VULNERABILITY AND IMPACTS ASSESSMENT FOR ADAPTATION PLANNING IN PANCHASE MOUNTAIN ECOLOGICAL REGION, NEPAL

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Authors

Ajaya Dixit, Madhav Karki, Ph.D and Ashutosh Shukla

Partner Organization

ISET-N
Institute for Social and Environmental Transition - Nepal

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ACRONYMS

CRF	Climate Resilience Framework
DNPWC	Department of National Park and Wildlife Conservation
EbA	Ecosystem-based Adaptation
GCM	Global Climate Model
GIS	Global Information System
GO	Government Organization
GoN	Government of Nepal
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
JICA	Japan International Cooperation Agency
LAPA	Local Adaptation Plan for Action
MAP	Medicinal and Aromatic Plants
MBT	Main Boundary Thrust
MCT	Main Central Thrust
MDO	Machapuchhre Development Organization
MEA	Millennium Ecosystem Assessment
MoFSC	Ministry of Forests and Soil Conservation
MoSTE	Ministry of Science, Technology and Environment
NCVST	Nepal Climate Vulnerability Study Team
NEA	Nepal Electricity Authority
NGO	Non-governmental Organization
NLSS	Nepal Living Standard Survey
NOAA	National Oceanic and Atmospheric Administration
NTFP	Non-Timber Forest Products
OECD	Organization for Economic Co-operation and Development
PMER	Panchase Mountain Ecological Region
PPF	Panchase Protected Forest
SILT	SILT Consultant
SLD	Shared Learning Dialogue
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
VDC	Village Development Committee
VIA	Vulnerability and Impacts Assessment
WECS	Water and Energy Commission Secretariat
WR	Western Region
WWF	World Wildlife Fund

EXECUTIVE SUMMARY

The Panchase Mountain Ecological Region (PMER) is a unique and rich ecosystem located in Nepal's Mid Hill region and comprises the 17 Village Development Committees (VDCs) of Kaski, Parbat and Syangja districts. The PMER is part of the country's Western Region (WR). With enchanting landscapes that offer spectacular views of Himalayan peaks including Annapurna, Dhaulagiri and Machhapuchhre, it is home to a diverse range of human cultures. Despite being an important ecological zone and one of the few ecosystems with both low and highland vegetation of distinct ecotype, the PMER has never been a priority for national environmental conservation. The core area of the PMER has been declared a protected forest and is dominated by the subtropical Schima-Castanopsis tree species and the lower temperate Oak-Laurel forest ranging in altitude from 1 450 to 2 589m above sea level. It is one of the few ecosystems where lowland and highland vegetation with distinct ecotypes can be found in the same geographical area. It is home to about 62 000 people living in an area of about 284km^2 who are dependent on agriculture, forestry and ecotourism for a livelihood.

The PMER is one of three global pilot sites for the Ecosystem-based Adaptation (EbA): Adapting to Climate Change in Mountain Ecosystem Project that aims to strengthen ecosystem resilience by reducing the vulnerability of communities and build local institutional capacities.

This report is a presentation of the tools and methods of a vulnerability and impacts assessment (VIA) of both climatic and non-climatic changes on ecosystem services and community livelihoods in the PMER. The assessment was conducted to develop the information and knowledge needed for human-centered adaptation strategies in order to develop a sustainable ecosystem management plan for the PMER and its surrounding areas. These types of strategies would reduce climate risks and enhance the resilience of local communities and ecosystems. The assessment of the impact of climate change on ecosystem services brings together top-down and bottom-up approaches to help prepare adaptation plans to ensure maintenance of the quality of ecosystem services. The VIA approach is based on the "embedded system- agent-climate exposure" model. It assesses vulnerability by measuring sensitivity, exposure and adaptive capacity at the ward and sub-watershed level of the PMER. The approach integrates vulnerability measurement and adaptation-planning tools with a step-wise participatory mapping of resources, climatic stresses and capacities. The approach, at both landscape and community levels, used 32 socio-economic, ecological, biophysical and institutional indicators to assess vulnerability of the PMER wards and sub-watersheds.

The results show increasing trends in both observed and projected temperatures and the unpredictability of precipitation and extreme weather events. A series of ward-level vulnerability maps show a landscape characterized by mountain hydrology with moderate-to-high slope gradients and south- and west-facing aspects, moderately exposed to the impact of climate change. The combined impact of high-to-moderate sensitivity and exposure indicates that the human-environment system is likely to face moderate climatic and non-climatic stress such as the drying up of water sources, increased landslides and floods, biodiversity degradation and declining agricultural productivity. With low to moderate resilience capacity at both agent and system levels, there is a need for EbA options, reflecting the needs of the coupled human-ecological system.

The EbA options were identified through a shared learning dialogue and include (i) mainstreaming climate resilience in eco-tourism; (ii) integrated management of ecosystem services, especially water, forest and non-timber forest products and resources; (iii) enhancing livelihood opportunities; (iv) promoting conservation agriculture; (v) wildlife management through habitat protection and improvement of habitats; and (vi) building local human resource capacities and skills.

The options aim for adaptation to and mitigation of the negative impact of climate change including loss of agricultural productivity, ecosystem degradation, habitat fragmentation and the occurrence of invasive species. These would help increase the resilience of local communities and the PMER.

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CHAPTER I

ECOSYSTEM SERVICES IN A CHANGING WORLD

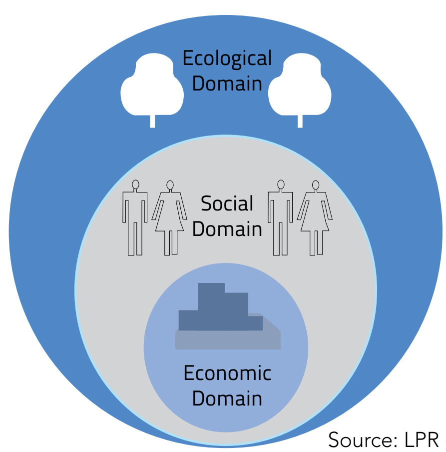
Context and starting points

Ecosystems and their services, such as food, freshwater, clean air, forage, fodder and genetic resources, are crucial for human survival and well-being (DST 2008). In turn, ecosystems depend on humans for their health and integrity but these ecosystems are being threatened by pollution, over-exploitation and human encroachment.

The 2005 Millennium Ecosystem Assessment (MEA) Report recognizes the interdependence of ecosystem health and social well-being. It defines an ecosystem as "a dynamic complex of plant, animal and microorganisms and the non-living environment, interacting as a functional unit" and ecosystem services as "the benefits people obtain from ecosystems, including provisioning services such as food and water; regulating services such as regulation of floods, drought, land degradation and diseases; supporting services such as soil formation and nutrient recycling; and cultural services such as aesthetics, recreational, spiritual support and similar non-material benefits" (Reid and others 2005). These benefits are determined by ecosystem health and integrity and have differential impact on human well-being and social and cultural relations (see Figures 1a and 1b) (Reid and others 2005).

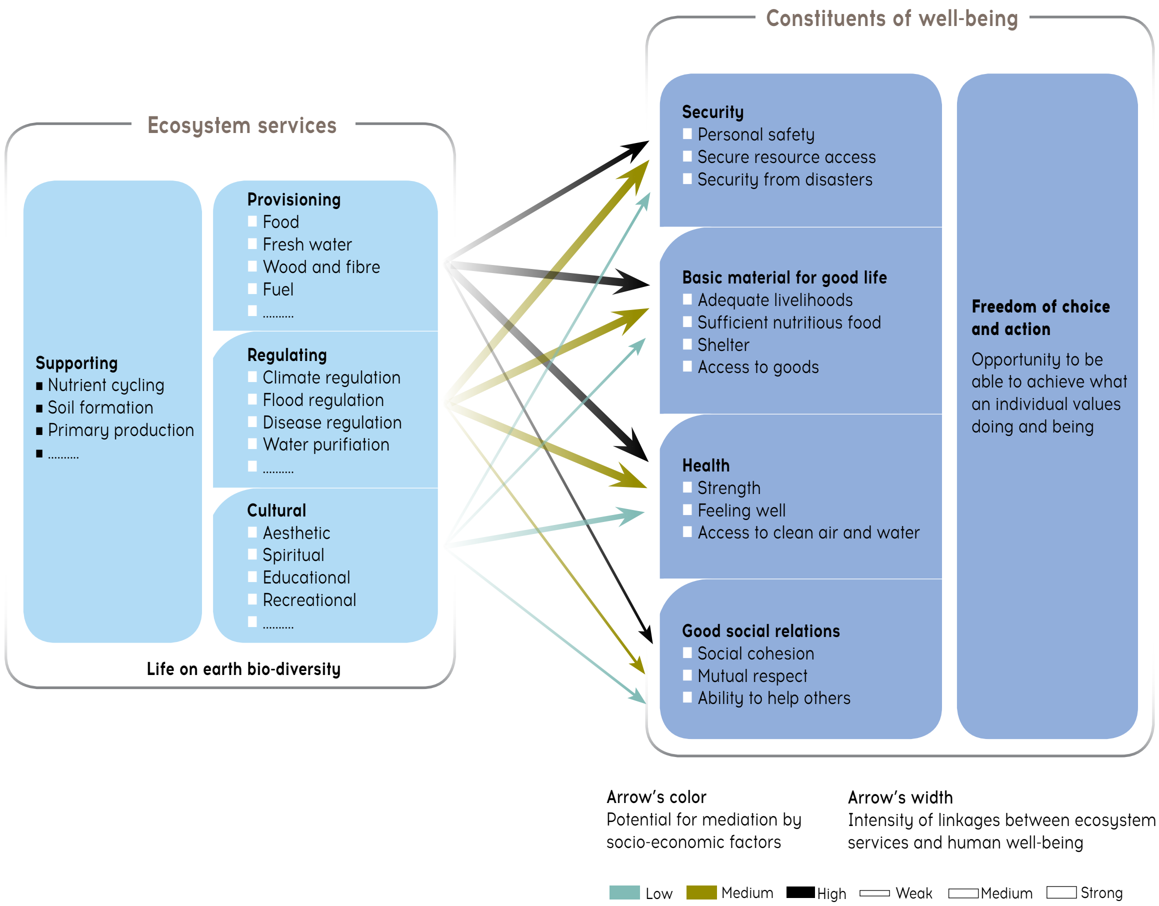
Ecosystems are facing greater stress from increasing human demand and recurrent changes in the biosphere. Increased water extraction due to the intensification of or shift away from agriculture to industry has reached unsustainable levels in many parts of the world. Deforestation, together with the intensification of crop cultivation and increased grazing in forests and on rangelands, has aggravated soil erosion and land degradation.

FIGURE 1A Framing of ecosystem services



Source: LPR (2014)

FIGURE 1B Ecosystem services and their links to human well-being



Source: Reid and others, (2005)

TABLE 1 | Ecosystem services

Provisioning	Regulating	Cultural	Support
The diverse range of physical products obtained from ecosystems: - Food crops - Forage and fodder - Leaves - Fish - Livestock - Water resources - Timber - Biomass fuels - Fibre - Non-mineral building material - Aromatic and medicinal plants Non-timber forest products (NTFPs)	Services which regulate natural systems and dependent physical and biological processes: - Flood moderation - Air and water quality - Water flow - Crop pollination - Waste assimilation - Control of pest and disease vectors Carbon absorption	Non-material benefits: - Spiritual enrichment - Aesthetic enhancement - Recreation Cultural identity	Services that support production of benefits: - Nutrient recycling - Weathering and biochemical synthesis for soil formation Pollination; and seed dispersal

Increased sedimentation in rivers as a result of accelerated upstream soil erosion is degrading river and lake ecosystems. Reduction of land cover can change the local hydrology by altering the relationship between rainfall and run-off.

Agricultural intensification, industrial expansion and urban development are resulting in the widespread decline in water quality (DST 2008). Mining of natural resources and small industries release organic and inorganic solids, dissolved nutrients and metals into local water bodies. Disposal of untreated human waste increases phosphate and nitrate loads, causing eutrophication in downstream water bodies. Human and industrial effluents contaminate water bodies with devastating impacts on ecosystems and human health. Over the past 50 years, nearly 60 per cent of the world's major ecosystems have undergone degradation (MEA 2005). The 2014 Living Planet Report by World Wildlife Fund states that growing human demands on nature have become unsustainable (LPR 2014).[1]

As urbanization increases, land use will change and the interaction between other drivers is likely to intensify, accelerating ecosystem degradation. When the health of an ecosystem degrades, its ability to provide goods and services diminishes, resulting in declining well-being of those dependent on their services (DST 2008). The degradation is often exacerbated by social and political factors, producing a vicious cycle of reduced human well-being, which disproportionately affects the socially vulnerable.

