the PMER. Both Phewa Lake and Aandhi Khola have been harnessed for hydropower generation and irrigation. With its unique location, Phewa Lake is a tourism, recreation and fish-farming site. This study has divided the PMER into 13 sub-watersheds.

Roads and trails

PMER residents want a road network to avoid the drudgery of walking up and down long and steep slopes. In 2014, the PMER had a total of 137 km of district-level roads (60 km in Kaski, 65 km in Parbat and 12 km in Syangja Districts), connecting different VDCs. Five trekking trails with a total length of 48 km link settlements, pilgrimage sites, lakes and scenic spots. About 10 buses and 10 jeeps are reported to be daily transporting people between Pokhara, Kushma and Putali Bazaar and other municipalities and towns. The road network links people to non-farm and other sources of income thereby helping locals overcome hazards such as floods and landslides that may be exacerbated by climate change. However, improperly built and poorly maintained roads can disturb the local hydrology, adversely affecting the flow of springs and streams. In some cases, as shown by the photograph on the next page, these types of roads can increase landslides, sediment flow and siltation.

Source: ISET-N field study (2013)

Note: This map is prepared using Google Pro and validated locally using GPS.


Cutting upper slopes releases a sediment mass.
Water flow carries that mass downward
The mass brought down by water then alters the dynamics of downstream river reaches and damages farms, communities and local infrastructure.

Photo: ISET-N

Sedimentation processes

Sheet, rill and gully erosion, landslides and mudflows are the major sedimentation processes in the PMER. Sheet and rill erosion are common on both terraced and sloping lands and, if unchecked, can lead to the formation of active gullies, resulting in landslides. Because of the weakness of the PMER geological formation, landslides, debris flow and landslips are frequent even in areas covered by vegetation and forest. Each landslide adds a huge amount of sediment to the already heavy load created by surface erosion. Irrespective of the type of erosion, rainfall is the primary trigger for sedimentation in the PMER, as is the case in other Mid Hill regions of Nepal. The sediment load is carried downstream where the river flow is too slow to continue carrying the heavy suspended particles that are deposited on floodplains. Only the lightest of particles - silt and clay – are transported further downstream.

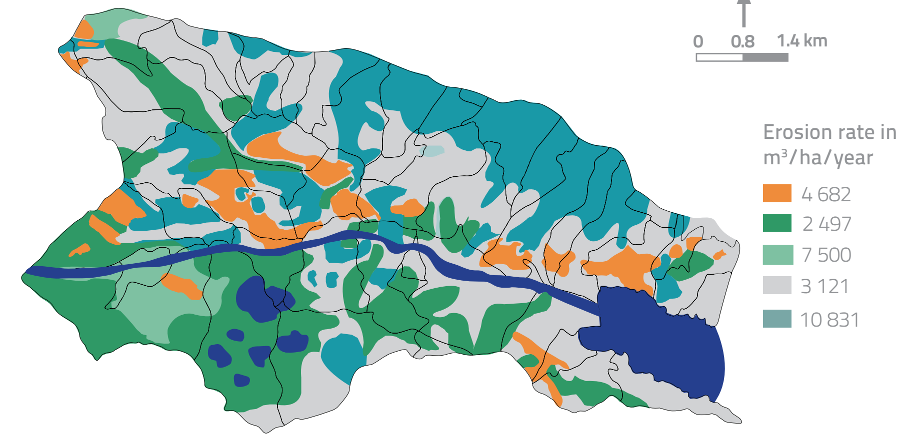
Types of mass wasting

Landslide

Shallow-seated slump

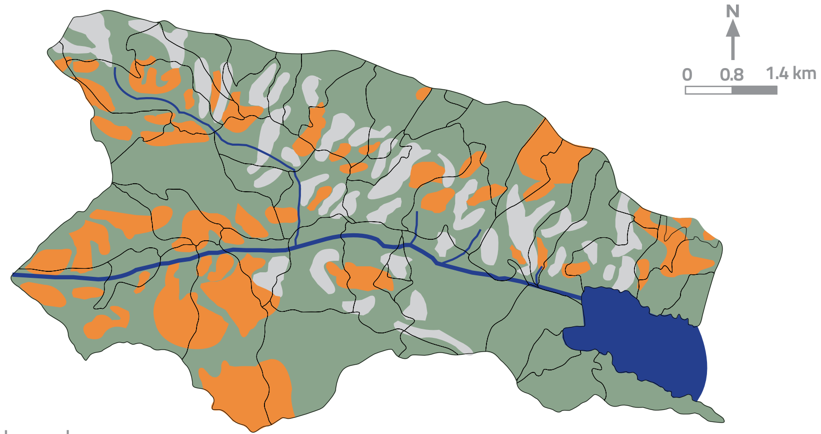
Debris flow

Erosion rates in Harpan Khola sub-watershed



Adapted from Ramsey (1985)

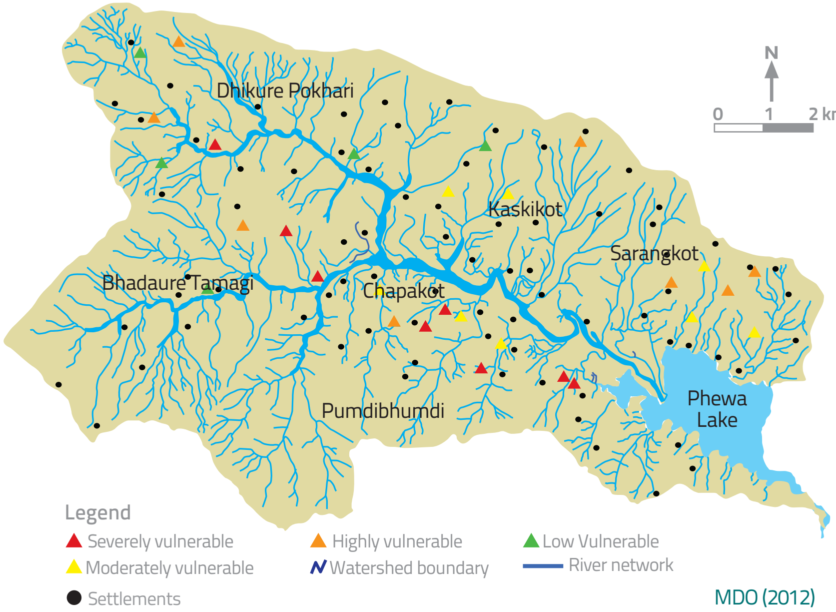
Potential sources of landslides in Harpan Khola sub-watershed



Adapted from Ross (1998)

Two decades of studies of the Harpan Khola sub-watershed have identified various sources of sediment production, including landslides. The effectiveness of initiatives to minimize sedimentation rates has not been well-documented, but there is enough empirical evidence for improved understanding of the potential threat of landslides and other forms of degradation associated with the rise in extreme rainfall induced by climate change.

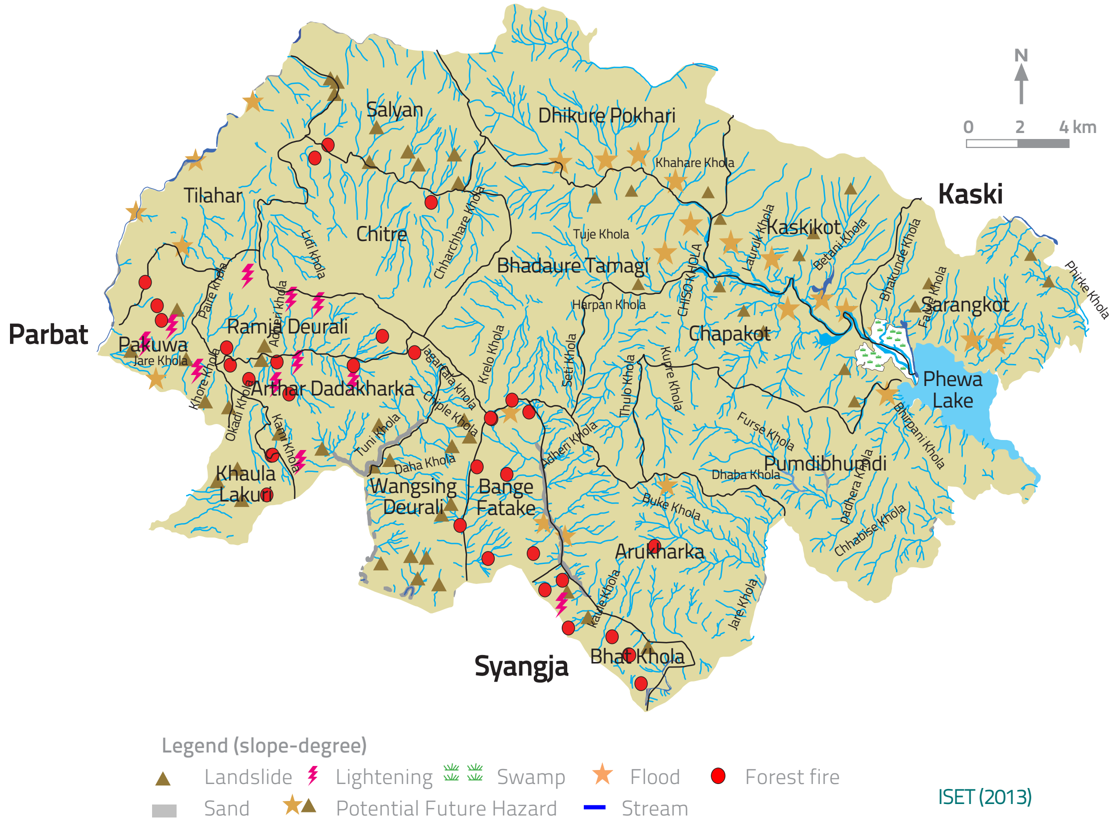
Note: The two maps are based on the GIS database managed by the Department of Survey, and the rates of erosion and potential for landslides are those arrived at in the studies of Ramsay (1985) and Ross (1998). The administrative boundaries at the ward and VDC levels have changed over time and should be treated as indicative.



MDO (2012)

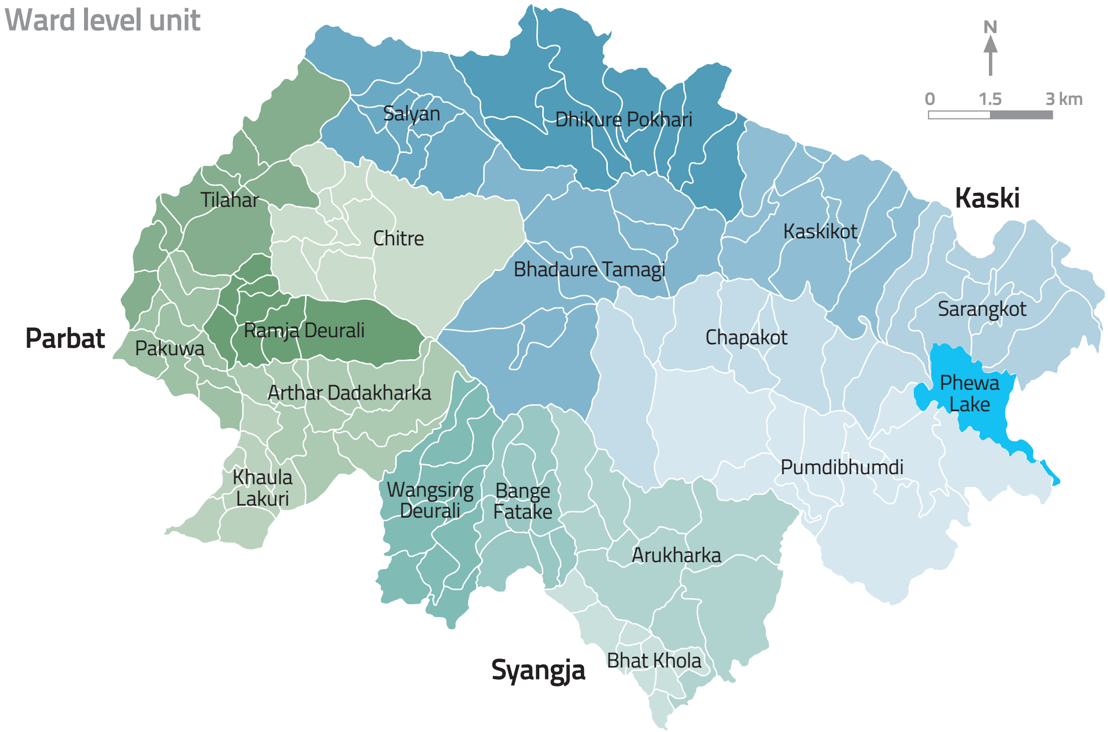
Current landslides

A 2013 ISET-N study found that all PMER sub-watersheds are vulnerable to landslides. The maps of the Harpan Khola sub-watershed prepared by the Machhapuchre Development Organization (MDO) and MoFSC show details of landslide locations (MDO 2012, MoFSC 2013). Landslide hazards need to be minimized to maintain the productivity and regenerative capacity of agricultural and forest ecosystems.