Climate change is an increasingly important driver of ecosystem degradation. The alteration of regional and local climate dynamics has adverse consequences on the function and integrity of ecosystems and, in turn, ecosystem degradation has a negative effect on regional and local climate systems (IPCC 2013). The Fifth Assessment Report (AR5) of the Working Group I (WGI) of the Intergovernmental Panel on Climate Change (IPCC) reiterates the importance of maintaining ecosystem integrity as a safeguard against atmospheric warming. Working Group II (WGII) of IPCC suggests that some unique and threatened natural and social systems are already at risk from climate change (IPCC 2014). AR5 states "people who are socially, economically, culturally, politically, institutionally or otherwise *marginalized* are vulnerable to climate change". The challenge is to reduce climate change risks by integrating risk reduction strategies with development and maintaining the health of natural ecosystems.

Climate change has the following effects:

- longer hot periods affect ecosystems, habitats as well as species structure and diversity;
- perturbations in ecological interaction, including competition among species, disease and pest dynamics, host-parasite interaction and pollination;
- changes in rainfall pattern, affecting water balance and freshwater availability;
- frequent and high-intensity rainfall, landslides and floods with resulting damage to sensitive ecosystems;
- declining availability of freshwater, affecting water supply and crop yields;
- drought conditions; and
- loss of biodiversity with conservation value.

Climate change threatens the ability of the earth's ecosystems to produce goods and services that sustain human lives and livelihoods. Forests, for example, not only provide timber and non-timber products, but also produce ecosystem services such as water storage, wildlife habitats and regulation of the atmosphere and climate.[2] An EbA approach can help prevent some of the effects listed above.

Ecosystems in Nepal: Rich diversity

Nepal has diverse climatic zones across a short distance, varying from subtropical to alpine as the country's altitude soars from 64 to 8 850m above sea level within less than 200 km along the north-south border. This has given rise to a wide range of ecosystems with services that provide livelihoods to about 17 million people (two thirds of the total population) who depend directly on forests, agriculture and aquaculture.[3]

Although Nepal occupies only 0.03 per cent of the earth's surface, it is home to nearly 5 and 9 per cent, respectively, of the world's mammal and bird species (MoPE 2001). Most of the country's biological diversity is found within its national parks, wildlife reserves, conservation areas, hunting reserves and buffer zones (Singh and Smith 2009). These areas make up 20 per cent of the country's total land area.[4] Local communities dependent upon the natural resources in these areas are being involved in efforts to conserve and manage their floral and faunal diversity.[5]

However, the benefits of conservation have not been equally distributed due to social and political circumstances and patterns of natural resource governance. Ecosystems are generally characterized as private, state, common or open access[6] in terms of rights to use their services. Private and state property regimes define entitlement clearly with ownership vested in individuals or state agencies. Open-access regimes provide free access to the resource. In common property regimes, the ownership, control of and access to a resource (endowment) is different from the ownership, control and access to benefits derived from the resource (entitlement).

The implementation of the EbA should be examined in the context of these four regimes as well as Nepal's prevailing social and political structures and cultural practices[7] to assess its likely effectiveness in improving ecosystem integrity and benefiting those vulnerable to the adverse impacts of climate change. The nature of resource governance and how stakeholders negotiate sharing access to ecosystem services will determine the benefits of EbA. Ideas of ecosystem governance, entitlement and access to natural resources and services are changing in Nepal, making it difficult to assess the benefits of EbA.

Almost two thirds of Nepal's population depends on ecosystems for a livelihood. A climate change vulnerability assessment based on an ecosystem-services perspective can identify adaptation measures to maintain ecosystem integrity. However this is not easy because of the complex relationship between ecosystems and human well-being.

Knowledge of different ecological systems is not only incomplete but also often elusive (Walters and Holling 1990). Ecosystems and their services interact with one another in complex and often unpredictable ways and their relations with humans are even more complex because human systems are dynamic and have unexpected outcomes. The interaction between ecosystems and humans is complex and unpredictable. There is a lack of basic data on critical ecosystems, their characteristics and services, and cultural services in particular. Assessing the cultural value of the natural environment in terms of landscape conservation, aesthetics, cultural heritage, recreation and spiritual significance is difficult (Klausmyer and others 2011, Daniel and others, 2012). Ecological systems and functions are not tangibly related to cultural values in ways that produce apparent gains for people (Daniel and others 2012, Kirchhoff 2012) but they do set the scene for cooperation and new relationships to evolve which is also the case in the PMER.

Unplanned infrastructure development, especially roads and unchecked extraction of construction material, is a threat to ecosystems. Urban growth in Nepal and the bordering Indian States of Bihar and Uttar Pradesh, are driving infrastructure development amid a weak natural resource governance regime in Nepal. Extraction of materials for construction has affected hydrological regimes with increasing surface run-off and sedimentation, impacting adjoining land and water bodies as well as downstream areas. Road and highway construction in the Tarai from east to west is obstructing the north-south flowing rivers and streams, increasing the extent of flooding. In both mountains and the Tarai, this process has led to habitat destruction and loss of ecosystems.

Urbanization and infrastructure development accompanied by rapid economic and social transformation are altering the relationship between ecosystems and livelihoods in Nepal. Increased migration and market-based livelihoods have reduced dependence on natural resources. Migration from rural areas has led to the uncontrolled growth of major urban centres such as Kathmandu. It is also being driven by loss of traditional natural resource-based livelihoods due to recurrent floods and droughts that can be linked to climate change though the reason for recurrent floods/droughts cannot be directly attributed to climate change. Other social, political and livelihood changes that create new stresses on local ecosystems and their services also influence the behaviour of communities who are dependant on these services.

How evident are the impacts of non-climatic and climate stressors in a specific context? The role of non-climatic drivers of change in the natural systems is pronounced, but it is difficult to identify which local impacts are the direct results of climate change. That is not to say that climate change is having no impact: it is more that the evidence of how climate change is depleting the resilience of the country's diverse ecosystems is anecdotal and fragmented. Both low-probability high-intensity (LPHI) weather events like torrential rain and high probability-low intensity (HPLI) weather events like dry winters or weak monsoons may decrease ecosystem resilience, the quality and quantity of its services and the adaptive capacity of communities. While LPHI events can cause sudden and widespread loss, HPLI events can have a cumulative effect, lowering the disaster preparedness capacity of communities (Cardona and others 2012). Frequent and intense weather events pose the greatest threat to social and economic infrastructure and services at the local level and result in increased disaster-induced poverty.

Together with unsustainable natural resource extraction,[8] these types of events could degrade ecosystems and threaten to derail national gains towards the Millennium Development Goals (MDGs) (Shepherd and others 2013). Countries like Nepal need to reverse the trend of migration from rural areas, especially of young people, to prevent the greying and feminization of agriculture which threatens the rich cultural wealth in addition to the changes in the socio-political and climatic characteristics.[9] The question of how these challenges should be tackled is yet to be answered.

It is unclear how diverse groups of decision-makers, policy-makers, researchers and other professionals should work together to enhance the resilience and adaptive capacities of communities. There is no knowledge about which practices and options will be effective in minimizing ecosystem vulnerability to climate change, reducing climate change-related risks and not be maladaptive. There is also no knowledge of the frameworks, processes, tools and techniques to address climate change-related risks through chosen adaptation measures. Adaptation analysts and practitioners should be aware of these limitations and try to improve practices, make public policy more effective and bridge the EbA knowledge gap.

Study objectives and scope

This study identifies EbA options that can help reduce ecosystem vulnerability to climate change, thereby sustaining their livelihood services. It assesses vulnerability sources in the PMER and treats ecosystems as part of the coupled human-environment system.

The study is part of the three-country Ecosystem-based Adaptation: Adapting to Climate Change in Mountain Ecosystem Project implemented in Nepal by the Government of Nepal (GoN) with the support of the United Nations Environment Programme (UNEP), United Nations Development Programme (UNDP) and International Union for Conservation of Nature (IUCN). In Nepal, the Ministry of Forest and Soil Conservation (MoFSC) was the implementing agency and the Ministry of Science, Technology and Environment (MoSTE), the coordinating agency of the project which was initiated in 2011 and completed its first phase in 2014. Supported by the Federal Ministry for the Environment, Nature Conservation Building and Nuclear Safety (BMUB) of the German

Government, the project is being implemented simultaneously in Nepal, Peru and Uganda. The objective is to support institutions and communities to manage ecosystems and their services in order to reduce ecosystem and human vulnerabilities by promoting EbA options to climate change.

The EbA approach is built on the idea that conservation, restoration and/or sustainable management of ecosystems can help build resilience of both the system and communities that depend on its services to emerging climate change-related and other vulnerabilities. Using a practical, flexible and locally grounded approach, an EbA assessment determines how human-environment systems can be managed to reduce vulnerability to climate change. Climate change scenarios developed for the WR (NCVST 2009) were used to assess future risks and vulnerabilities and options to enhance resilience in the PMER.

National and global assessments suggest that climate change, specifically changes in precipitation, is likely to make Nepal more vulnerable (NCVST 2009, NAPA 2010, Maplecroft 2011, Harmeling and Eckstein 2012). It is predicted that intense precipitation of short duration will exacerbate flooding, landslides and sedimentation (NCVST 2009, NAPA 2010). Changes in precipitation patterns will adversely affect ecosystems like the PMER by altering the distribution of run-off and soil moisture regimes and increasing erosion and landslides. This will affect the diversity of wild orchid species in the region and its wetlands, among others. The drying of streams and rivers has a negative impact on aquatic plants and fish species. The decrease of wetlands in Rupa Lake of Kaski District due to low water levels in upper streams has reduced local fish species (Regmi and others 2008)[10] and this has had major livelihood implications for local fishing communities.

The impact of climate change on ecosystem services has become more evident at the sub-watershed level. As ecosystem services are available within a hydrological boundary such as a watershed, this should be the unit of vulnerability analysis. However, in many countries including Nepal, hydrological boundaries do not coincide with administrative boundaries while social and economic data are collected at an administrative level. This makes it very difficult to identify and implement climate change adaptation measures. This study, therefore, conducted VIAs initially at the ward and village development committee (VDC) spatial level[11] and then at the sub-watershed level. At the same time, the study identified key ecosystem services and stressors of vulnerability. The PMER was selected for the EbA pilot study because its biophysical and socio-economic characteristics match the project's criteria, namely a) ecosystem services vulnerable to climate change; b) human well-being highly dependent on ecosystem services; c) EbA options available and acceptable to local communities; d) partners ready with institutional capacity to implement EbA options; and e) potential for scaling-up.. The four main objectives of the study were as follows:

a. conduct a VIA of the PMER, focused on important ecosystem services;
b. identify EbA activities that could reduce vulnerabilities or increase resilience to climate change;
c. map vulnerability and EbA options; and
d. make recommendations for the implementation of EbA in the PMER.

The study mapped current hazards, developed future hazard scenarios and assessed their impact on important ecosystem services and identified EbA options to reduce vulnerability and enhance the PMER's resilience to climate and non-climate stresses. The assessment of current vulnerability provided a basis for envisioning future vulnerability to climate change as well as identifying viable EbA options to build resilience and adaptive capacity. These options were chosen to improve ecosystem health, promote social well-being and minimize climate-related disasters. The project listed vulnerabilities at the ward and sub-watershed levels in a geographical information system (GIS) platform.

CHAPTER II

PANCHASE MOUNTAIN ECOLOGICAL REGION AND SERVICES

Ecosystem types

Straddling the three districts of Kaski, Syangja and Parbat in Nepal's Western Development Region, the PMER covers an area of 283 km^2 west of Pokhara Municipality, including 17 VDCs (see Figures 2a, 2b and 2c). Panchase, which translates as "five seats", is the meeting place of five mountain peaks.

The PMER's vegetation ranges from subtropical to cold temperate. The region is home to diverse ecosystems including forests and wetlands, a wide vegetative variety, including rhododendrons and endemic orchid species, as well as religious and cultural diversity. The PMER comprises the headwaters of Phewa Lake and Aandhi Khola,[12] two important water bodies used extensively for hydropower, irrigation, recreation, tourism and aquaculture. The Rati/Jare Khola drains the remaining area of the PMER. In 2012, the GoN declared 57.76 km^2 of the PMER (20 per cent of the total area, including 9 of the 17 VDCs) as the Panchase Protected Forest (PPF).

Physical features: The elevation of the PMER ranges from 742 m above sea level near Phewa Lake to 2 517 m at the top of Panchase Peak.[13] Almost 79 per cent of the total area lies between altitudes of 1 000 to 2 000 m above sea level and just four per cent is above 2 000 m. The remaining 17 per cent is located at altitudes below 1 000 m (see Figure 3a). The 17 VDCs in the PMER have all types of slopes (see Figure 3b). A significant area of the PMER has steep slopes. The moderate-to-gently sloping terraces and flat valley floors are intensely cultivated with rich soils irrigated by canals. Land that slopes less is more stable and these areas have less frequent slope failure and wasting during extreme precipitation events.

Geology: The PMER is located in the central section of the Lower Himalaya, a region with a 7 000 m thick section of para-autochtonous crystalline rock. Separated by the Main Boundary Thrust (MBT) and the Main Central Thrust (MCT), this section comprises of mostly unfossiliferous sedimentary and meta-sedimentary rocks such

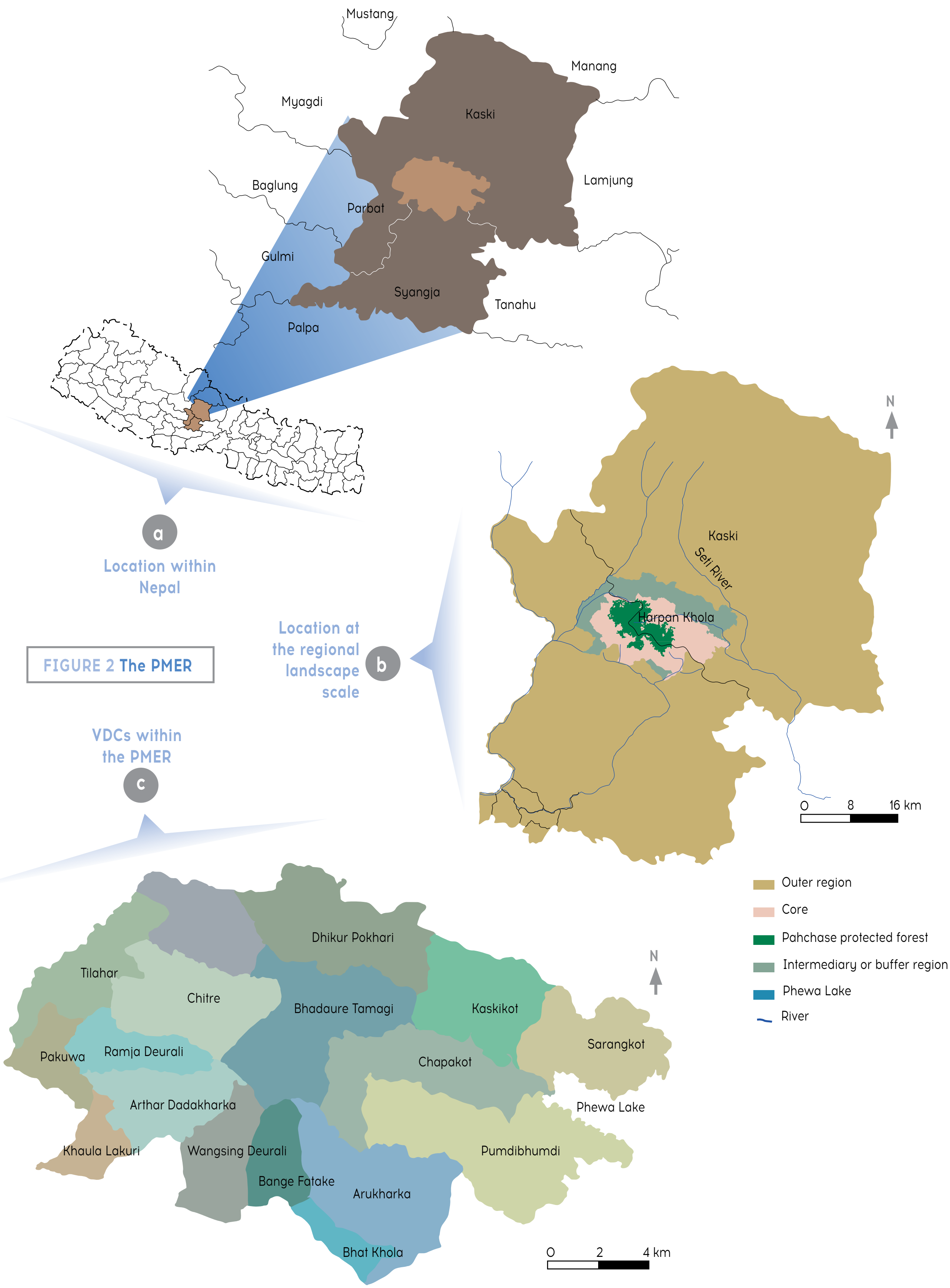
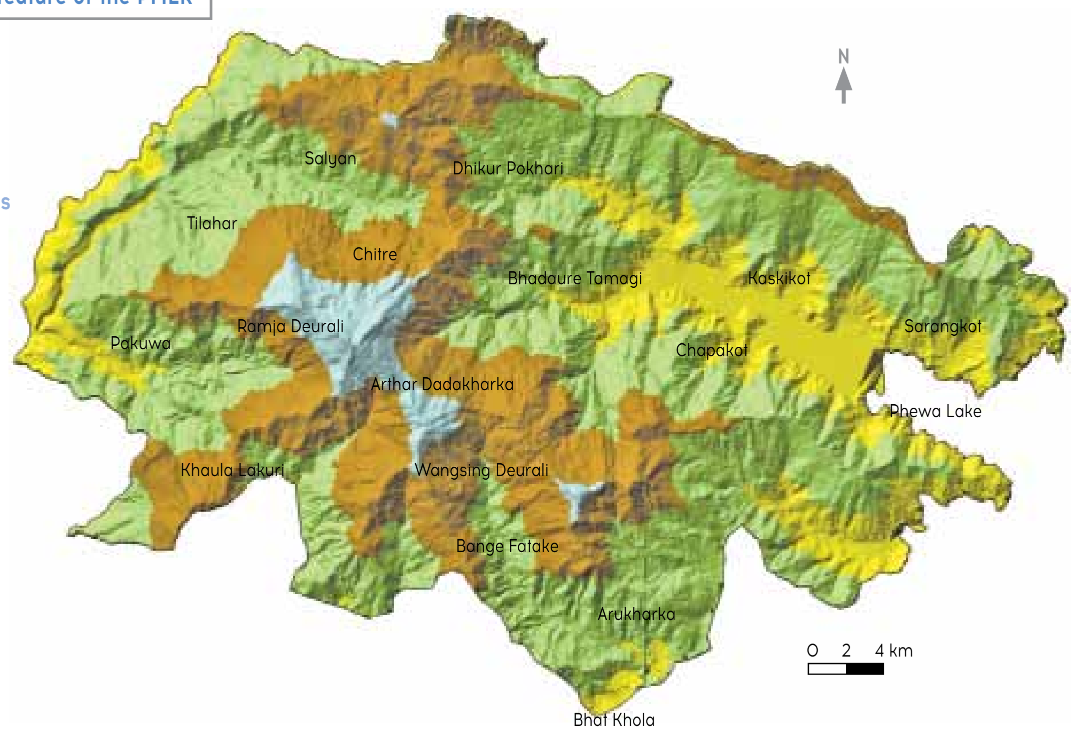


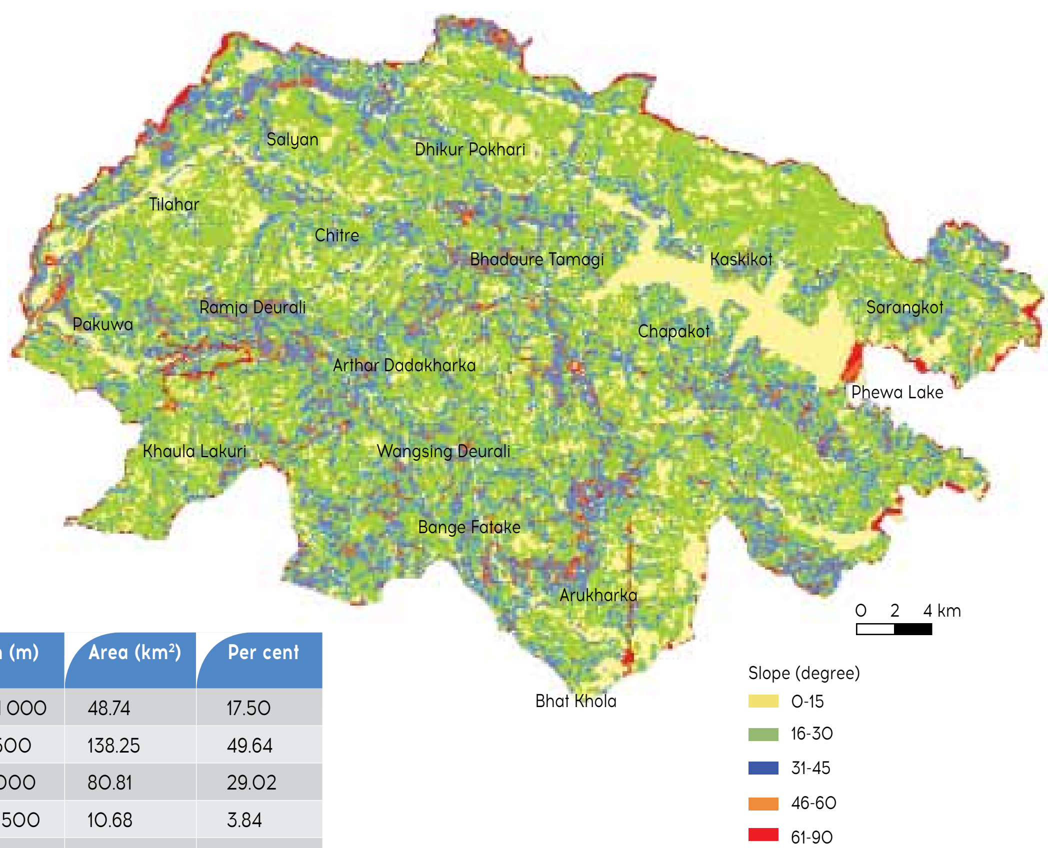
FIGURE 2 The PMER

FIGURE 3 Physical feature of the PMER

a Area distribution by elevation class



b Slope categories



Class	Elevation (m)	Area (km²)	Per cent
1	less than 1 000	48.74	17.50
2	1 000-1 500	138.25	49.64
3	1 500-2 000	80.81	29.02
4	2 000-2 500	10.68	3.84
		278.49	100

as shale, sandstone, conglomerate, slate, phyllite, schist, quartzite, limestone and dolomite. The lower slopes are covered in thick soil. Folding, faults and thrusts add to the geological complexity of the area. Other major geological formations include Naudanda, comprising of white fine-to medium-grained quartzite with ripple marks inter-bedded with green-phyllites and seti which is in turn made up of grey-greenish gritty chlorite muscovite sand and grit stones with conglomerates and white-quartzite in its upper parts. Morphologically, the region can be classified into five major land units: alluvial plains and fans (depositional), alluvial plains, ancient river terraces (*tars*) and moderate-to-steep mountain slopes. The geomorphic character is significant because it is directly and closely related to lithology and vegetation as well as human settlement patterns and cultural practices. For example, agriculture is concentrated in alluvial plains and river terraces because the soil is most fertile in those areas.

Specific geological information is only available for the Harpan Khola sub-watershed. According to Rana (1990) and Ross (1998) weakly-bedded, low-to-mid-grade metamorphic rocks, phyllitic schist underlie the river's catchment area. It is likely that the Andhi and Rati/Jari Khola sub-watersheds have similar geological structures.

Phyllites composed of micas and chlorites, characterize the northern section of the catchment while grey phyllitic schist dominates the southern section. The fragility of phyllites and the steep topography make the northern section geologically more susceptible to erosion than the southern section. In contrast, sections of the southern catchment consist of mid-grade metamorphic rocks like quartzose and moderately strong bedding structures that help resist mass wasting. Red phyllitic schist is found in most of the southern section of the sub-watershed while landslide-prone carbonaceous conglomerate and inter-bedded quartzite schist and grey-phyllitic schist, respectively, are found in the east and southwest.