ISET (2013)

Ward level unit



Sub-watershed level unit

Spatial units: wards and sub-watersheds

The 17 VDCs in the PMER were chosen as the spatial unit for assessing vulnerability to climate change. Compared to other ecosystems such as a mangrove forest or a rainforest, the PMER is small. Despite its size, the PMER is home to diverse ecosystems. Therefore the assessment covered all elements of the different ecological, physical and social systems in the 153 PMER wards. The ward-level assessment was then aggregated to create vulnerability categories at the sub-watershed level. The fact that the boundaries of the wards and the 13 sub-watersheds did not coincide meant that the data had to be adjusted and this added an element of uncertainty to the assessment.

Indicators and Vulnerability categories

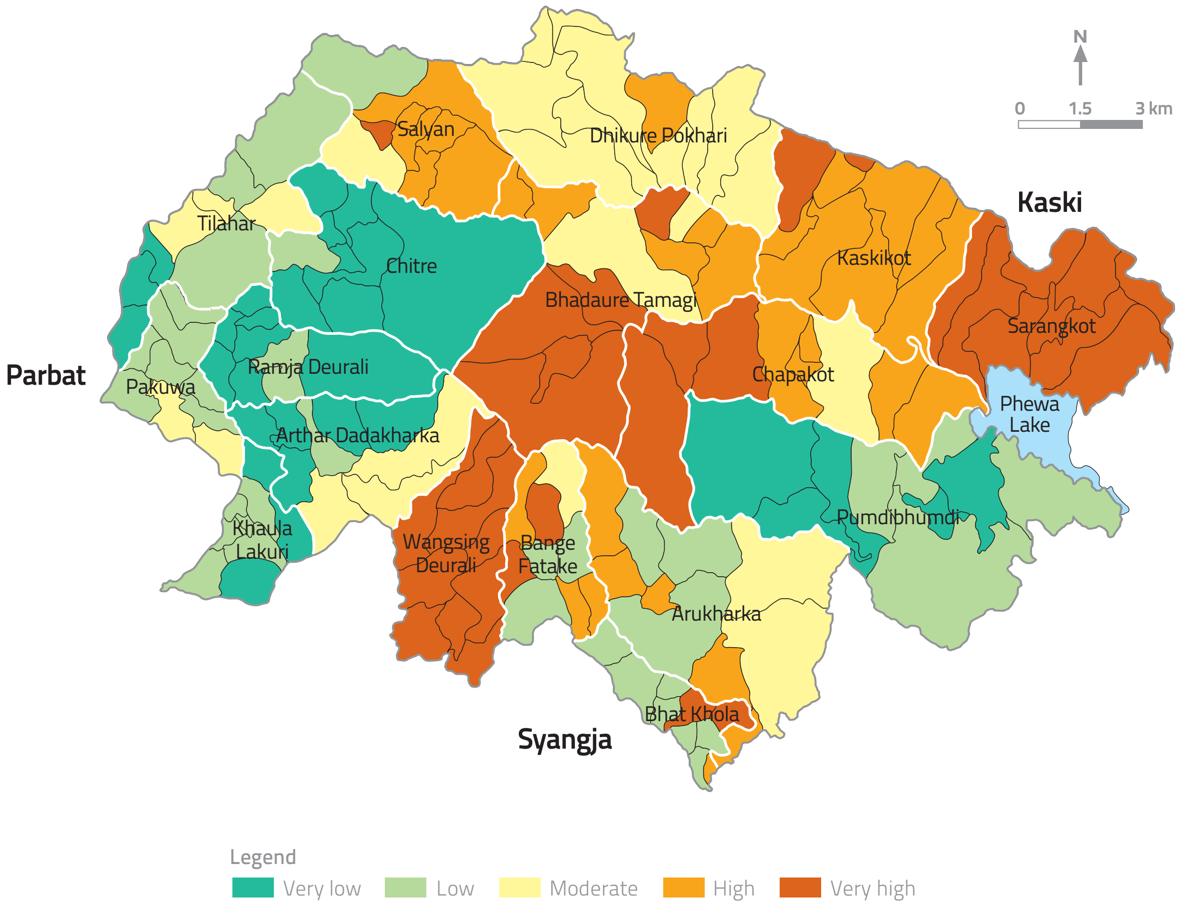
Data on all 32 indicators was collected for each of the 153 wards and weighted to calculate a vulnerability index for each.[2] For each indicator, a value of 1 was assigned to the ward with the best score and 153 to the ward with the worst score.

Each exposure and sensitivity variable was assigned a numerical value of up to 0.5. A joint exposure and sensitivity value was then calculated, weighted equally, with a total maximum value of 1. From that total, a value for adaptive capacity, also a maximum of 1 was subtracted to yield a composite vulnerability index ranging between -1 and +1. A color code was used to designate the five vulnerability categories as follows: very high (red, 0.61 to 1), high (orange, 0.21 to 0.60), moderate (yellow, 0.21 to 0.19), low (light green, -0.2 to -0.6) and very low (dark green, -0.6 to -1). The vulnerability indices for the VDC and sub-watershed level were calculated by summing the vulnerability indices of the constituent wards.

- **Very high vulnerability** (0.61 to 1.00)
- **High vulnerability** (0.21 to 0.60)
- **Moderate vulnerability** (0.21 to 0.19)
- **Low vulnerability** (-0.20 to -0.60)
- **Very low vulnerability** (-0.61 to -1.00)

[2] Eight indicators were related to the ecosystem and its condition, another eight to exposure and 16 to adaptive capacity.

Categories	Indicators	Rationale
Exposure	Landslide-affected area (per cent)	Affected land makes residents vulnerable and limits agricultural production.
	Landslide-affected households (no.)	Indicates high exposure.
	Flood-affected area (per cent)	Decreases arable land and lowers agricultural production.
	Flood-affected households (no.)	Flood-affected households are likely to be more vulnerable than non-flood-affected households.
	Forest fire-affected area (per cent)	Damages vegetation and ecosystems makes land barren and may lead to increased sediment yield.
	Forest fire-affected households (no.)	Affected households will be more vulnerable.
	Change in temperature (degree)	Temperature is directly linked to production, environment, and comfort.
	Change in precipitation (mm)	Precipitation changes are directly linked to production and health of ecosystems.
Sensitivity	Population density (no. of people/km^2)	Higher population density means greater sensitivity to changing climate.
	Landless households (per cent)	Landless households have low adaptive capacity as they are dependent on ecosystem services for their livelihood.
	Food sufficiency (per cent)	Food sufficiency indicates higher capacity to adapt.
	Ecosystem-based households (no.)	Households dependent on ecosystems are vulnerable to climate stress.
	Useful plant species (no.)	Sensitive to changes in climate and variability.
	Invasive species (no.)	Invasive species destroy food crops and NTFPs.
	Pest/disease infestation (no.)	Climate change induced temperature rises triggers infestation.
	Topographic feature (elevation)	Ecosystem characteristics vary according to elevation and high elevations have higher risk of landslides.
Adaptive capacity	Literacy rate (per cent)	A literate population can access and use information to respond to climate change related stresses.
	Walking distance to regular market (km)	Markets in neighborhood enable easier access to purchase food, sell their produces and generate income.
	Primary health service (no.)	Access to primary health services can reduce vulnerability.
	Access to piped water (per cent)	Piped-drinking water system can help improve health condition enhancing adaptive capacity of households during stress.
	Irrigated land (per cent)	Irrigation services increase production and enable crop diversification.
	Households with access to electricity (per cent)	Households can use reliable and affordable energy (electricity) for lightning, cooking, accessing information, manufacturing, commuting and transport, exploring markets, engaging in social networks, and exploring financing opportunities.
	Pakka (cemented) households (per cent)	*Pakka* households may survive climatic hazard, hence used as an indicator of wellbeing.
	Households with mobile phones (per cent)	Mobile phone can help Individuals use it to get information before, during and after hazardous climatic event and make adaptive response.
	Functioning organization (Non-governmental and Community-based Organizations) (no.)	Support households during and in the aftermath of conditions of stress and help in rehabilitation and restoration.
	Government organizations (GOs) (no.)	Provide basic services to local households and communities in normal condition and make emergency responses during disasters.
	Traditional networks (no.)	Traditional networks and local social institutions help community groups enhance their understanding of risks from climate change and identify adaptation solutions that suit their context.
	Finance (cooperatives/saving group) (no.)	Access to loans and financial services can act as safeguard against crop failure and livestock loss and thereby increase adaptive capacity during climatic extremes condition.
	Road density (motorable road) (km/km^2)	Road networks help people move from place of living to workplace and maintain non-farm or agricultural sources of income.
	Open forest area (per cent)	Open forests is vulnerable to degradation that lowers nutrient circulations and does not support building adaptive capacity.
	Close forest area (per cent)	Helps buffer ecosystem services by minimizing erosion and maintaining health of ecosystems.
	River density (no. of river/ha)	High river density can contribute to increase flow response till a certain threshold is reached.



Exposure

In the PMER, exposure to climate hazard is an outcome of the local topography, as well as rainfall and temperature. Eight indicators were used to assess vulnerability to climate change in the PMER wards and the vulnerability rankings were depicted in a map.

Data on the indicators was collected for each ward.

Assumptions: South-facing, steeply sloped areas identified as critical by local stakeholders, are likely to be increasingly exposed to climate-related events such as rising temperature and unpredictable and extreme rainfall.

Indicators

- Landslide-affected area (per cent)
- Landslide-affected households (no.)
- Flood-affected area (per cent)
- Flood-affected households (no.)
- Forest fire-affected area (per cent)
- Forest fire-affected households (no.)
- Change in temperature (degree)
- Change in precipitation (mm)

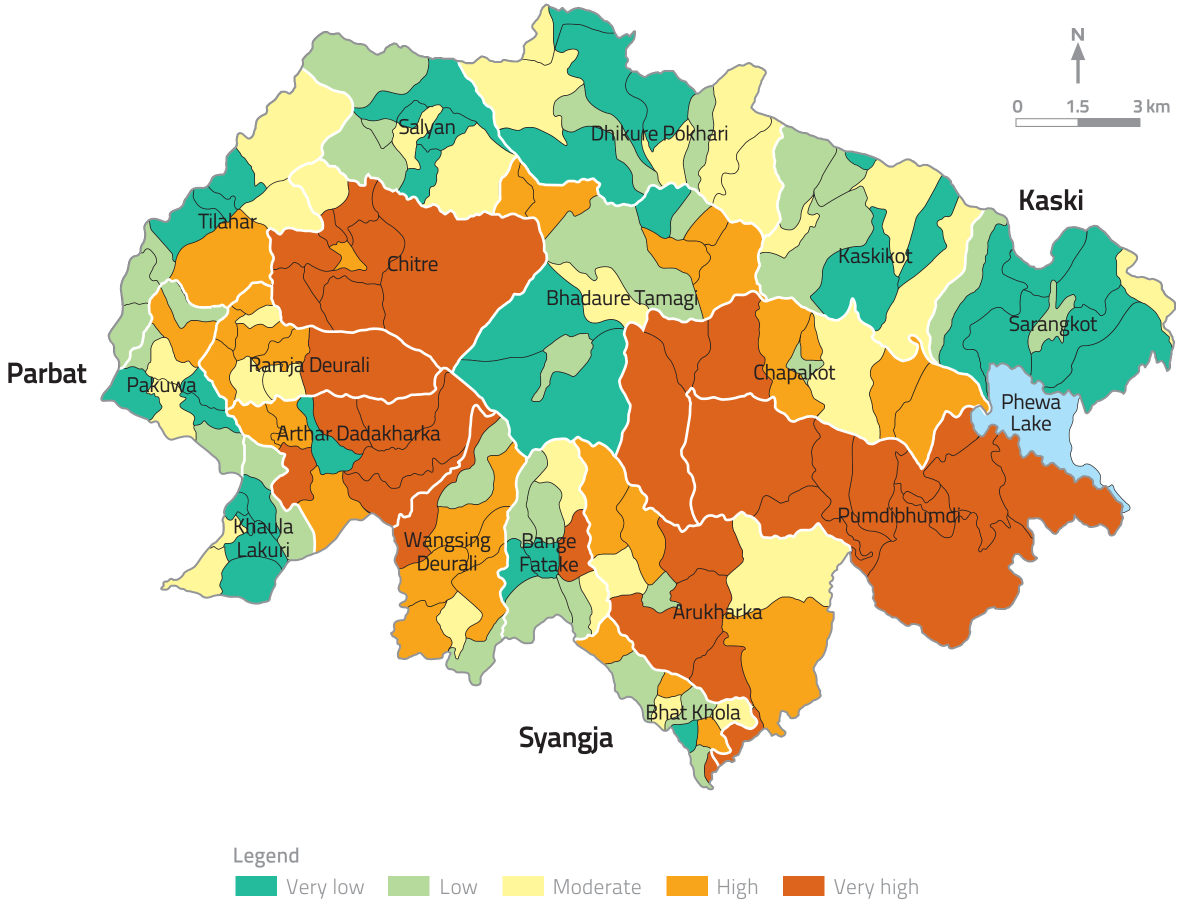
Sensitivity

The sensitivity of a system denotes its response to the impact of climate change

This map is based on local resource maps prepared by field observation. The data on invasive species and the incidence of pest infestation and disease was derived from secondary sources and informed judgment.