Temperature and precipitation: The climate of a region is determined by two factors: local-scale features and large-scale climate patterns. The PMER is no different. In the Himalaya region, local-scale features include terrain, relief, elevation, vegetation type and land use. Large-scale climate patterns result from changes over large geographical spaces, such as the El Niño Southern Oscillation and snow-capped higher elevations.

The PMER climate varies from subtropical to cold temperate. At lower elevations, summers are warm whereas at higher elevations these range from cold to very cold. In winter the Panchase peaks are covered in snow for a limited period of time. However, snowfall is not monitored. In terms of large-scale climate patterns, the annual precipitation cycle of the PMER is similar to the rest of Nepal and is dominated by the Asian monsoon system. The PMER has specific local characteristics, producing behavior typical of Nepal's micro-scale climate of valley and hills (Domoroes 1978) – when a valley receives high rainfall, the amount of rain in its upper hills may be low and vice versa. Monitoring of climatic parameters such as temperature, humidity, evaporation and precipitation across the PMER is inadequate which means it is not possible to provide a detailed explanation of all specific local features.

The marked differences in elevation over short distances in the PMER influence daily, seasonal and annual temperatures and rainfall. Therefore rainfall may vary significantly over short horizontal distances with sharp changes in the elevation. While the lack of data from the few meteorological stations in the region makes it impossible to confirm this hypothesis, the Lang and Barros (2001) study of the Mid-Mountain watershed of the Marsyangdi River, about 50 km east of Pokhara Valley, found that precipitation on valley floors can vary by up to eight times when compared with that on the ridges. The PMER also has large microclimatic differences and if more stations were set up to collect precipitation data, the differences could be better explained.

Climatic variability in the PMER was assessed using data from the three meteorological stations within the PMER (one in each of the three constituent districts of Kaski, Syangja and Parbat) and eight in its immediate surrounding (five in Kaski, two in Parbat and one in Syangja).[14] The three stations within the PMER measure only temperature while the other eight have precipitation data between 1977 and 2009 and temperature data for different periods. The data indicates that the mean maximum temperature in the PMER is about 29°C and the mean minimum temperature is 5.3°C. The coldest month is January with an average monthly minimum temperature of 4.3°C. Temperatures begin to rise in February and reach a maximum of 36.5°C in May. The temperature begins to fall with the onset of the monsoon rains in June. On average, the PMER receives 3 882 mm of rainfall every year, well above the national average of 1 857 mm (Practical Action 2009) (see Tables 2a and b). As in other parts of the country, most of the rainfall occurs during the monsoon.

The mean monthly distribution of temperature and rainfall at 11 selected stations is shown in Figures 5a to 5f and several trends can be observed. Rainfall does not show significant inter-annual variability, but data for each station shows microclimatic variations across the region. Rainfall is unevenly distributed over the year. Rainfall is expected to vary dramatically from year to year, but it is hard to provide evidence supporting this because of the limited availability of data on intensity that is measured by hourly rainfall. Only one station, located at Pokhara Airport outside the PMER, monitors hourly rainfall but as records are available only for a short period, it is not possible to estimate hourly trends. Records of hourly rainfall are needed to generate insight into extreme events and the likelihood of them occurring in future in the context of a changing climate.

The highest hourly rainfall recorded at Pokhara Airport was 107.8 mm on 10 June 2013[15] and the second highest of 70 mm was recorded in 1998 (Ross 1998). The recent hourly rainfall record may indicate a rise in rainfall intensity but without data for a longer period this hypothesis cannot be accepted with any degree of certainty. Nor can it be attributed to global climate changes. It is important to ask whether the June 2013 hourly rainfall event was the result of a regional climatic pattern or a localized event and whether such events will become more frequent. But questions like these cannot be answered without setting up monitoring stations to improve spatial and temporal coverage of climate information such as daily and hourly rainfall. The records available are insufficient to analyze local hydrological systems, to understand, for example, how changes in rainfall will alter streamflow. Ross (1998) suggests that rainfall at Pokhara Airport is positively correlated with the flow volume in Harpan Khola, but it is important to note that rainfall data from outside the PMER only provides a general indication of trends in the PMER itself. It will not be able to represent micro-contexts of the region's sub-watersheds.

Vegetation and land use: The PMER is biophysically diverse with lower elevations having a subtropical climate, gradually changing to colder temperatures with increasing elevation. The region has three distinct vegetation strata determined by temperature, namely subtropical, mixed and temperate. It is home to diverse species, including rare plants such as orchids, tree ferns and coniferous trees. It also includes valuable forest ecosystems, which are important habitats for animal and plant species, especially rhododendrons and a number of endangered orchid species. Forest ecosystems in the region are changing driven by multiple causes and these changes can pose a threat to local livelihoods and biodiversity.

GIS overlays between 1990 and 2010 (see Figures 6a and 6b) show significant spatial changes in land use in the PMER over the last 20 years (see Table 3). The increase in forest cover during this period is associated with a decrease in shrub-covered land and grassland. An increase in built-up areas due to the construction of roads, schools,

FIGURE 4 Meteorological stations around the PMER

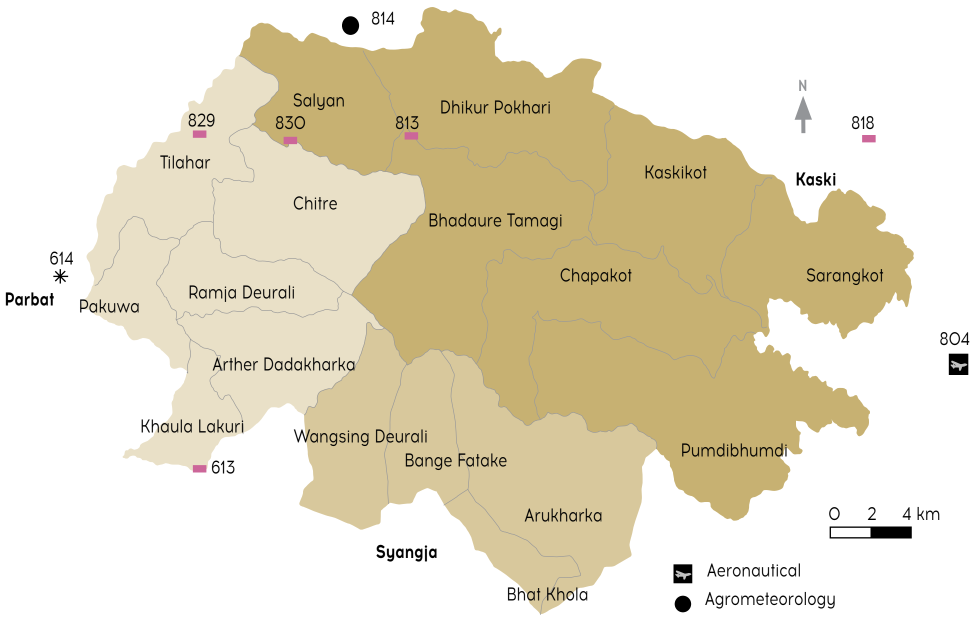


TABLE 2 | Meteorological stations' summary

a List of stations and periods for which data is available

Stations	Districts	Elevation (masl)	Duration of data availability	
			Rainfall	Temperature
804 (Pokhara airport)		827	1977-2009	1976-2009
813		1 600	1977-2009	NA
814 (Lumle)	Kaski	1 740	1977-2009	1971-2009
818		1 070	1977-2009	NA
830		1 160	1977-2009	NA
613		NA	1977-2009	NA
614	Parbat	891	1977-2009	1977-2009
829		1 000	1977-2009	NA

Note: NA= Not Available

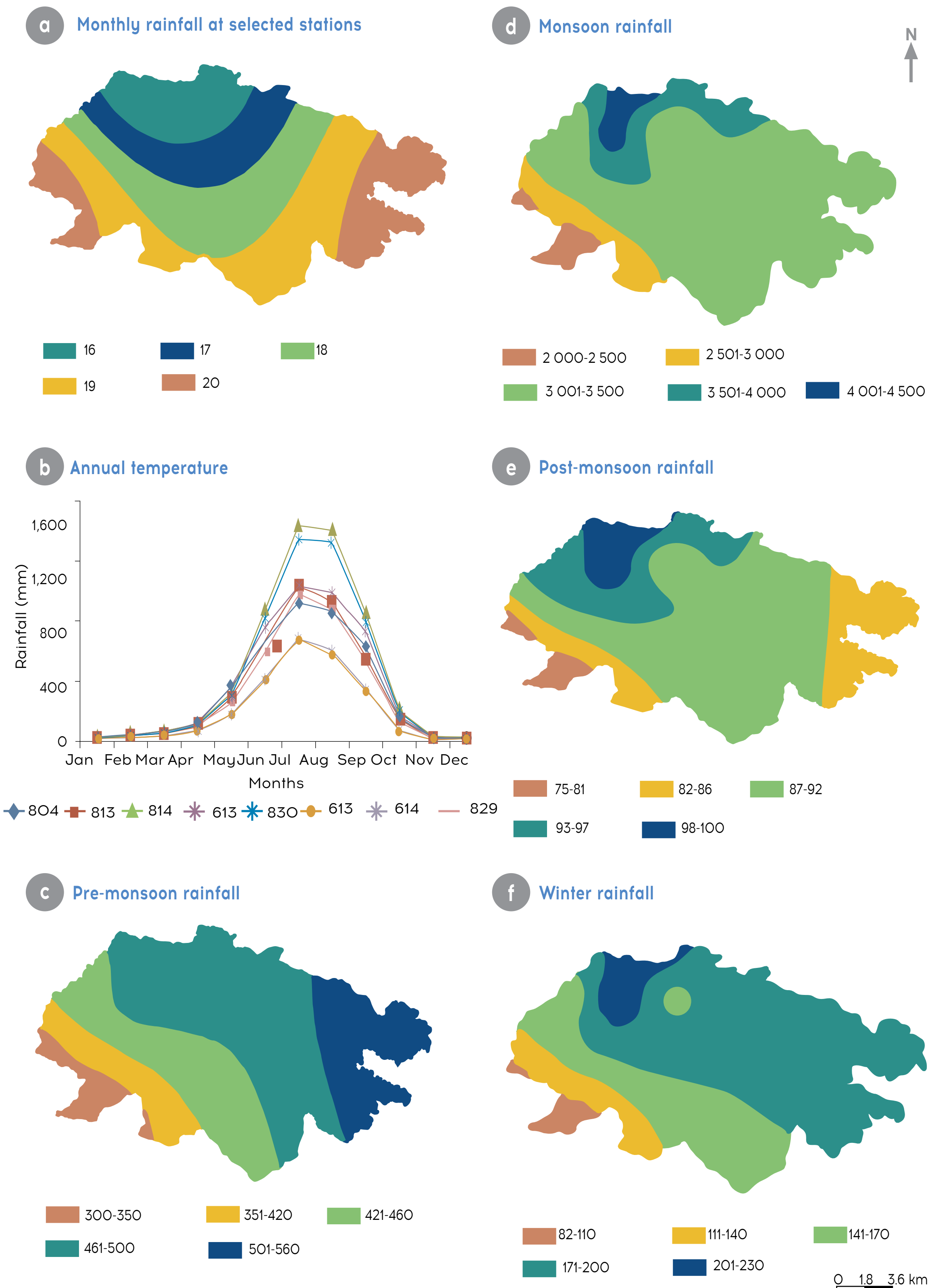
b Annual average rainfall and temperature in each station

Stations	Districts	Elevation (masl)	Annual average rainfall (mm)	Annual mean temperature (°C)
804 (Pokhara airport)		827	3 627.09	20.9
813		1 600	3 913.80	
814 (Lumle)	Kaski	1 740	5 411.58	15.95
818		1 070	4 364.76	
830		1 160	5 102.80	
613			2 451.14	
614	Parbat	891	2 515.03	20.86
829		1 000	3 671.72	

c Mean monthly temperature and rainfall in the PMER

Month	Rainfall (mm)	Temperature (°C)
Jan	25.64	11.06
Feb	38.66	13.76
Mar	60.35	19.93
Apr	105.84	20.67
May	283.73	21.79
Jun	652.10	23.25
Jul	1 014.12	23.19
Aug	949.54	24.27
Sep	600.58	23.38
Oct	142.27	20.68
Nov	20.43	16.26
Dec	23.27	12.89

FIGURE 5 Rainfall distribution in the PMER



residential buildings and other community infrastructure can also be observed. Of the three PMER watersheds, the Harpan/Firke Khola has undergone the most noticeable changes in land use (see Table 4).

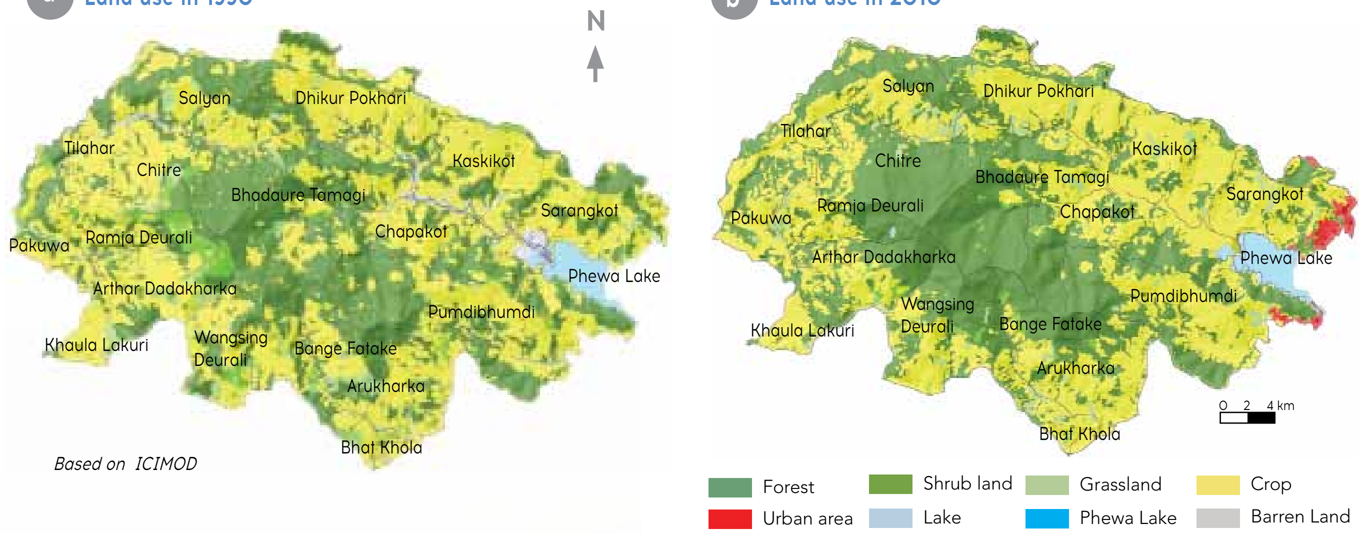
River systems: The PMER comprises the headwaters of three river systems, namely the Harpan Khola, Aandhi Khola and Rati/Jare Khola with watershed areas of 135 km^2, 59 km^2 and 88 km^2, respectively, and which feed into the Seti, Modi and Kali Gandaki rivers, respectively. The entire Harpan/Firke Khola watershed lies within the PMER as does 83.5 per cent of the Rati/Jare watershed. Only 9.1 per cent of Aandhi Khola watershed is located within the PMER (see Figure 7a). These can be subdivided into 13 sub-watersheds and several micro-watersheds. The main stem of the Harpan/Firke sub-watershed has a slope of 1.14 per cent up to its confluence with Phewa Lake, while the Rati/Jare slopes 2.34 per cent up to its confluence with Modi Khola. The Aandhi Khola slopes 4.45 per cent up to its confluence with the Kali Gandaki.

The rugged PMER topography and geology result in a dense network of small, steep, rapid-flowing streams. This dense network (see Figure 7b) immediately drains the rain run-off, at least until a certain threshold is reached and accounts for the region's low vulnerability to large-scale flooding. However, this may change if the current threshold is reached due to changes in rainfall. Once the threshold value is reached or exceeded, rainfall may trigger landslides and mass wasting, threatening ecosystems and their services. A comprehensive examination of the threshold concept and this relationship is needed to understand how increased exposure will exacerbate landslide risks.

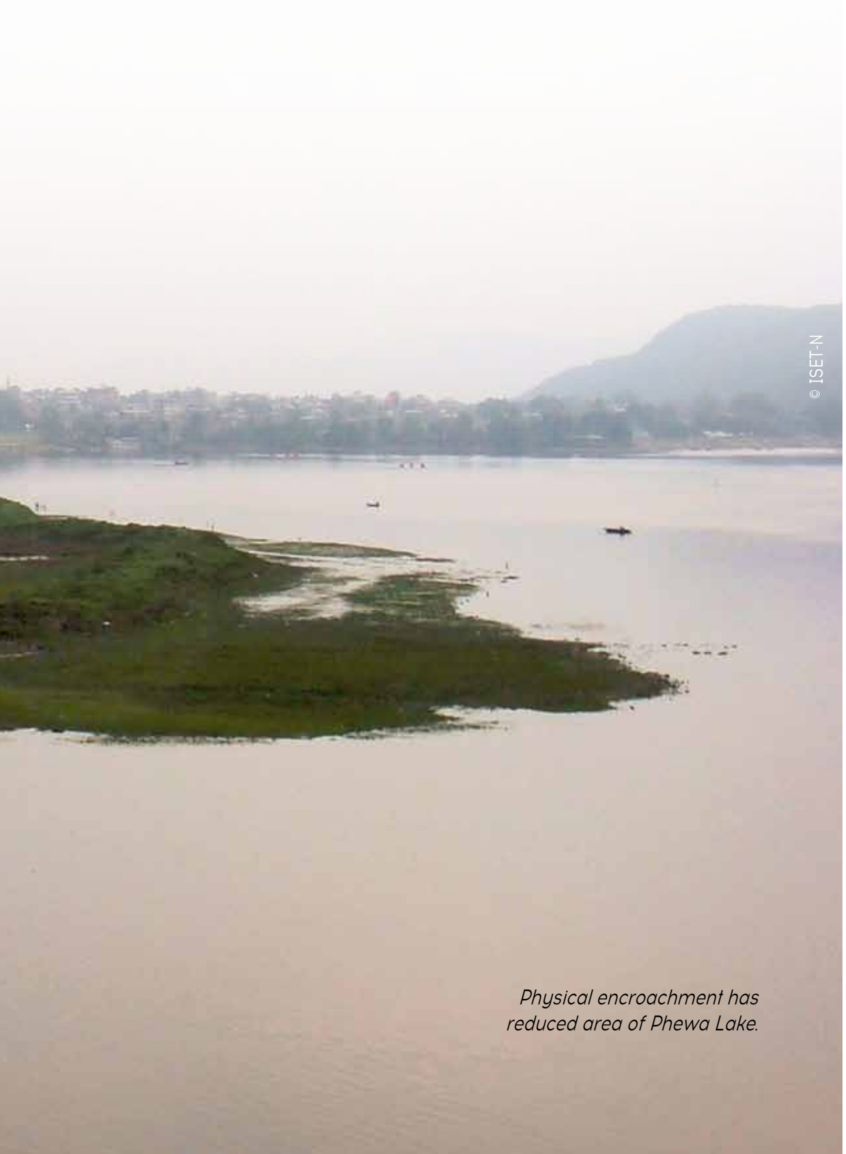
FIGURE 6 Land use in the PMER

a Land use in 1990

b Land use in 2010



Based on ICIMOD



Physical encroachment has reduced area of Phewa Lake.

TABLE 3 | Land use status of the PMER

Land cover	1990		2010	
	Area(km²)	Per cent	Area(km²)	Per cent
Built up	0.003	0.001	2.82	+0.99
Rocky Outcrop	0.17	0.061	0.075	+0.03
Agriculture	147.58	52.015	135.091	-47.61
Forestland	115.03	40.543	132.66	+46.76
Grassland	8.79	3.097	7.36	-2.59
Shrubland	10.43	3.677	4.89	-1.72
Water bodies	1.72	0.606	0.82	-0.29
	283.73	100.00	283.73	100.00

Source: Based on figure 6a & b

TABLE 4 | Land cover in the watershed of Phewa Lake

Land use type	Area (ha.)	Total per cent
Agriculture	4 605.84	43.65
Build-up	253.15	2.40
Forest	5 179.52	49.09
Grassland	65.11	0.62
Sand	108.14	1.02
Shrubs	184.03	1.74
Swamp area	115.26	1.09
Water body	39.93	0.38
Total	10 550.98	100.00

Source: MoFSC/UNDP/MDO (2012)

Aquatic system: The PMER is home to numerous ponds, lakes and wetlands. Phewa Lake in Chapakot VDC, southwest of Pokhara Valley, is the major aquatic system in the region. The PMER contains several ponds and lakes. One such lake in the PMER is the Panchase Lake, which is much smaller than Phewa. The Phewa Lake is fed by the Harpan Khola and a number of seasonal streams, including the tributaries of Harpan Khola, namely the Khahara, Thotne, Lauruk, Thado, Betani, Bhakunde, Faure, Kamni, Kutuje, Orlan and Turung. The Sedi Khola, Firke Khola and Seti canal also flow into the lake, but the Harpan Khola accounts for 70 per cent of the total water flow into the lake.

Erosion and sedimentation: The sediment load carried by rivers and streams affects water systems at local and basin levels, damaging the intake of irrigation and drinking water systems, blocking irrigation canals and filling up lakes and reservoirs. The sediment is produced by surface erosion, primarily mass wasting and landslides caused by steep slopes and geologically weak landforms. Recurrent sheet, rill and gully erosion and the erosion of bed and riverbanks are other causes.

A number of factors affect sediment production in Nepal's watersheds, including the Himalayan plate tectonics, geology and human intervention such as deforestation, grazing and infrastructure development. The monsoon rainfall contributes to sediment production, especially in the mountains, but it is impossible to quantify this contribution as it varies across space and time. Most assessments of sediment production processes are based on a measurement of the concentration of suspended sediment in rivers, but this is an unreliable measure in the Mid Mountains where suspended sediment flow is non-linear and episodic (Brasington and Richards 2000). It increases sharply after extreme rainfall. Bed-load, the largest share of sediment discharge, is not measured regularly.

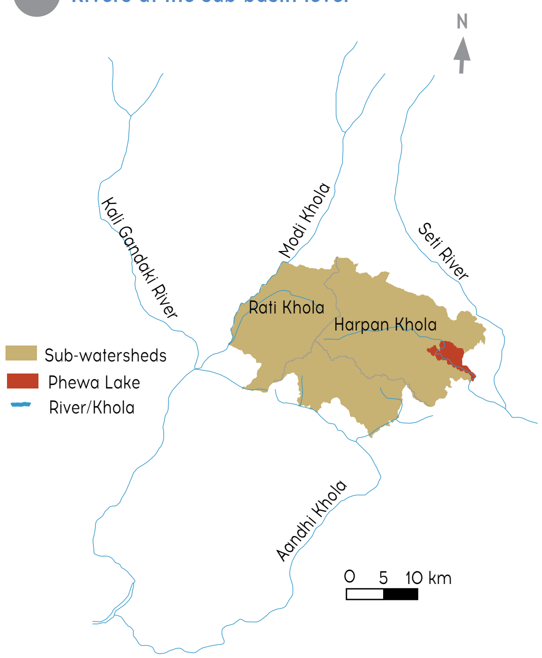
Despite these limitations, erosion rates in a few catchments have been estimated (WECS 1987) using assumptions about sediment-delivery ratios, trap efficiency and contributions from gully and non-gully sources. These rates vary from 16 800m^3/km^2/year in heavily degraded mountain slopes, to 368 m^3/km^2/year[16] in protected pastures (Laban 1978). The dynamics of sedimentation in the PMER is similar to those in other parts of the country (Ross 1998), but it is impossible to assess how it influences ecosystems and their services because of limited data.

The vegetation in the Mid Hills offers some protection against rainfall-induced sheet and rill erosion and this explains why the rate of soil loss caused by sheet erosion is very high on cultivated land, especially if it is sloped (*bari*) or rain-fed with outward-sloping terraces. Bari land experiences high rates of surface erosion whenever the erosive intensity of rainfall exceeds a certain threshold (see Box 1). In contrast, flat bench-terraces of an irrigated field (*khet*) have relatively low erosion rates (Wu and Thornes 1995). The bund at the outer side of the terrace creates an intermediate storage space for water as well as finer sediment. A flood flow caused by extreme rainfall, however, can bring sediment from upstream areas changing local dynamics and causing terraces to collapse and be washed downhill. This results in a dramatic one-time increase in the regional sedimentation rates.