Indicators

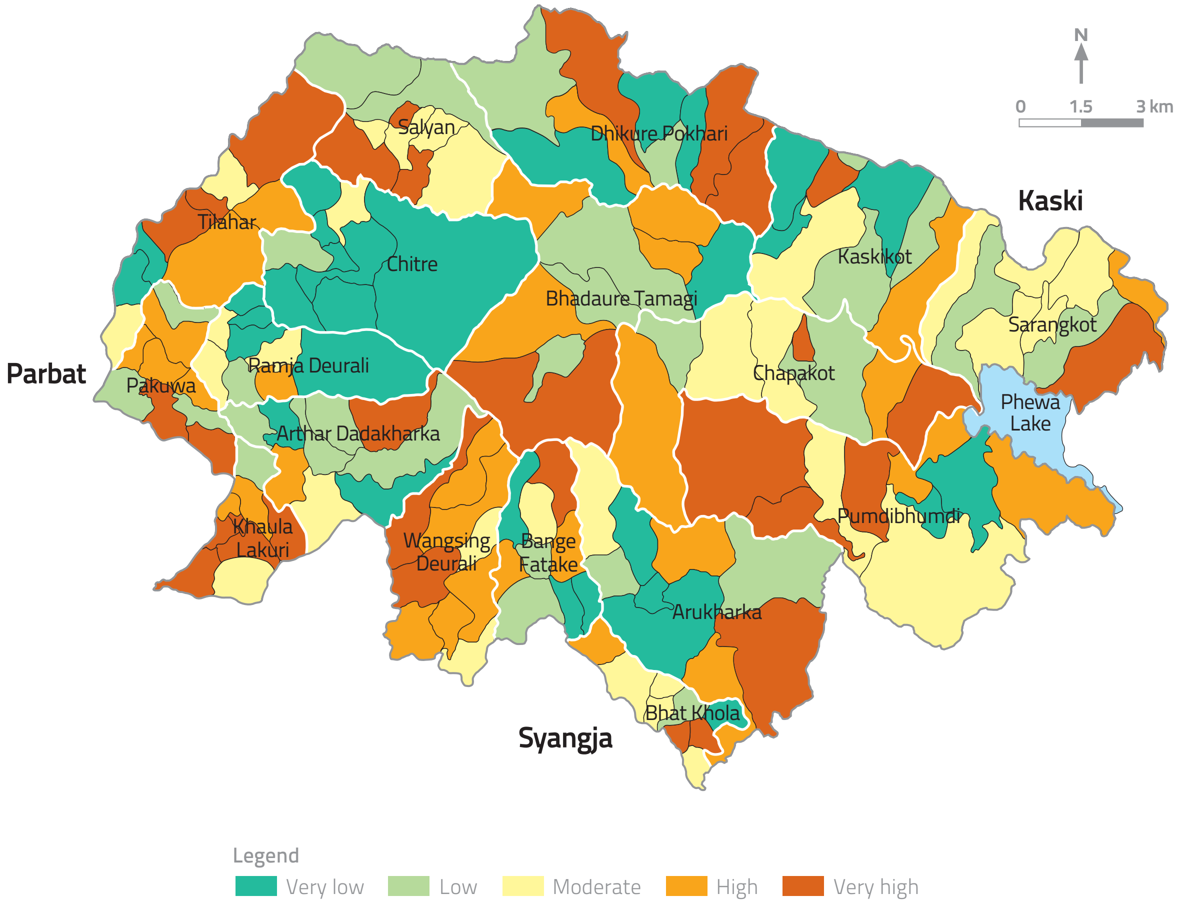
- Population density (no. of people/km^2)
- Landless households (per cent)
- Food sufficiency (per cent)
- Ecosystem-based households (no.)
- Useful plant species (no.)
- Invasive species (no.)
- Pest/disease infestation (no.)
- Topographic feature (elevation)



Assumptions: As population density increases, so does sensitivity to climate change. The fewer tree species there are, the greater the forest's vulnerability. A single-species forest is at higher risk of external shock than one with diverse vegetation species.

Adaptive capacity: Scenario one

IPCC presents adaptive capacity as one of the three determinants of vulnerability. Higher adaptive capacity implies reduced vulnerability. The adjoining map shows the adaptive capacity rankings of the wards in the 17 VDCs of the PMER, based on 16 indicators.



Indicators

- Literacy rate (per cent)
- Walking distance to regular market (km)
- Primary health service (no.)
- Access to piped water (per cent)
- Irrigated land (per cent)
- Households with access to electricity (per cent)
- Pakka (cemented) households (per cent)
- Households with mobile phones (per cent)
- Functioning organization (Non-governmental and Community-based Organizations) (no.)
- Government organizations (GOs) (no.)
- Traditional networks (no.)
- Finance (cooperatives/saving group) (no.)
- Road density (motorable road) (km/km^2)
- Open forest area (per cent)
- Close forest area (per cent)
- River density (no. of river/ha)

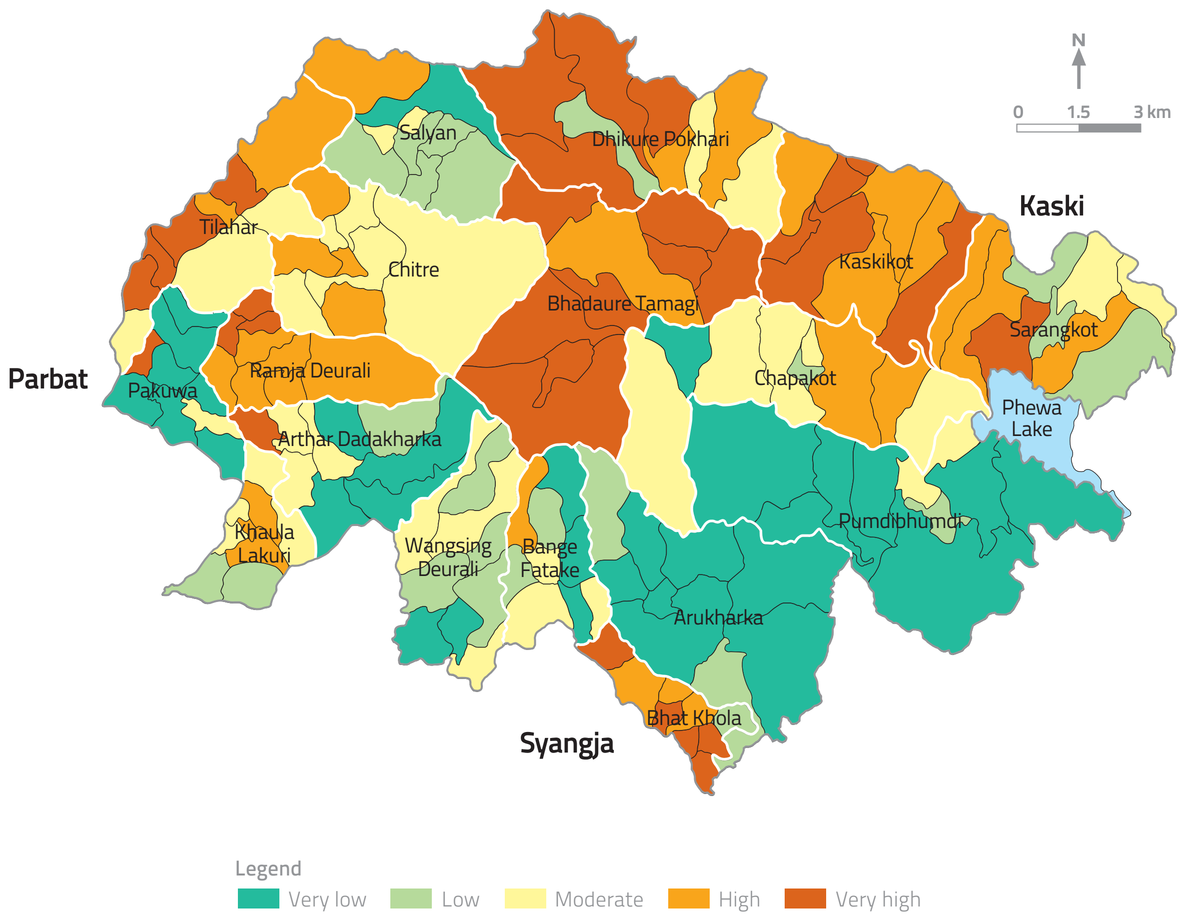
Assumptions: People with access to drinking water and renewable energy, those making judicious use of natural resources and/or living in areas with many government offices, have higher resilience than those residing in wards lacking adequate access to basic services. The quality of ecosystems and services, local knowledge and skills and institutional characteristics are also important determinants of adaptive capacity. The map is based on data from 16 indicators related to socio-economic factors collected at the ward level.

Adaptive capacity: Scenario two

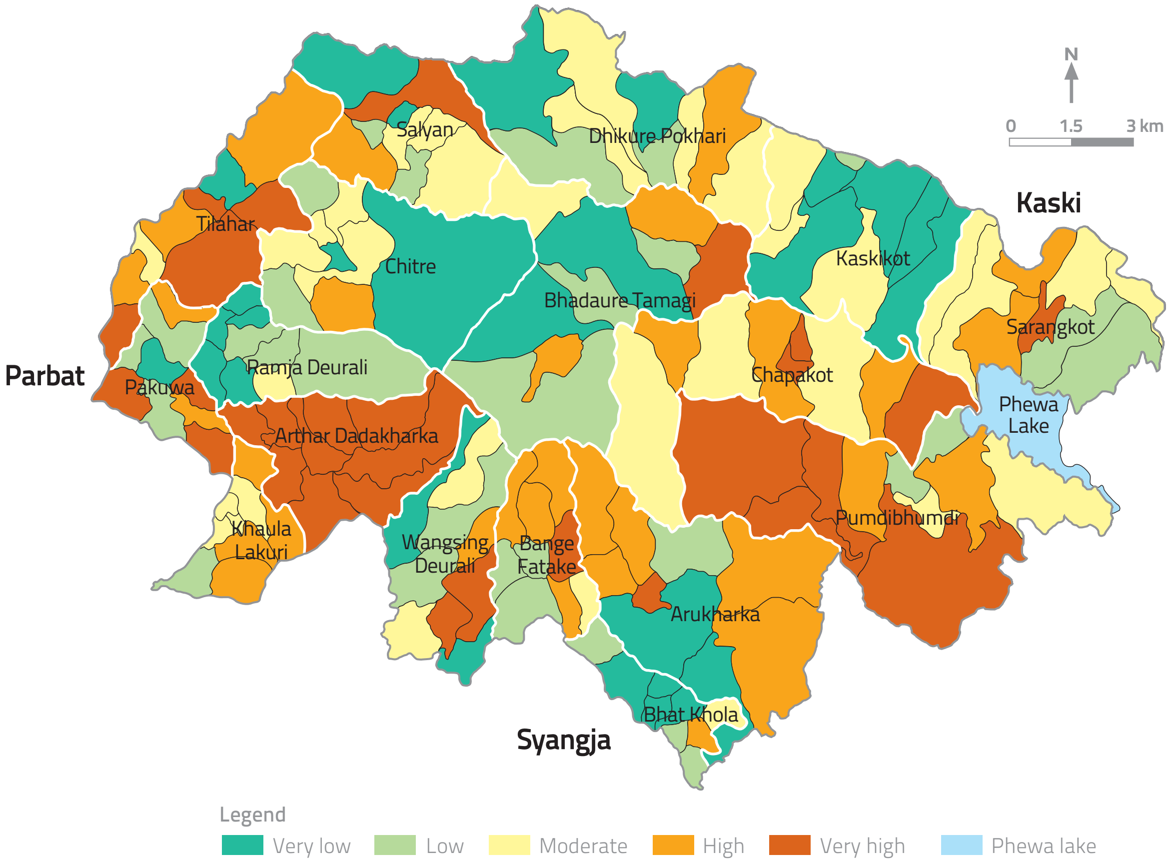
As explained earlier, the ward ranking changes when the number of indicators are changed. The adjoining map shows ward-level adaptive capacity ranking when only 10 adaptive capacity indicators are used.

Indicators

- Literacy rate
- Health service
- Access to piped-drinking water
- Percentage of irrigated land
- Clean energy
- Pakka household type
- Percentage of household using mobile phone
- Govenmental agencies
- Financial institution
- Road density



Assumptions: Of the 16 adaptive capacity indicators, 6 are not considered for developing composite value.



Composite vulnerability of wards

The map and adjoining tables show the 153 wards categorized on the basis of a composite value of the vulnerability indicators.