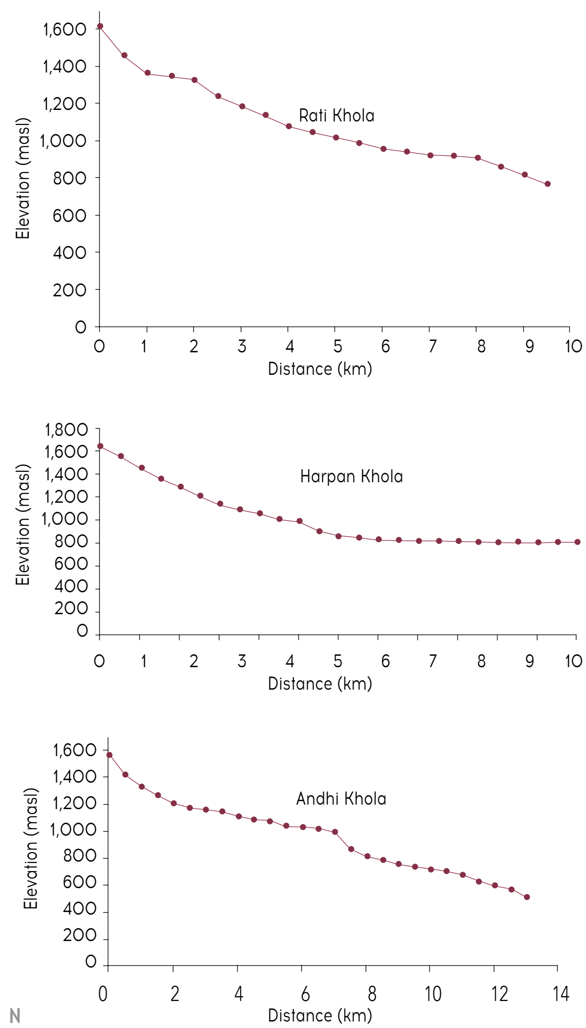
While the Harpan Khola sub-watershed has been studied in some detail, especially its erosion and sedimentation processes, the results of the study have not been synthesized. About two thirds (64 per cent) of the land in the Phewa Lake watershed is classified as erosion-prone (New Era 2000; GoN/MoFSC and DoF 2013) and the annual average erosion rate is estimated at 4 880 m^3/km^2. Landscape-scale figures are useful, but offer limited insight at the ward, sub-watershed and micro-catchment levels. Micro-watershed and farm-level measurements that would improve knowledge on sediment hydrology have not been taken in most of Nepal, including the PMER.

FIGURE 7 River systems, watersheds and river slopes

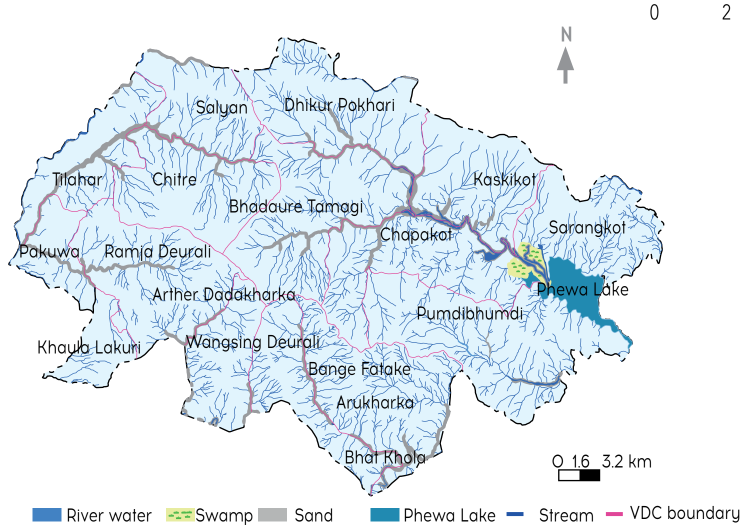
a Rivers at the sub-basin level



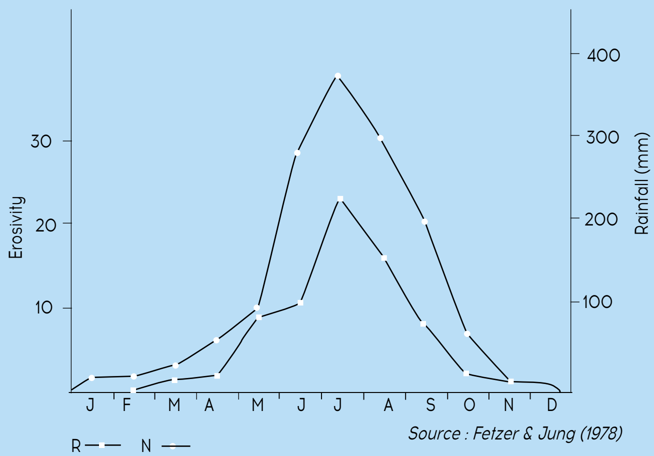
c River slopes within the PMER



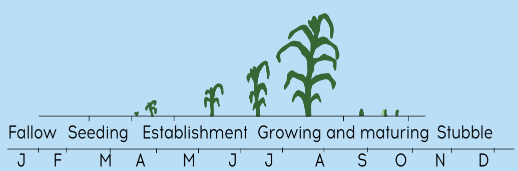
b River network within the PMER



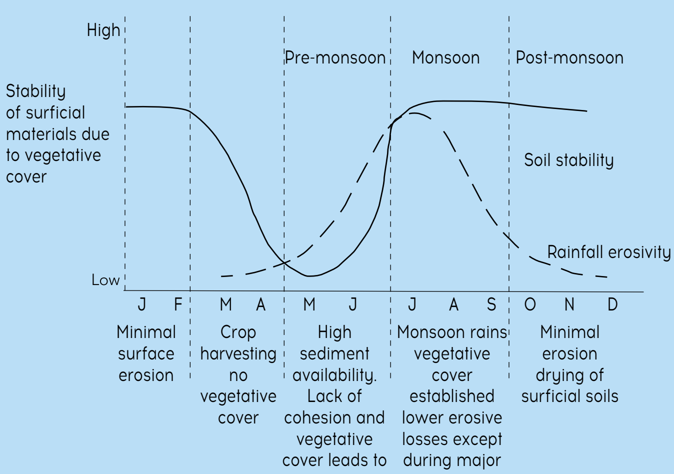
BOX 1: Relationship between rainfall, surface erosion and vegetation in Nepal's Mid Mountains



Source : Fetzer & Jung (1978)



Source: Fetzer & Jung (1978)



Source: Carson (1985)

Sheet, rill and gully erosion as well as mass-wasting (landslides, landslips and mudflows) are major sedimentation processes in Nepal's mountains. The resulting sediment is transferred to rivers, where riverbed and bank erosion adds to the load. Sheet and rill erosion is common in both terraced and sloping land and can result in the formation of gullies. Weak geological formations in the hills mean that mass-wasting processes such as landslides are common even in areas covered with vegetation and forest. Landslides create more sediment than routine surface erosion. Irrespective of the mechanics of erosion and mass movement, rainfall is the primary cause of sedimentation in the Mid Mountains. Much larger natural dynamics determine sediment production rates at the sub-watershed and basin levels. Carson (1985) finds surface erosion, locally significant, accounting for only a small per centage of total sediment production in the Mid Mountain watersheds. The proportion of sediment contributed by point sources such as landslides is very high.

Erosion in the mountains is determined by the erosive power of rainfall, which increases with intensity. Slope, soil type, geology, seismicity and vegetative cover determine the amount of mass eroded. Rainfall triggers erosion on sloping fields and other exposed sloping land surfaces. In theory, erosion is highest when erosive power is highest in July and August at the peak of the monsoon rains, but this is not always the case. The beginning of the monsoon sees intense vegetation growth, both in forests and fields when the erosive power of the rain is at its peak. The vegetation canopy offers a protective cover to the soil, reducing erosion (see adjoining figure). However, sediment erosion can occur below root zones and, therefore, reforestation will not help prevent this form of erosion.

The dynamics of vegetative growth has important implications for sedimentation and can be used to minimize farm erosion in ways that conserve water sources, enhance agricultural productivity and promote the health of micro-ecosystems. While reduced surface erosion will not make a significant difference to significantly lower sediment production at the watershed level, where mass movements generate the bulk of the sediment, on-farm activities to minimize erosion can build resilience. All activities should support existing cultivation and conservation practices.

Demography: The total population of the PMER is 62 000 of which only 44 per cent are male (see Table 5a) because of the high rate of migration. The census does not count household members absent for more than six months. Although some young men from the PMER still follow the traditional employment path by joining the army, youth in the region now prefer to work abroad in the Gulf or Southeast Asian countries. Others migrate to Nepal's urban centres in search of employment and education.

The PMER has a diverse ethnic composition with the Gurung community being the majority in Kaski District, while Brahmins form the majority in Parbat and Syangja districts. The Dalits, Gurungs and Chhetris follow in decreasing proportions in the two districts. Hinduism is the majority religion, followed by Buddhism, Islam and Christianity. The PMER is located close to the towns of Kusma in Parbat District, Baglung Bazaar in Baglung District and Putali Bazaar in Syangja District. While the population of these towns is declining, the population of Pokhara is growing rapidly (see Table 5b). The outward migration of males of working age has resulted in the feminization of the production sector in the PMER, particularly agriculture. While these changes have created new vulnerabilities, they can also be an opportunity for building resilience.

Livelihood and poverty: Agriculture is the main livelihood of about 71 per cent of the population in the PMER. Parbat and Syangja districts have higher poverty levels than Kaski District (see Table 6), but poverty data for individual VDCs is not available. The PMER is located in the WDR, which has a poverty rate of 23.5 per cent, slightly lower than the national rate of 25.16 per cent (NLSS 2011). This suggests that between 13 500 and 15 000 people in the PMER are poor.

Ecosystem services

The ecosystems within the three PMER watersheds produce the following provisioning, regulatory, cultural and support services.

Provisioning services

Grazing and fodder: Grassland, pastures and grazing patches within forests are critical PMER ecosystem resources. Although decreasing, these are an important source of animal fodder, non-timber forest products (NTFPs), medicinal and aromatic plants (MAPs) and allow for the free grazing of livestock. Important fodder species include blady grass *(Imperata cylindrica)*, thatch grass (*Themeda villosa* and *Saccharum spontaneum)*, dallis grass *(Paspalum* species) and Bermuda grass (*Cynodon dactylon)*. Overgrazing

TABLE 5 | Population details in the PMER

a) VDCs within the PMER

VDCs	Male	Female	Total
Bhadaure Tamagi	1 468	1 789	3 257
Dhikur Pokhari	3 288	4 030	7 318
Chapakot	1 151	1 486	2 637
Pumdibhumdi	3 358	4 033	7 391
Salyan	1 566	1 975	3 541
Kaskikot	2 591	3 301	5 892
Sarangkot	3 899	4 455	8 354
Arthar Dandakharka	1 121	1 497	2 618
Ramja Deurali	783	996	1 779
Chitre	767	973	1 740
Tilahar	1 954	2 660	4 614
Pakuwa	983	1 213	2 196
Khuala Lakuri	858	1 274	2 132
Wangsing Deuralli	996	1 378	2 374
Arukharka	1 462	1 935	3 397
Bange Fatake	461	641	1 102
Bhat Khola	700	959	1 659
Total	27 406 (44%)	34 595 (56%)	62 001

Source: CBS (2011)

b) Population growth in Kaski, Parbat and Syangja districts

District	Population (2001)	Population (2011)	Rate of growth/ decline
Kaski	380 527	490 429	+2.9%/year
Parbat	158 726	147 076	-0.68%/year
Syangja	317 320	288 040	-0.923%/year

Source: CBS (2011)