Vulnerability category	VDC	Wards	Total area (in sq. km.)
Very high	Arthar Dandakharka	1,2,3,4,5,6,7,8,9	13.74
	Arukharka	5	0.55
	Bage Fatake	7	1.02
	Bhadaure Tamagi	5	2.44
	Bhat Khola	3	0.37
	Chapakot	1,4,5	3.22
	Pakuwa	1,3,5	2.61
	Pumdibhumdi	2,7,8,9	19.65
	Salyan	5	2.45
	Sarankot	1	0.83
	Tilahar	1,5,7,8	6.61
	Wangsing Deurali	5,8	2.33
High	Arukharka	1, 2,4, 8, 9	14.00
	Bage Fatake	1,2,3,8	4.29
	Bhadaure Tamagi	1,8	2.53
	Bhat Khola	7	0.43
	Chapakot	2,6,9	6.17
	Chitre	8	1.66
	Dhikur Pokhari	2	2.62
	Khaula Lakuri	2,3, 8, 9	3.47
	Pakuwa	4,9	1.31
	Pumdibhumdi	3,6	5.16
	Salyan	7	2.25
	Sarankot	2,3	3.39
	Tilahar	2,4,9	6.35
	Wangsing Deurali	4	0.78
Moderate	Bange Fatake	9	0.62
	Bhadaure Tamagi	2	0.86
	Bhat Khola	8	0.55
	Chapakot	3,7,8	13.43
	Chitre	2,3,5 7	4.44
	Dhikur Pokhari	1,3,5,7	8.96
	Khaula Lakuri	4,5,6,7	6.05
	Kaskikot	1,9	1.49
	Pumdibhumdi	1,4	4.18
	Ramja Deurali	3	0.70
	Salyan	1,3 4	4.57
	Sarankot	4,5, 8, 9	6.91
	Tilahar	3	0.62
	Wangsing Deurali	2,7	2.80
Low	Arukharka	3	2.32
	Bange Fatake	4,5,6	2.80
	Bhadaure Tamagi	4,9,6	12.18
	Bhat Khola	4,9,6	1.28
	Chitre	6,9	2.69
	Dhikur Pokhari	8,9	4.75
	Khaula Lakuri	1	0.16
	Kaskikot	5	0.95
	Ramja Deurali	4,5,6	2.83
	Pakuwa	2,7,8	1.61
	Pumdibhumdi	5	6.02
	Salyan	2,8	1.11
	Sarankot	6,7	5.17
	Wangsing Deurali	6,3	3.71
Very low	Arukharka	6,7	2.32
	Bhadaure Tamagi	3,7	2.80
	Bhat Khola	1,2,5	12.18
	Chitre	1,4	1.28
	Dhikur Pokhari	4,6	2.69
	Kaskikot	2,4,6,7,8	4.75
	Ramja Deurali	1,2,7,8,9	0.16
	Pakuwa	6	0.95
	Salyan	6,9	2.83
	Tilahar	6	1.61
	Wangsing Deurali	1,9	6.02

Composite vulnerability of sub-watersheds

The Andheri Khola sub-watershed is the most vulnerable of the 13 sub-watersheds within the PMER measured by exposure, sensitivity and adaptive capacity.

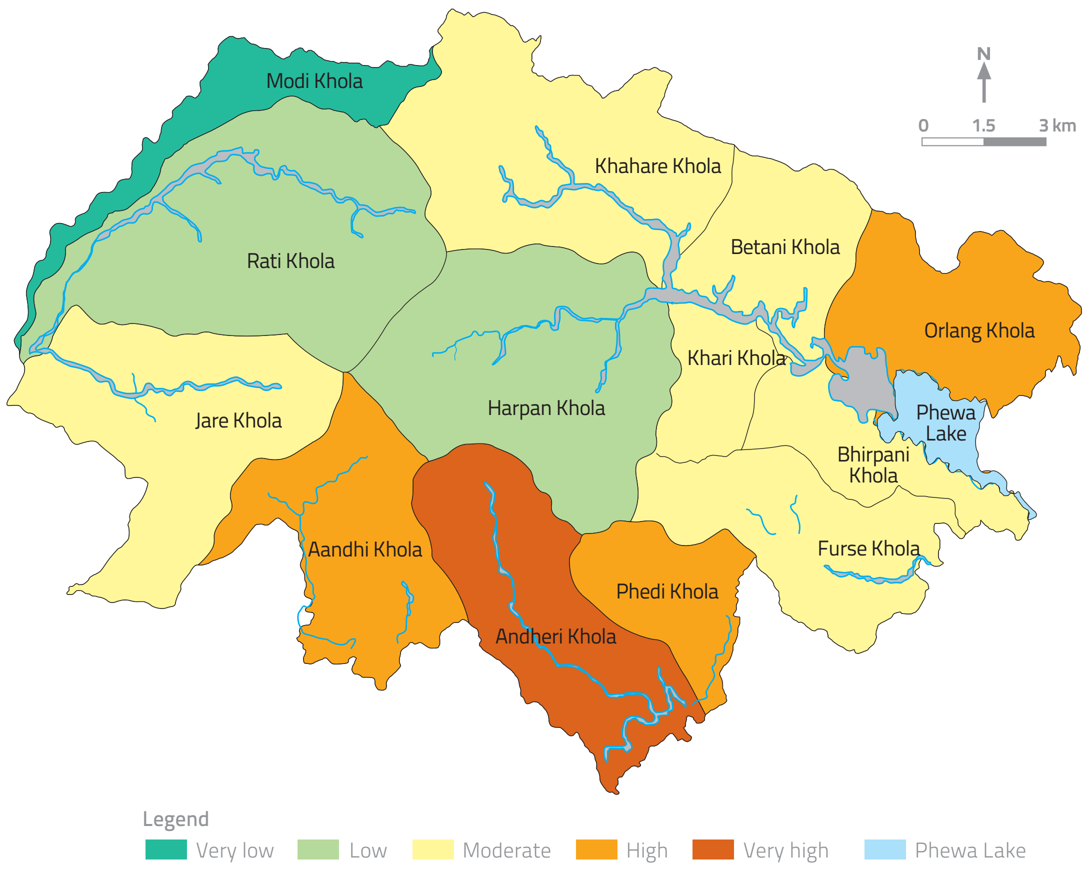
Assumption: Socio-economic development is low because the population in this sub-watershed has the least access to productive resources and services. It has a low rank for almost all 32 indicators. The sub-watershed characteristics include:

- Pronounced increase in temperature
- A large proportion of households affected by disasters
- Many invasive species
- Limited access to irrigation
- Low road density
- Many "kachha" (temporary) homes
- Steep slopes
- Many livelihoods reliant on natural resources
- Poor health services
- Few governmental organizations
- High food deficiency.

If these conditions continue, the Andheri Khola sub-watershed is likely to become more vulnerable to climate change.

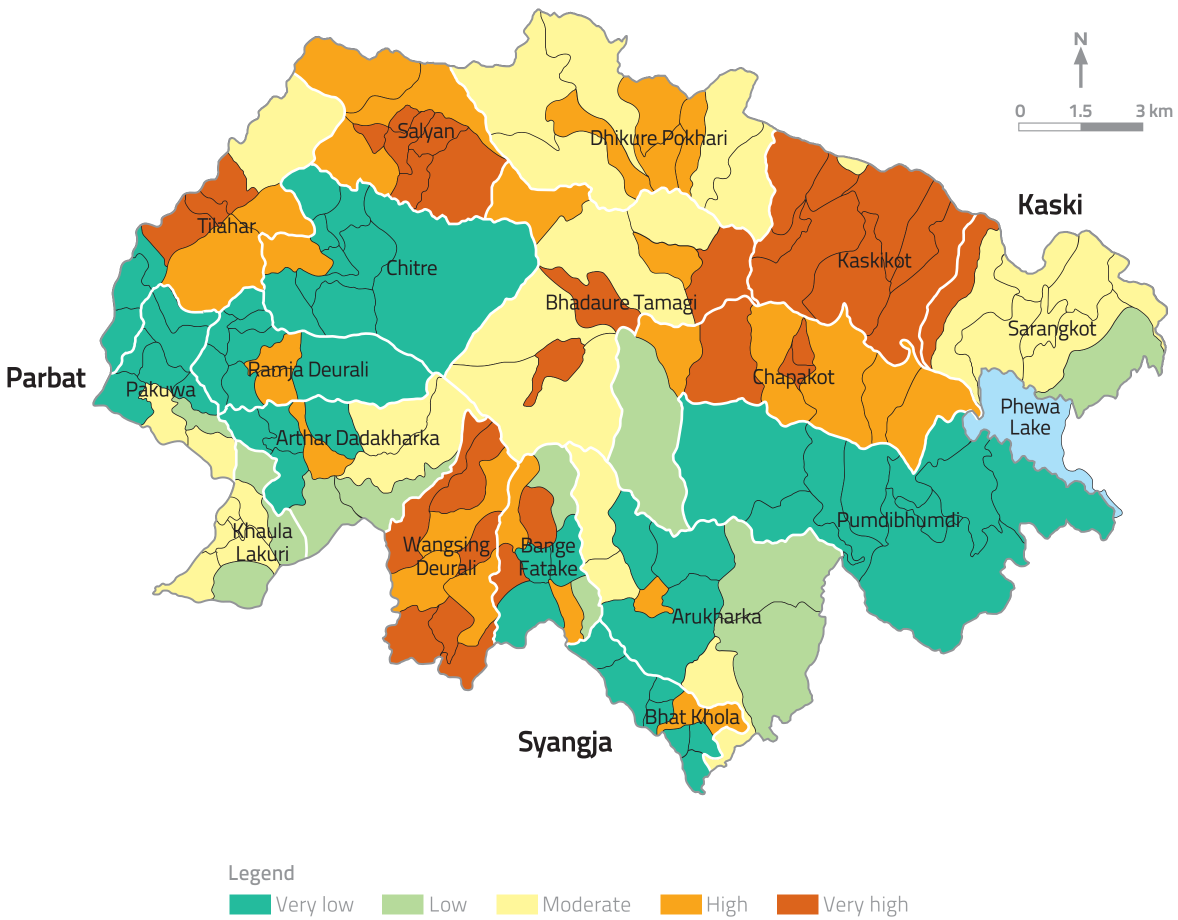
In contrast, the Rati/Jare sub-watershed is in the low vulnerability category because it rates relatively high on the majority of the 32 indicators with the following characteristics:

- Minimal temperature and rainfall fluctuation
- High drinking water and sanitation coverage
- Limited dependence on climate-sensitive livelihoods with many dependent on non-farm activities
- Good communication facilities
- Improved mobility due to road connectivity
- Many "pakka" (cemented) houses
- High literacy level
- Many governmental organizations.



Sub-watershed	VDC	Wards	Vulnerability category
Modi	Tilahar	6	Very low
	Salyan	9	Very low
Jare/Rati	Arthar Dandakharka	1,2,3,4,5,6	Very high
	Tilahar	1,2,3,4,5,7,8,9	Very high to high
	Chitre	All 9	Moderate to low
	Khaula Lakuri	All 9	High to moderate
	Pakuwa	All 9	Very high to low
	Ramja Deurali	All 9	Very Low
	Salyan	1,2,3,4,5,6,7,8	Moderate to low
Andhi	Arthar Dandakharka	7,8,9	Very high
	Bange Fatake	4,6	Low
	Wangsing Deurali	All 9	Very high to moderate
Andheri	Arukharka	1,2,4,5,6,7,9	High
	Bange Fatake	1,2,3,5,7,8,9	High to low
	Bhat Khola	All 9	Moderate to low

Sub-watershed	VDC	Wards	Vulnerability category
Phedi	Arukharka	3,8	High
Furse	Pumdibhumdi	2,4,6,7,9	Very high to low
Bhirpani	Pumdibhumdi	2,3,5	Very high to low
	Chapakot	1,2	High to moderate
Khari	Chapakot	3,4,5,6	High to moderate
Orlang	Sarangkot	All 9	High to moderate
Betani	Kaskikot	2,3,4,5,6,7,8,9	Moderate to very low
Khahare	Dhikur Pokhari	All 9	Moderate to low
	Kaskikot	1	Moderate
	Bhadaure Tamagi	1,2	High to moderate
Harpan	Bhadaure Tamagi	3,4,5,6,7,8,9	Moderate to low
	Chapakot	7,8,9	High to moderate
	Pumdibhumdi	1,2	Very high



Vulnerability: Landslides

Landslide occurrence is a function of topography, precipitation and human intervention such as haphazard road construction and urbanization.