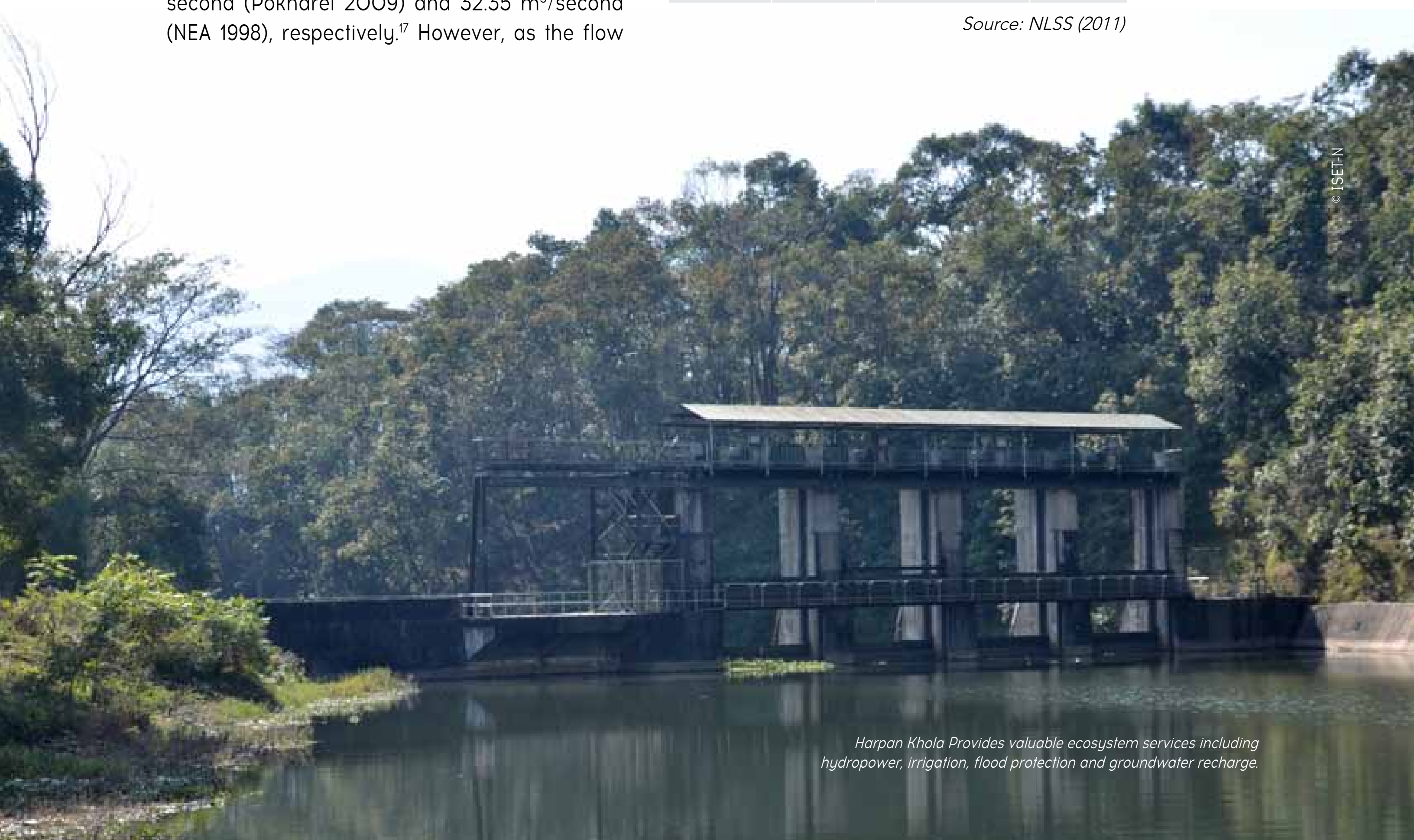
has had negative consequences with some grasslands being taken over by invasive species such as crofton weed (*Eupatorium adenophorum*) and blady grass while others are turning into wasteland. Farmers cultivate fodder trees and winter grass. Examples of fodder trees include monkey jack (*Artocarpus lakoocha*), white lead (*Leucaena leucocephala*), *Litsea monopetala*, mountain ebony (*Bahunia variegata*) and various fig species, including *Ficus auriculata*, *Ficus lacor*, *Ficus neriifolia* and *Ficus semicordata*.

Freshwater: The Harpan, Andheri, Rati, Mahabir, Jare, Ghatte, Sawan and Tooni are major PMER streams (see Figure 5b) draining into the Seti, Modi and Kali Gandaki rivers. A number of wetlands and ponds provide religious, environmental and water-provisioning services to the community. Run-off is highly temporal with 80 per cent of the annual rainfall concentrated in the four monsoon months of June, July, August and September. The mean flows of the Harpan Khola and the Aandhi Khola are 5.58 m^3/second (Pokharel 2009) and 32.35 m^3/second (NEA 1998), respectively.[17] However, as the flow of the latter was measured outside the PMER boundaries, it gives only a rough indication of the water flow in the PMER catchment. The Rati/Jare Khola flows have not been measured. Figures 8a and 8b show hydrographic measurements for the Harpan Khola in an upstream stretch where it debouches into Phewa Lake at Pardi. The PMER water is used for drinking and sanitation purposes, irrigation, hydropower generation and aquaculture. Approximately 33 per cent of water is used for domestic purposes and irrigation (MDO 2012).

Table 6 **Poverty incidence in Kaski, Parbat and Syangja districts**

District	Total	Number of poor	Per cent
Syangja	288 044	>100 000	34.7
Parbat	147 076	>75 000	34
Kaski	490 429	>50 000	10.2
Total	793 179	>200 000	21.6

Source: NLSS (2011)



Harpan Khola Provides valuable ecosystem services including hydropower, irrigation, flood protection and groundwater recharge.

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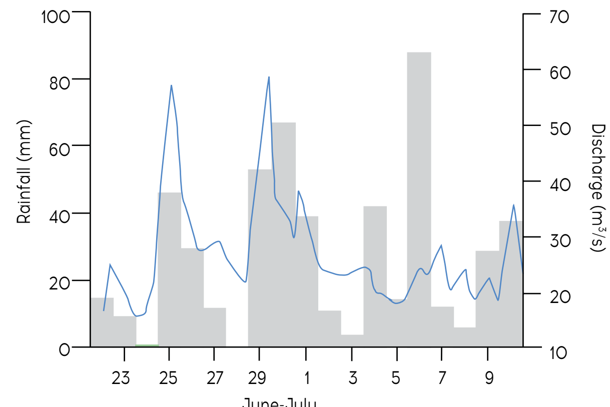
NTFP and MAP: The PMER is home to over 600 plant species with food, medicinal and ornamental value, including more than 107 species of medicinal plants 45 of which are used locally, 8 Fibre-yielding species, 23 species of natural dyes, 18 wild species with the floriculture potential (excluding orchids), 113 orchid species, 56 wild mushroom species of which 6 are edible and 98 different fern species of which 15 are edible (Subedi 2006). Himalayan Paris (*Paris polyphylla)*, felwort (*Swertiaaugustifoila)*, *pakhanbed (Saxifragaligulata*), *guduchi* (*Tinosporacordifolia)* and wolf's claw (*Lycopodiumclavatum*) are common NTFPs used locally by traditional Ayurvedic healers and others for common health ailments (MDO 2012). Other medicinal plant resources include *satuwa* (*Paris polyphylla)*, *chiraito* (*Wertia chirayita)*, *pakhanbed* (*Bergenia ciliate)*, *tite* (*Swertia nervosa)*, *gurjo* (*Tinopsora sinensis)* and *nagbeli* (*Lycopodium phlegmaria)*. *Satuwa* is used to relieve stomach pain and heal wounds, *chiraito* and *tite* to mitigate fever and *pakhanbed* and *gurjo* to treat diarrhea and diabetes respectively (Sharma and others 2013).

Agro-ecological: About 135 000 ha or 48 per cent of the PMER is agricultural land. While 40 per cent of the total agricultural land is irrigated (MDO 2012), a higher per centage is irrigated in Kaski compared to Parbat or Syangja. Subsistence-level mixed farming dominated by food crops is the main agricultural activity. Almost all farmers cultivate cereals such as paddy, maize, wheat, barley, finger millet, naked barley and common buckwheat, legumes such as soybeans, black gram and lentils, oilseeds like rapeseed and mustard, vegetables including potato, cauliflower, cabbage, carrot and tomato, spices such as ginger, turmeric and garlic and horticultural crops on both *bari* and *khet*. Chemical fertilizers are widely used but farmers also apply compost. Most of the vegetable production is consumed locally but some is sold in urban centres like Pokhara. Locals reported a decline in the quantity and regularity of irrigation water supplies because of depleting spring sources and poor maintenance of

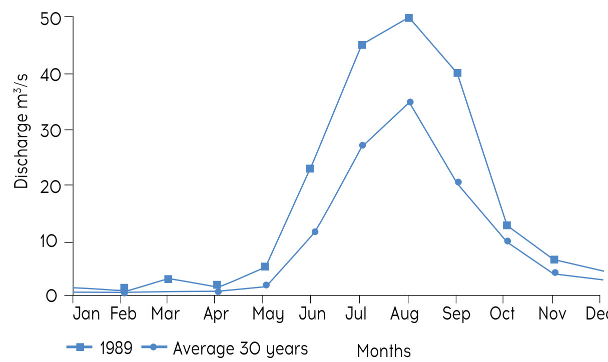
FIGURE 8 Hydrographs of streams in the PMER

a Harpan Khola at its debouchment into Phewa Lake



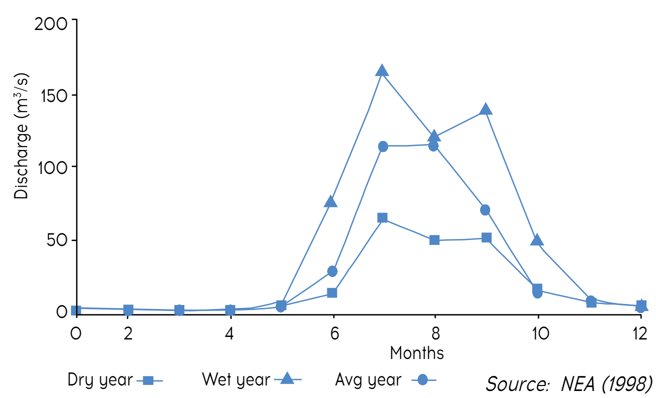
Source: Ross (1998)

b Harpan Khola at the downstream end of Phewa Lake



Source: Rana (1990)

c Hydrograph of Andhi Khola near the confluence with the Kali Gandaki River



Source: NEA (1998)

irrigation systems. The recent increase in outward male migration from the PMER has left women in charge of agriculture; with fewer male workers to plough the land, the fallow area has increased.

Regulating services

Forest resources: The PMER forests play a crucial role in maintaining agricultural and ecosystem productivity by promoting growth of understory vegetation, which helps recharge springs and groundwater. With pastures and shrubland, it also helps stabilize slopes and minimize erosion, decreasing flash floods and landslides. There are five major types of forest in the PMER. Alder, chir pine (*Pinus roxburghii*), East Himalayan oak-laurel, lower temperate oak and *Schima castanopsis* species dominate altitudes of 800-1 800 m above mean sea level. At altitudes of 2 400-2 750 m, *Quercus semecarpifolia* and other *Quercus* species such as rhododendron (*Rhododendron arboretum*) prevail. Needlewood (*Schima walichii)*, chestnut (*Castanopsis indica)*, *Daphniphyllum himalayense* and *sal* (*Shorea robusta*) dominate the low elevations (MoFSC 2013). At altitudes of 1 500-2 000 m, the *Daphniphyllum himalayense* tree species is common, followed by *Maesa chisea* and *Rhododendron arboretum*. In primary growth forests, *Rhododendron arboretum* is found at altitudes of 1 400-3 600 m above sea level. *Quercus* was once the dominant species but is now being replaced by *Daphniphyllum himalayense*, *Shoerea robusta*, *Schima walichii* and *Castanopsis indica* because of human intervention - mainly forest fires and deforestation. These are all species that dominate the landscape at lower altitudes. The PMER forests are home to at least 589 plant species including trees. Field observations in 2014 found that the designation of a major portion of the total forest area as protected forest managed by the MoFSC has reduced indiscriminate cutting and burning.

The PMER forest resources are under increasing biotic and abiotic pressure. Livestock farming, a key livelihood source for small and landless farmers, is a major reason for the forest degradation. The traditional practice of free livestock grazing in the PMER forests, grasslands and agricultural fields means that small and large ruminants such as sheep, goats and cattle, damage tree saplings, trample undergrowth and expose topsoil. In high-altitude forests, which are more bio diverse and less fragmented than those at low altitudes, animals graze for extended periods. The mounting human and animal pressures have pushed valuable timber species, including the high-altitude yellow jade orchid tree (*Michelia champaca*), Himalayan white pine (*Pinus wallichiana*) and *Prunus napaulensis* to the verge of extinction (New Era 2000). Machhapuchre Development Organization (MDO) (2012) found overharvesting of *Quercus semecarpifolia* because of its high nutritional value for lactating animals. The *Schima walichii* and *Quercus* timber species are also in high demand for household construction needs. Other ecosystem goods include animal fodder, wooden stakes for vegetable farming and fuelwood for household cooking and heating. Community forestry users' groups in the PMER permit harvesting for daily needs. Table 7 summarizes the major types and areas of forests in the PMER.