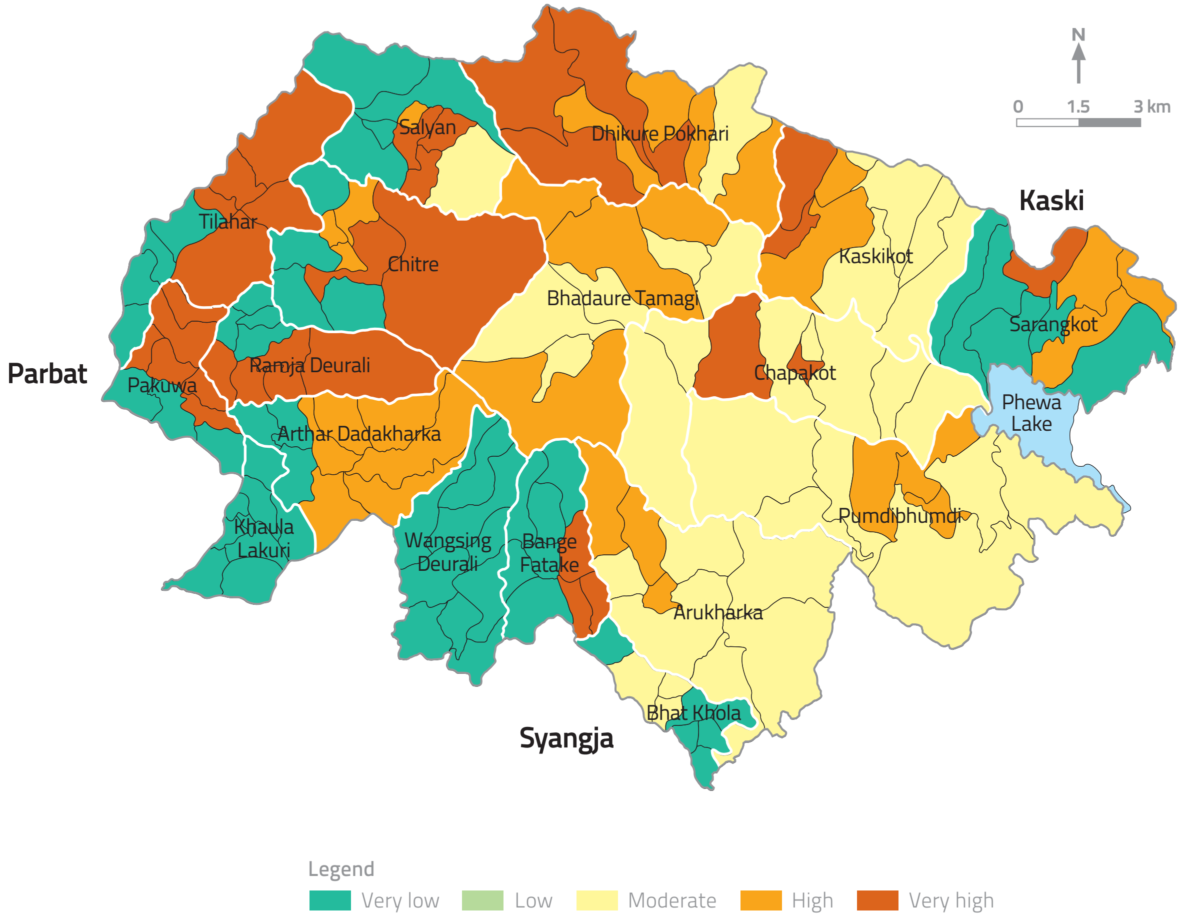
Data on landslides is obtained from field observation and secondary sources including maps and images and discussion with informed representatives of local communities.

Assumptions: Regions with steep slopes that have had landslides and/or identified as landslide-prone due to erratic rainfall are most vulnerable.

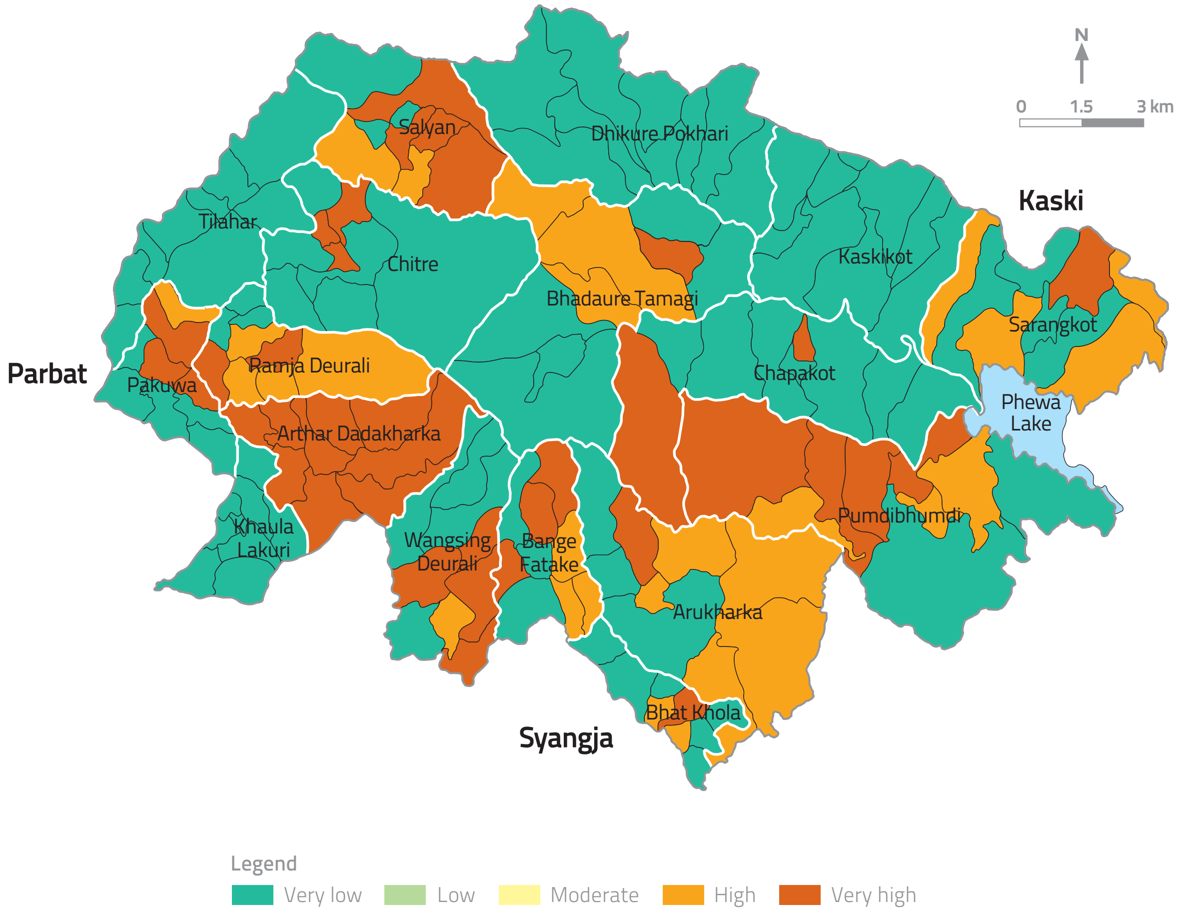
Vulnerability: Climate-related disasters

Climate-induced disasters include landslides, floods and riverbank erosion during the monsoon season and drought, high winds, forest fires, storms and hail during the pre-monsoon season.

Data based on maps of local resources and field-level observation.



Assumptions: Local experience of disasters and climate trends can help explain climatic trends in the PMER, particularly with regard to temperature and rainfall pattern.



Coverage of drinking water

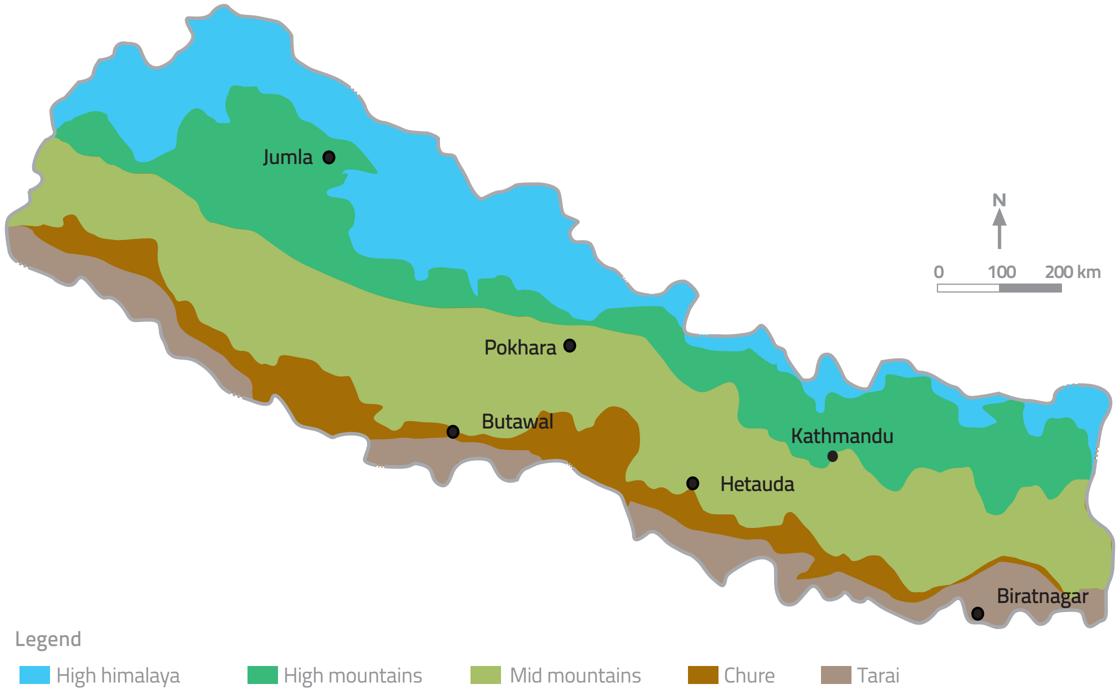
The capacity to respond to stress, including that induced by climate change, depends on access to safe drinking water, a consideration that depends on sanitation and hygiene services, gender, poverty and social inclusion.

Data on indicators for each ward collected in FGDs.

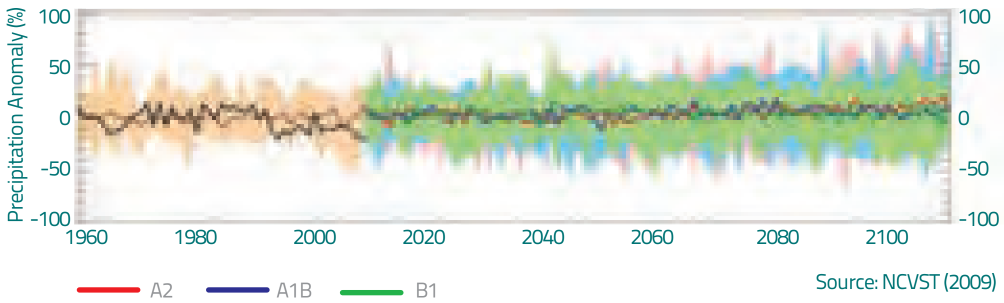
Assumptions: The quality of drinking water systems is low because of poor maintenance, declining discharge at sources, haphazard road construction and landscape changes such as conversion of forest land and paddy fields into housing plots, which damages water sources and supply lines.

Use of global climate change scenario study results

The study consulted the WDR-scale climate scenario developed by NCVST (2009) although its results cannot be scaled down to the PMER level, as the site-specific features of local climates were not available. At the same time results of climate models cannot be adapted to the WDR-scale. The findings of the NCVST (2009) study suggest a likely increase in mean annual temperature in the WDR of between 3.0°C and 6.3°C.[8] A study by Mc Sweeney (2008) suggests an increase in temperature between 2°C and 5°C by the end of the century. The projections of the GCMs for future precipitation in the WDR vary widely from -32 to +64 per cent (NCVST 2009)[9] and from -30 to +100 per cent (Mc Sweeney 2008). It must be noted that GCMs have a spatial resolution of 2.5°x2.5° latitude/longitude (NCVST 2009),[10] which is too large to cover the country's topographic variation and the characteristics of its macro, meso and microclimates.[11]



Nepal: Annual precipitation anomaly (%)



Source: NCVST (2009)

Predicted increases in temperature

Time period	Annual	Pre-monsoon	Monsoon	Post-monsoon	Winter
2030s	1.4 (0.9, 2.0)	1.7 (0.8, 2.5)	1.4 (0.5, 2.2)	1.2 (0.7, 2.0)	1.6 (0.9, 2.8)
2060s	3.0 (1.7, 4.1)	3.1 (1.9, 4.7)	2.5 (1.0, 3.4)	2.6 (1.8, 4.1)	3.4 (1.9, 4.6)
2090s	4.9 (3.0, 6.3)	5.4 (3.5, 7.0)	4.5 (1.9, 5.5)	4.6 (3.2, 5.9)	5.4 (3.7, 7.1)

Source: NCVST (2009)

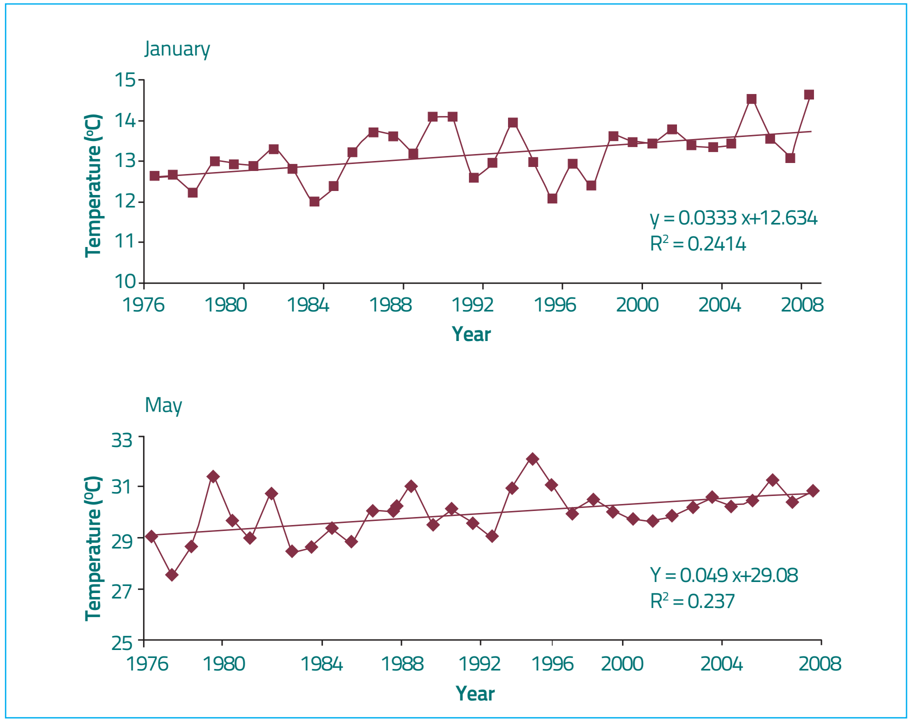
Predicted changes in precipitation

Time period	Annual	Pre-monsoon	Monsoon	Post-monsoon	Winter
2030s	0 (-34, 22)	-7 (-32, 11)	5 (-17, 40)	-4 (-26, 86)	-10 (-43, 13)
2060s	0 (-36, 47)	-10 (-45, 19)	10(-37, 79)	4 (-15, 119)	-11 (-42, 11)
2090s	7 (-32, 64)	-13 (-54, 36)	19 (-46, 123)	4 (-42, 132)	-19 (-56, 21)

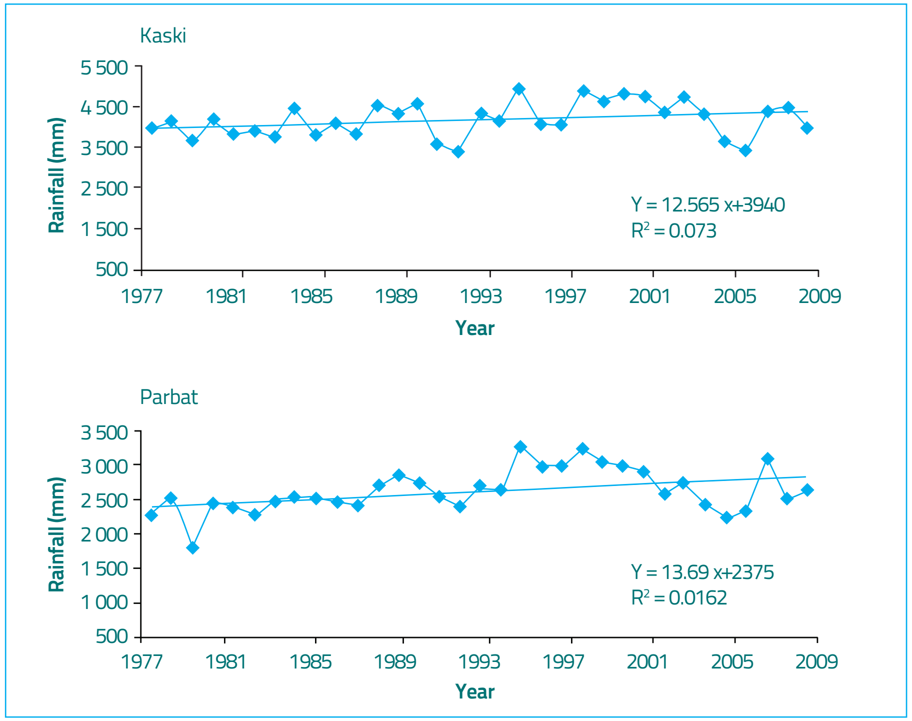
Source: NCVST (2009)

8 Baseline data from 1970-1999. Projection year is 2090.
9 Baseline data from 1970-1999. Projection year is 2090.
10 This corresponds to a grid 270 km x 270 km
11 Three grid points differentiate eastern, central and western regions but there is no real differentiation between southwestern and northeastern slopes (NCVST 2009).

Trends in the average temperatures of the PMER (Based on data recorded in Pokhara Airport)



Trends in the annual precipitation of the PMER (Based on data recorded in stations in Kaski and Parbat districts)



Historical climate trend

This exercise reviewed available historical temperature and precipitation records for stations in and around the region as a proxy to analyze climate trend characteristics in the PMER.

Temperature: Historical trend analysis shows that temperatures in the PMER are increasing as they are in the rest of the country. Records of meteorological stations close to the PMER, at Pokhara for example, show temperatures increasing in both winter and summer.

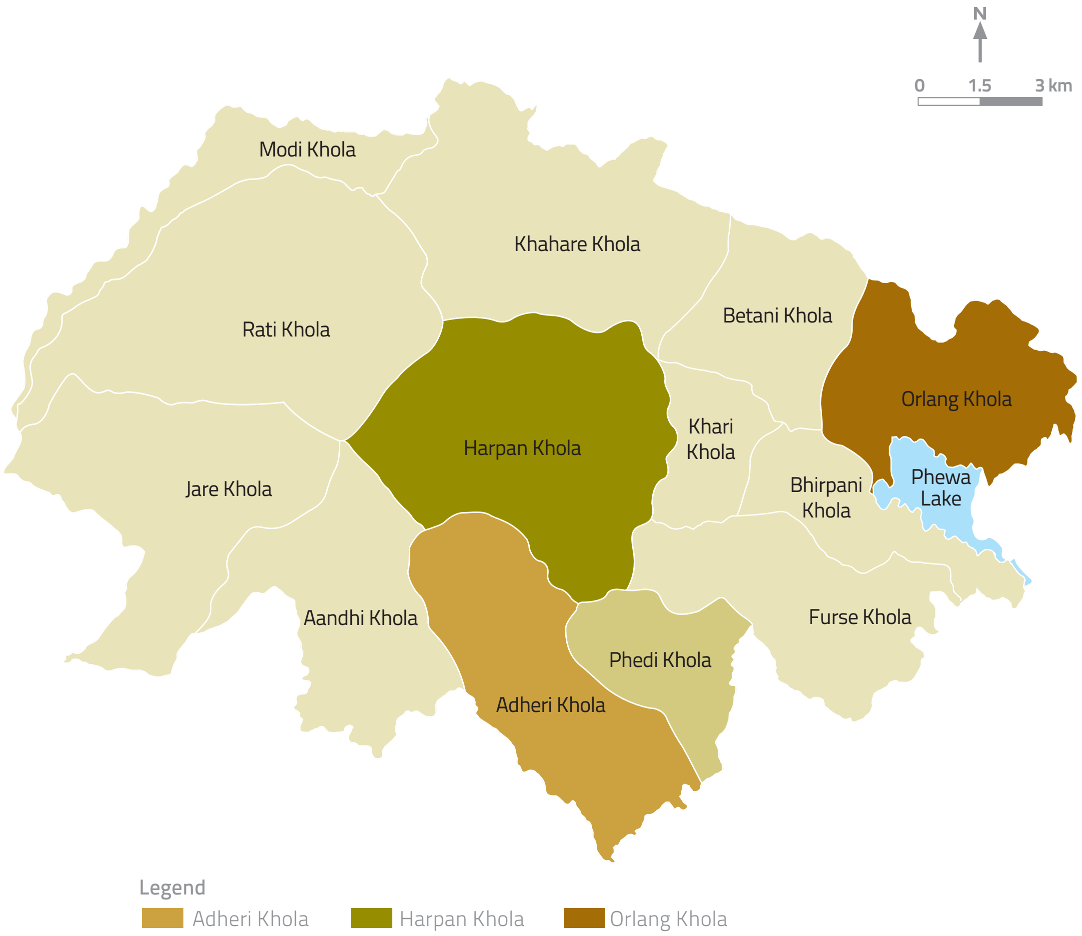
Precipitation: Records on precipitation do not show any clear trends.

Local perceptions

Attempts were made to understand local perceptions of climate change and these were compared with historical temperature and rainfall data as well as the results from the NCVST study (2009) on temperature and precipitation for WDR. Finally, an attempt was made to combine the three insights to assess future vulnerability. Stakeholders were involved in envisioning future development aspirations and identified climate-vulnerable sectors.

District		VDCs	Drinking water	Forest	Agriculture	Irrigation	Roads/Trail	Endangered species	Electricity	Alternative energy	Communication	Grazing area	Ecosystem
District	Parbat	Khaula Lakuri	Very high	Very high	Very high	Very high	High	Not available	Not available	Not available	High	Not available	Not available
		Ramja Deurali	High	High	Very high	Very high	Very high	Very low	High	High	Not available	Not available	Very low
		Chitre	High	Low	High	Not available	Not available	Not available	Not available	Not available	Not available	Very high	Not available
		Tilahar	Very high	Not available	Very high	High	High	Not available	Not available	Not available	Not available	Not available	Not available
		Arthar Dandakharka	Moderate	Not available	Very high	Low	High	Low	High	Not available	High	Not available	Moderate
		Pakuwa	Very high	Very high	Very high	Very high	Moderate	Low	Not available	Not available	Not available	Not available	Not available
	Kaski	Chapakot	Low	Low	Moderate	Not available	Very high	Low	Low	Not available	Very low	Not available	Not available
		Pumdibhumdi	High	Moderate	Very high	Not available	High	Moderate	Very high	Not available	Moderate	Low	Not available
		Kaskikot	Very high	Very low	Moderate	Not available	Moderate	Very high	Not available	Low	Not available	Not available	Not available
		Sarangkot	Moderate	Low	Moderate	Not available	Very high	Not available	Moderate	Not available	Very low	Not available	Not available
		Dhikur Pokhari	Moderate	Low	High	Not available	Low	High	Not available	Moderate	Very low	Not available	Not available
		Bhadaure Tamagi	Moderate	Low	High	Not available	Low	Not available	High	Very low	Moderate	Not available	Not available
		Salyan	Very high	High	High	Not available	High	Not available	Not available	Not available	Not available	Not available	Not available
	Syangja	Bhatkhola	Very high	High	Moderate	Not available	Not available	High	Not available	Not available	Not available	Not available	Not available
		Bange Fatake	High	Low	Very high	Not available	High	Not available	Very high	Not available	Low	Not available	Not available
		Arukharka	High	Very low	Moderate	Not available	Very high	Not available	Not available	Not available	Not available	Not available	Not available
		Wangsingh Deurali	Very high	High	High	Not available	High	High	Not available	Not available	Not available	Not available	Very high

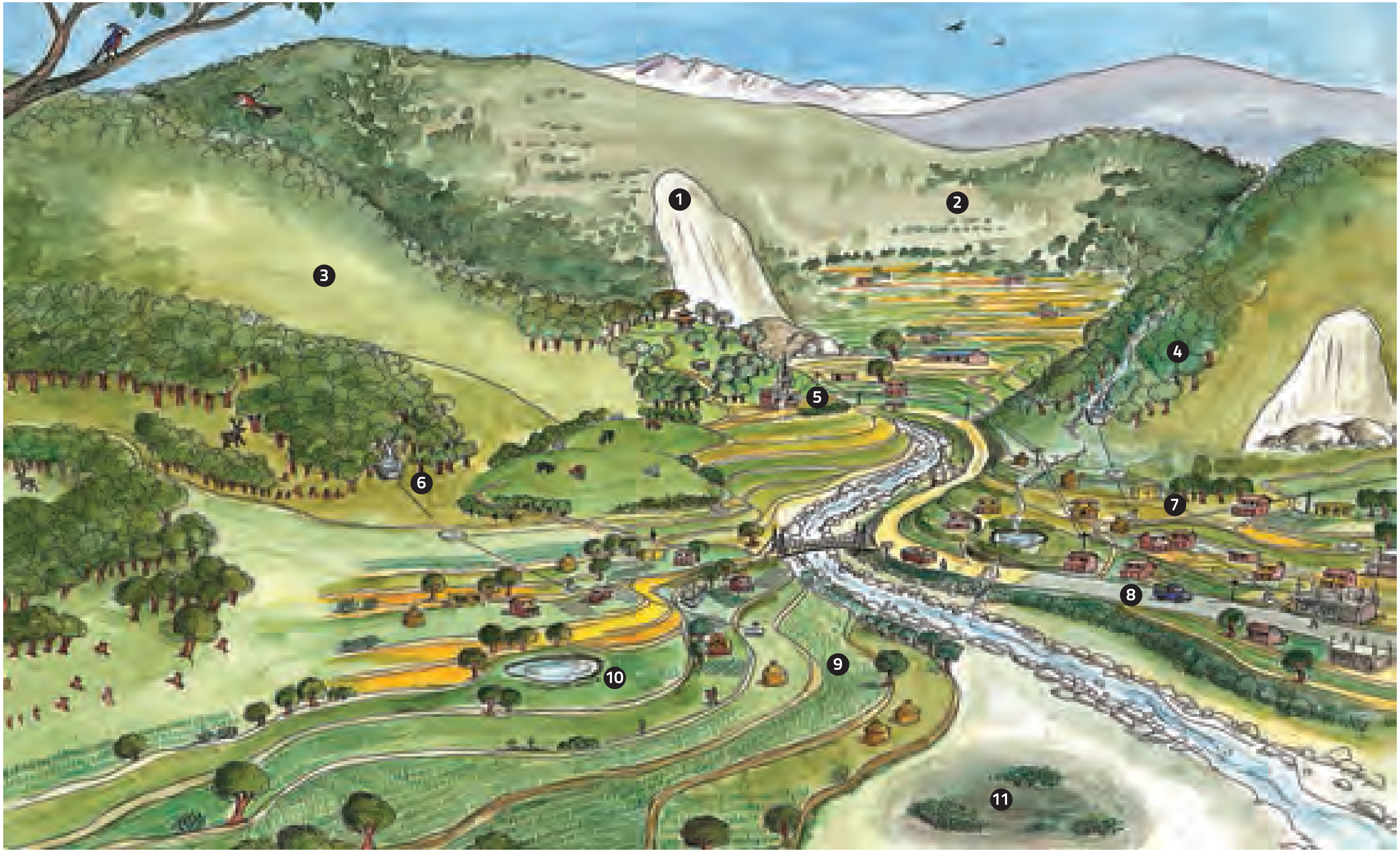
Very low Low Moderate High Very high Not available



Vulnerability of the three selected sub-watersheds

This study classified the Andheri Khola sub-watershed as the most vulnerable in the PMER and the Orlang Khola sub-watershed as the next most vulnerable. These were selected for planning EbA options because of their vulnerability. The Harpan Khola sub-watershed was chosen as the third sub-watershed because of its direct contribution to Phewa Lake. Two scenarios were considered for each sub-watershed – drier and wetter than at present. These are depicted hypothetically in the three sketches on pages 42, 43 and 44.

A hypothetical watershed



Ecosystem goods and services (Present)

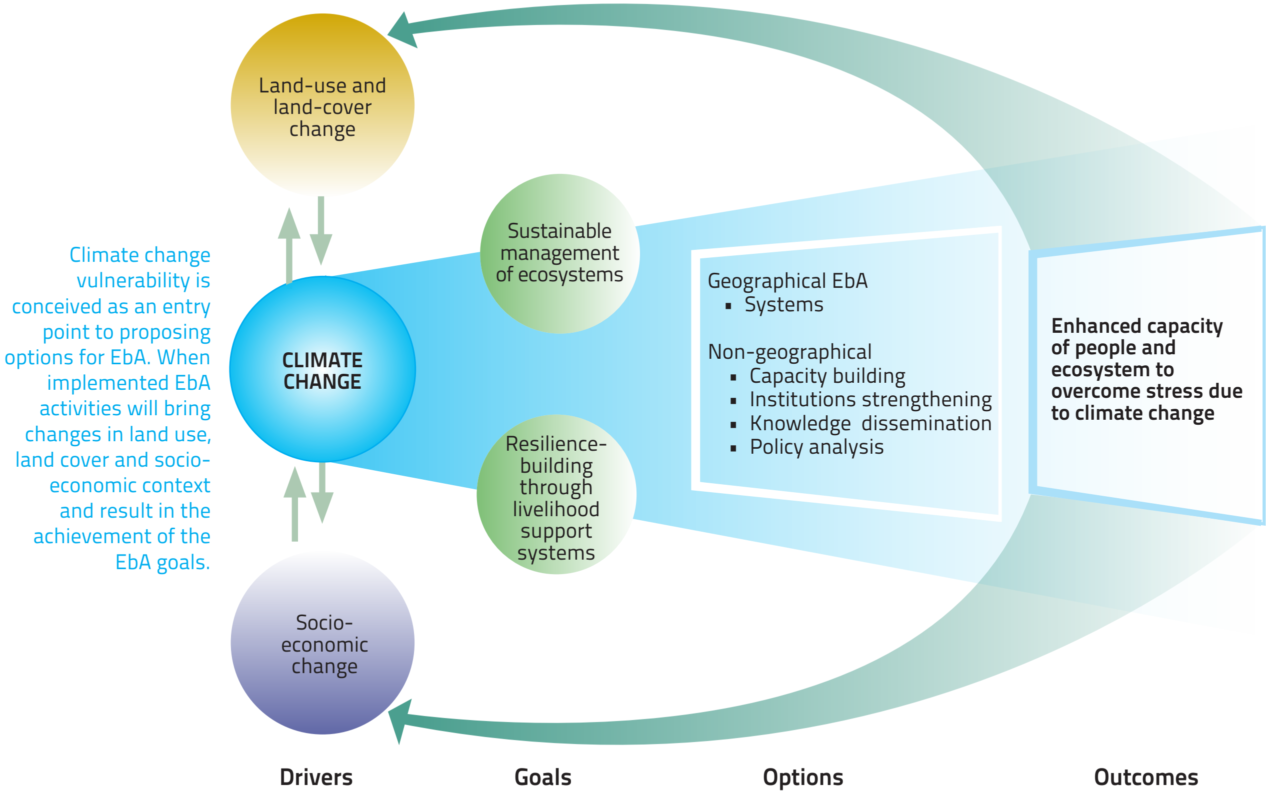
1. Landslide as a normal event affect land and river
2. Pockets of deforestation
3. Grass land is left open for grazing
4. Forest conserve local water sources
5. Mobile tower helps communication
6. Spring source tapped for community drinking water system
7. Extention of distribution line improves access to electricity
8. New road improves mobility
9. Paddy fields
10. Village pond recharges groundwater
11. River wetland

Watershed if there is erratic and high rainfall

1. A new landslide damages forest land.
2. A new landslide threatens homes and fields
3. Landslide covers agricultural land
4. Bridges are threatened
5. Roads are washed away
6. A flash flood damages an intake
7. Pond is filled with sediment
8. Riverside fields are submerge and crops destroyed
9. Flood washes over wetlands, covering them with debris

Watershed if the future is drier

1. Forest fires breakout
2. Hydroelectric output decreases
3. Water sources dry up
4. Discomfort from higher temperature and heat effects
5. Crop productivity declines
6. Conservation ponds dry up
7. Women have to walk further to fetch water
8. River flow dwindles, pollution increases, and wetlands are adversely affected



Principles of Ecosystem-based Adaptation and EbA Framework

The EbA approach is rooted in the fundamental premise that climate change will affect local ecosystems and their services. The approach also recognizes that the interaction between biophysical and socio-economic entities is complex. This understanding should help stakeholders identify and address critical points of vulnerability by implementing EbA options. The implementation of EbA options should be based on the following principles:

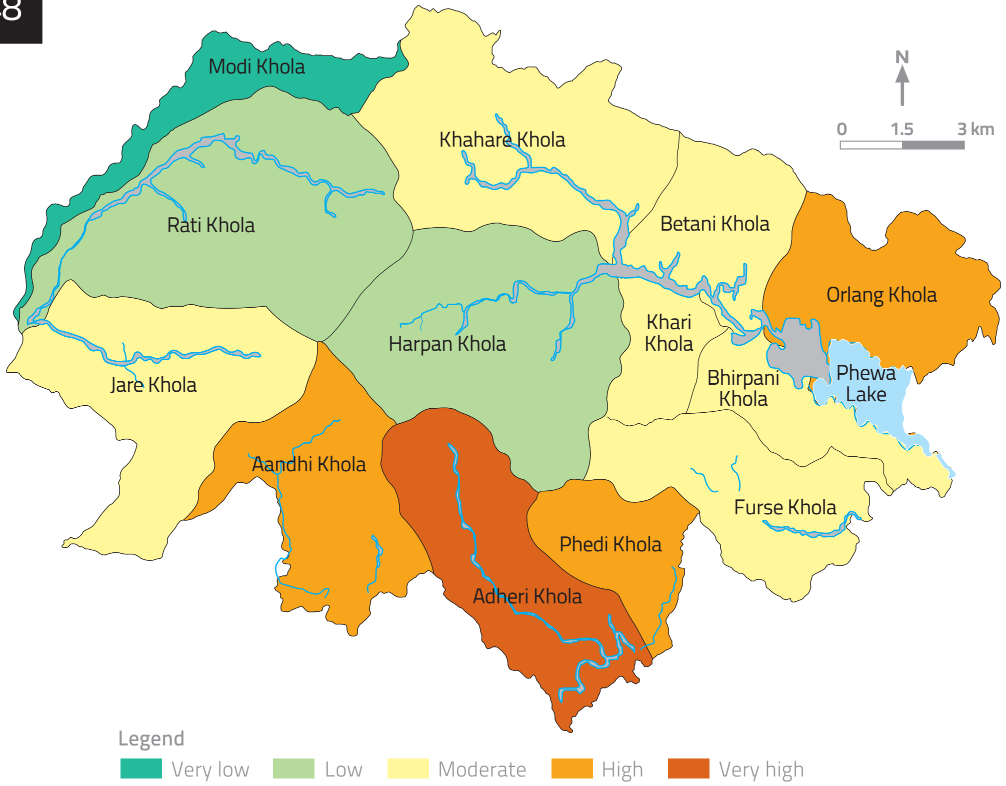
- Build upon existing good practices
- Involve local communities
- Pursue a multi-partnership strategy
- Integrate EbA options with larger adaptation strategies

The study conceptualizes EbA options within the CRF and sets the stage for their implementation in the three selected sub-watersheds. The implementation of EbA options will enhance the capacity of the PMER ecosystem and of those dependent on its services, to deal with climate change stresses. An effective EbA strategy needs repetition of the steps in the planning process in order to guide implementation, mainstream learning-by-doing, foster experimentation and testing, process results and reassess the policy context.

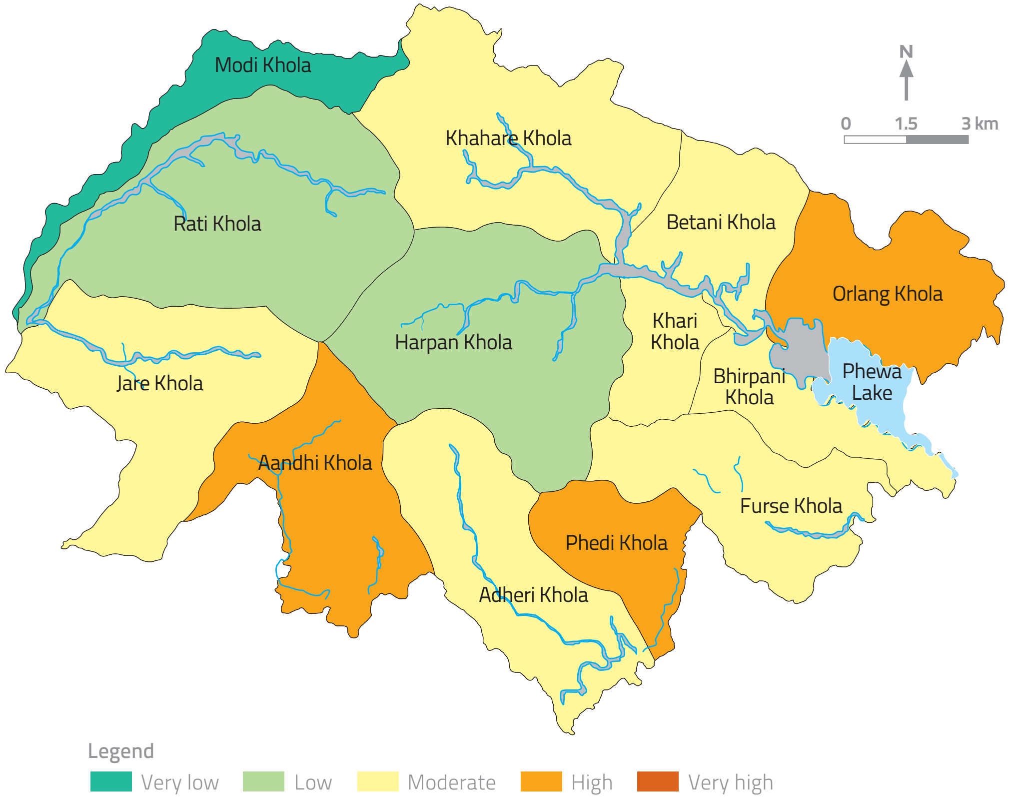
A scenario: Case for Andheri Khola sub-watershed

The map shows a future where adaptive capacity has been built by improving access to drinking water, sanitation and reliable energy in the Andheri Khola sub-watershed. The exercise was conducted to assess changes in vulnerability categories following the implementation of EbA options. If coverage of basic services reaches 100 per cent, it is likely that this will reduce the vulnerability level of the sub-watershed from high to moderate. The local community would then be more capable of responding effectively to climate change even if faced with higher risk.

Another future scenario could be a catastrophic cloudburst over the sub-watershed like the one in central Nepal in 1993 (NCVST 2009) or in far western Nepal in 2013. The cloudburst could severely damage land, forest, agriculture, orchard, infrastructure, wetland and lake systems and reduce the capacity of agents, with serious consequences for already marginalized households. The adjoining map depicts this scenario and can be used as a tool to support response and resilience-building decisions.



Map of sub-watershed with baseline vulnerability condition

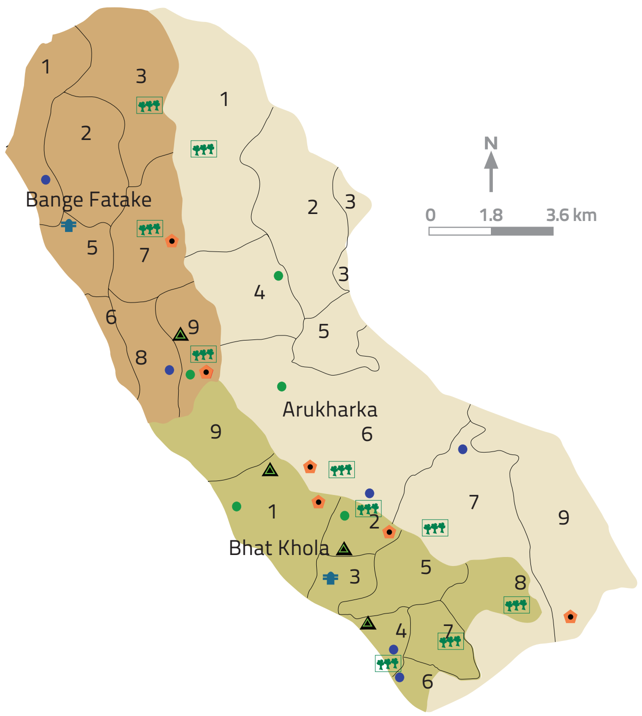


Map with adaptation options identified through scenario envisioning in Andheri Khola sub-watershed

Issues	Future scenario		Resilience strategies
	Rainfall	Temperature	
Land degradation	▪ Extreme rainfall and hailstorms damaging crops ▪ Extreme rainfall events accelerating soil erosion and occurrence of landslides, further aggravating land degradation	▪ Higher temperature increases evaporation rates, drying of small water sources in the dry season ▪ Increase in instances of crop pests and diseases	▪ Revitalizing the use of fallow and degraded land by planting vegetation with a comparative advantage, such as citrus fruit trees or coffee plants ▪ Use of agricultural technologies such as drip and sprinkler irrigation to improve water-use efficiency ▪ Promotion of bio-engineering for river training and bank protection ▪ Rehabilitation of degraded land and soil fertility restoration through conservation of existing ponds
Unemployment of youth and low skills	▪ Economic return from farming will decrease due to erratic rainfall and disasters	▪ The temperature rise will reduce labour output due to increased incidences of diseases and sickness	▪ Skill-based training to develop entrepreneurship and employment ▪ Enhanced connections with micro-finance institutions to increase access to credit for income generating activities to pursue technological innovation, new knowledge, managerial capacity and add to product value chain ▪ Enhanced skills to transform current agricultural systems and practices- from a subsistence to a remunerative approach
Low level of awareness	▪ Increased occurrence of extreme rainfall events will further limit people's mobility and access to knowledge and skill development	▪ Temperature rise will make local living more uncomfortable and people will migrate to cities but with lower advantage of indigenous knowledge and skill	▪ Initiation and continuity of awareness programs targeted at changing social stereotypes (such as superstition and other social evils) ▪ Emphasis on gender inclusion in designing and implementing awareness and skill development programs ▪ Increase disseminating information on future impacts
Biodiversity and ecosystem	▪ Extreme rainfall events and more incidences of landslides and mass wasting may accelerate the degradation of ecosystems and biodiversity loss	▪ Higher temperature could create favorable conditions for forest fire and habitat destruction	▪ Inventory and ethno-botanical studies of medicinal herbs and plants as first step towards their conservation ▪ Developing and implementing strategies to control forest fires

Resilience options

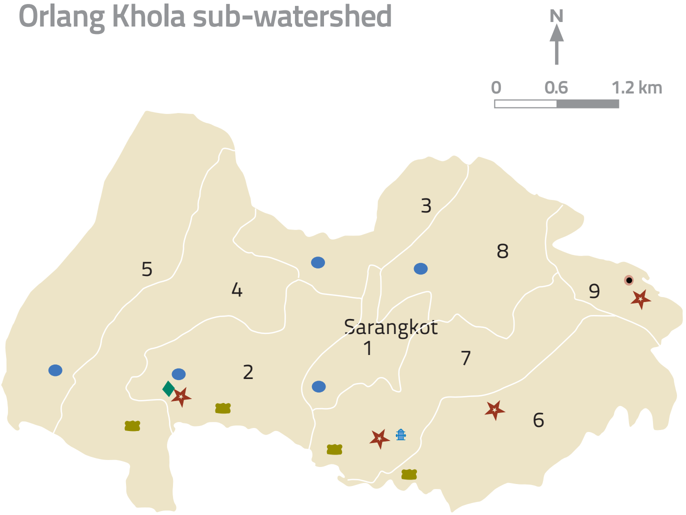
Andheri Khola sub-watershed



Legend
- Construction of embankments and use of bio-engineering to control erosion
- Conservation and replantation of local varieties along riverbank
- Plantation of abandoned and fallow land
- Restoration of degraded land
- Use of sprinkle and drip irrigation systems
- Restoration of ponds

Numbers indicate wards

Orlang Khola sub-watershed

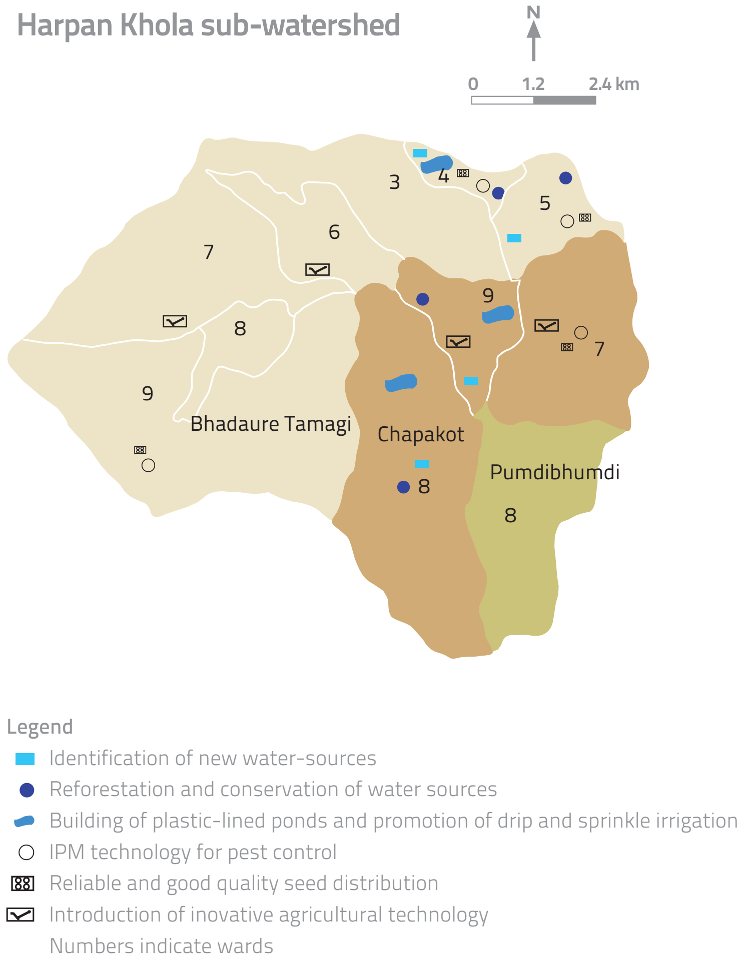


Legend
- Construction of check dam to control sediment flow into Phewa Lake
- Improved sanitary system
- Improved water and irrigation system
- Construction of storage pond
- Promotion of recreation and fish farming
- Promotion of water-source protection

Numbers indicate wards

Issues	Future scenario		Resilience strategies
	Rainfall	Temperature	
Lower food production	▪ Increase in intensity of rainfall (extreme events), accelerating land degradation, and soil fertility loss contributes to reducing agricultural productivity ▪ Increased instances of hailstorms and flood damaging crops	▪ Drying up of smaller water sources will lower availability of water in the dry season ▪ Land fertility loss due to soil heating ▪ Occurrence of new crop pests and diseases	▪ Protect and maintain water-sources and irrigation appurtenances and services to support agriculture ▪ Build ponds and small reservoirs to harvest rains, foster infiltration, and recharge springs ▪ Create incentives for youths to get engaged in agriculture ▪ Initiate programs on improving access to knowledge relating to climate smart and remunerative agriculture ▪ Produce, promote and market high value agricultural commodities ▪ Begin education programs to educate people on causes of land, soil and water degradation and their control, micro insurance stress resistant seeds
Settlement and urbanization	▪ Extreme rainfall events triggering occurrence of landslides and floods ▪ Increased sedimentation in rivers, steams and reservoirs including Phewa Lake ▪ Erratic rainfall with prolonged dry spells lowering discharge in the rivers and affecting crop growth and development	▪ Increase incidences of diseases ▪ Increase incidences of forest fire as well as heat island effect in denser communities	▪ Develop regulatory capacity at the VDCs and DDCs to help develop more resilient, settlements ▪ Improve management of existing drinking water systems ▪ Promote use of sanitary systems and improve hygiene practices ▪ Identify and implement activities for developing local entrepreneurship and employment ▪ Implement activities to build awareness on climate change induced vulnerabilities ▪ Assess social, economic and environmental impacts of changing dynamics of Phewa Lake and their impacts on aquatic biodiversity, tourism and recreation ▪ Accord priority to conservation of Phewa Lake by taking action against invasive species, pollution and increasing sediment loads ▪ Initiate dialogue with conservation groups, watershed and environmental organizations, local community and other stakeholders to conserve Phewa Lake and include other lakes around Pokhara in this initiative

Issues	Future scenario		Resilience strategies
	Rainfall	Temperature	
Migration	▪Extreme rainfall events and accelerated land degradation will further accelerate outmigration rates ▪Increase soil erosion and fertility loss will reduce agricultural productivity that will lower incentive for the youth to remain in farming	▪Temperature rise lowers human comfort and crop productivity. The later effects will further promote outmigration	▪Create alternative livelihood opportunities through promotion of local entrepreneurship
Social disputes	▪Social dispute will further increase due to loss of reliable water sources to meet irrigation and drinking water needs	▪Warming will further lead to erosion of natural resource degradation, limit access to them and heighten social differences	▪Begin programs to build cooperation and emphasize collective action around natural resources management
Increase in fallow land (agricultural land out of cultivation) and decrease in crop productivity	▪Extreme and erratic rainfall induced land degradation and soil fertility loss will further lower incentive for crop cultivation	▪Increased incidences of newer pests and diseases in crops ▪Lower productivity of local crop cultivars due to change in temperature and people living land fallow will further lower production	▪Introduce innovative agricultural technology ▪Ensure reliable distribution of high quality seeds ▪Promotion of Integrated Pest Management for pest control ▪Encourage households to build plastic ponds to increase storage of water for agricultural uses
Water scarcity	▪Erratic rainfall events will aggravate drought ▪Extreme rainfall events, landslides, and mass wasting will accelerate land degradation and soil fertility loss	▪Increases evaporative loss that will lower the water availability in the dry season	▪ Reforestation activities in the forest and public lands to increase vegetation coverage and help recharge of local water sources ▪Identification of alternative water sources to meet the increased demand
Conservation of Phewa Lake	▪Extreme rainfall events, landslide, and mass wasting will increase sediment flow to the lake	▪Temperature increase will alter bathymetric character that will alter lake environment to support aquatic life	▪Synthesize existing knowledge to build awareness of local population towards minimizing vulnerabilities of the lake and the surrounding environment



Watershed with EbA options identified

1. Identification of new reforestration area in degraded sections
2. Forest fire protection training
3. Expansion of jurisdiction of community user group to promote forest conservation
4. Improvement of terraces
5. Development of program to achieve total sanitation
6. Implementation of landslide prevention measures
7. Prepartion of inventories and status of drinking water systems and implimentation of a management improvement strategy
8. Construction of recharge ponds to begin augmenting springs systems
9. Construction of households level rain water harvesting tanks to augment drinking water supplies
10. Restoration of existing ponds
11. Stabilization of banks using bio-engineering methods
12. Construction of plastic-lined ponds to store water and installation of drip and sprinkler systems for cultivating high-value crops
13. Cultivation of local high-value varieties on fallow land as an income generating activity

Concluding remarks

This assessment has attempted to find answers to the following questions: Why are certain ecosystems and people vulnerable to climate change while others are not? What can be done to minimize this vulnerability?

The answers have helped design an EbA strategy for better management of resource delivery and use. The assessment used a systematic approach to understand vulnerability, future climate scenarios and identify options for building resilience. The approach ranked wards and sub-watersheds by vulnerability, developed a climate change scenario for the PMER area and identified EbA options by envisioning the future on the basis of the developed scenario. The approach highlighted the necessity of participatory planning through SLDs that brought global climate science and local perceptions together. The methodology used to assess and plan resilience-building for PMER area can also be applied to other ecosystems in Nepal and in other countries. EbA implementation will provide decision-makers with a new perspective on development that places people and ecological considerations at the centre of adaptation interventions.

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