Cultural services

The PMER has historical, religious, environmental and cultural value not only for local people but also the rest of Nepal. It is a key tourist site because of the presence of Buddhist shrines and Hindu temples, including the 200-year-old Shraban Kumar temple. Panchase Lake attracts thousands of pilgrims during the Balachaturdasi festival in November. The PMER offers spectacular views of Himalayan peaks and is close to world-famous trekking routes, including the Annapurna Circuit and treks to Ghorepani, Tatopani, Jomsom and Muktinath. Recreational tourism, including paragliding and trekking, depends on surrounding forests, the aesthetic appeal of Phewa Lake, the PMER biodiversity and the local wind system.

TABLE 7 | Types of forest in the PMER

S.N.	Forest types	Area (km^2)	Per cent of area
1	Katus-Chilauni	97.46	57.1
2	Chir pine	32.38	19
3	Gurans-Rakchan	27.12	15.9
4	Hill-Sal	4.74	2.8
5	Utis	3.87	2.3
6	Shrub/Bush	5.16	3
Total		**170.75**	**100**

Source: GoN, DoF, MoFSC (2013)

Support services

The floral and faunal diversity of the PMER is an integral part of local cultural practices and attracts tourists. Although covering just 0.039 per cent of Nepal's land area and accounting for only 0.2 per cent of the country's 29 030 km^2 of protected areas (DNPWC, undated), the PMER is home to more than 600 flowering plant species and a number of wild animals, including the Asian black bear (*Selenarcto thibetanus*), barking deer (*Muntiacus muntjak*), leopard (*Panthera pardus*), jungle cat (*Felis chaus*), fox (*Vulpus vulpus*), jackal (*Canis aerus*), wolf (*Canis lupua*), monkey (*Macaca mulata*), porcupine (*Hystrico morphhysticidae*) and rabbit (*Lepus curpaeums*).

Common local birds include the pheasant *(Lophura leucomelana*) and the wild cock while the demoiselle crane (*Anthropoides virgo*) and the parrot (*Psittacula himalayana*) are important migratory birds. The cuckoo *(Cuculus canorus*), Himalayan bulbul (*Pynnonotusleucogenys*), crow, demoiselle crane *(Anthropoides virgo)*, barbary falcon *(Falcon peregrines)*, sparrow, crane, laughing dove (*Struptopeliase negalensis)*, yellow-throated marten (*Martes flavigula*) and Nepali house marten (*Delichon nipalense)* are common. The diversity of wild animals and birds is at risk due to illegal poaching and habitat loss (MDO 2012).[18]


© ISET-N
River feeding into Phewa Lake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Household and vegetation interdependence

CHAPTER III

VULNERABILITY AND CONCEPTUAL FRAMEWORK FOR ASSESSMENT

Vulnerability

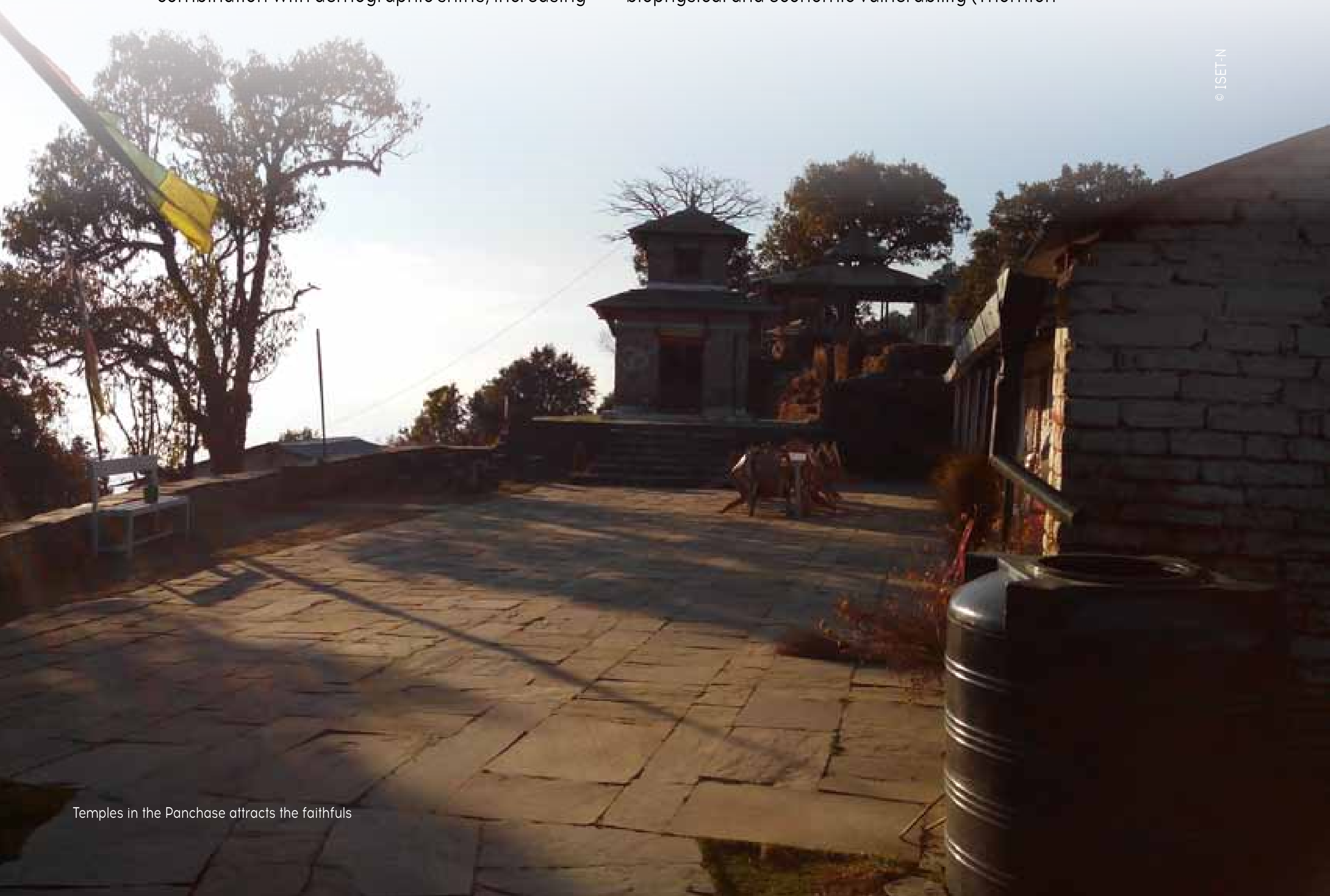
The concept of climate change vulnerability helps to understand the cause/effect relationship behind climate change, its impact on people, economy and socio-ecological systems (Fritzsche and others 2014). Some vulnerability studies focus on systems, places and activities (Cutter 1996) while others examine individuals, livelihoods, landscape and ecosystems (Blaikie and others 1994). Loss of resilience creates vulnerability (Holling 1995), but there is no standard definition of vulnerability which is generally described as the capacity of a person, group or natural and human system to anticipate, cope with, resist and recover from the impact of natural hazards. It involves a combination of factors that determine the degree to which an individual's life and livelihood is put at risk by a discrete or identifiable event in nature or society (Blaikie and others 1994). According to Adger (1999) vulnerability is the exposure of individuals stress as a result of the impact of extreme climate events.

AR4 of the IPCC (1997) uses another definition: the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate change and variation to which a system is exposed, its sensitivity, and its capacity to deal with the impact that the change may bring (Parry and others 2007). According to the 2000-2015 Hyogo Framework, adopted by the United Nations World Conference on Disasters in 2005, vulnerability is a "set of conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of a community to the impact of hazards" (Hyogo 2005). Although the specifics can vary, all four definitions agree that exposure, sensitivity and adaptive capacity are key elements of vulnerability.

The concept of vulnerability is central to understanding how ecosystems, communities, institutions and social relationships such as gender (Ahmad 2006) are affected by climate change. While natural scientists and engineers consider vulnerability in terms of physical exposure to extreme events and its adverse outcomes, social scientists see it in terms of socio-political factors, which affect certain groups differentially when faced with external shocks and in the absence of entitlement to resources (Adger 2006). This suggests that it is important to highlight the social construction of vulnerability: vulnerability does not exist in isolation but is highly contextualized in social and political spaces. Vulnerability is exacerbated by poverty, caste and gender (Mustafa 1998).

Vulnerability should be analysed in the context of opportunities and risks offered by technological development and economic globalization, which in combination with demographic shifts, increasing consumption, climate change and other drivers of change, affect livelihoods. However such a broad analysis is beyond the scope of this assessment. To address the uncertainty in all change drivers, the method for assessing vulnerability must be based on continuous learning.

There is no universally accepted method for assessing vulnerability to climate change. Analysts (Bohle and others 1994, Blaikie and others 1994, Fussel and Klein 2006, O'Brian and others 2007) have proposed a number of frameworks for assessing the vulnerability of natural systems to climate change. These recognize that vulnerability analysis needs to be dynamic enough to fit the context of the analysis and that both climatic and non-climatic drivers, including political, institutional and socio-economic are taken into account. Others have suggested tools for assessing social, biophysical and economic vulnerability (Thornton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Temples in the Panchase attracts the faithfuls

BOX 2: **Exposure, risks, vulnerability, disaster and adaptive capacity in Nepal**

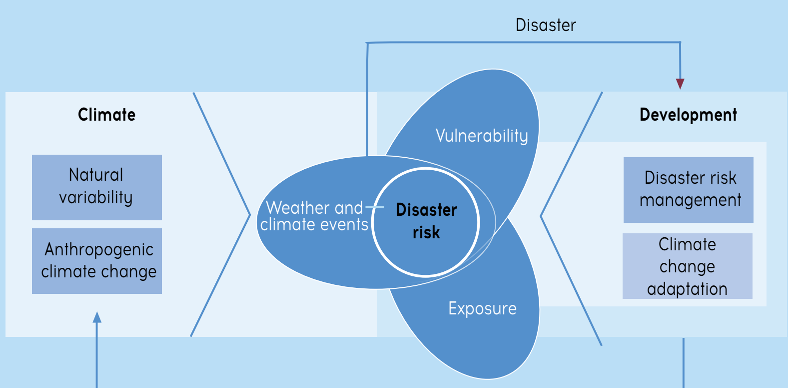
The concepts of hazard, exposure, vulnerability and risks are increasingly used in climate change adaptation and disaster risk reduction program. Because climate change-influenced weather anomalies may cause floods that increase the risk of loss of life, assets and infrastructure, disaster risk reduction and climate change adaption must converge. Both aim to reduce vulnerability. An examination of this convergence will provide new insights into policy, practices and knowledge of risk reduction. Generating insights into this is critical because Nepal faces high climate change exposure to both HPLI and LPHI events.

The 2013 cloudburst in India's northern Himalayan Uttarakhand State, the 2010 floods in Pakistan, the 2009 floods in the Indian metropolis of Mumbai and the 1993 cloudburst in central Nepal are examples of extreme anomalies. In all these cases, the intensity of the events and exposure to them exacerbated vulnerability and losses. Even individuals who would be considered less vulnerable lost their life because they were exposed to the extreme floods. Thus exposure is more critical than vulnerability in explaining the impact, though in the long-term, marginalized populations and those with low adaptive capacity will be most seriously affected. The vulnerability of exposed ecosystems, human built systems and people can play an important role in understanding the impact of LIHP events. The cumulative effect of both types of disasters on natural resources, livelihoods and communities will increase as ecosystems are affected and the capacity of local communities to respond to future disasters will be reduced.

Vulnerability varies across temporal and spatial scales. It depends on economic, social, geographic, cultural, institutional, governance and environmental factors. Wealth, education, race/ethnicity/religion, gender, age, class/caste, disability and health determine the degree of vulnerability for an individual. In many developing countries, including Nepal, high vulnerability and direct exposure are also the outcomes of shortsighted development processes made more inadequate by environmental mismanagement, demographic change, rapid unplanned urbanization in hazard-prone areas, poor governance and scarce livelihood options. These factors are linked to low levels of socio-economic development increasing further the vulnerability of Nepal's population to climate change. Low scientific culture and technological base also adds to the gap and limits Nepal's capacity to understand climate change processes.

This makes assessing vulnerability to and risks from climate change particularly challenging. Both quantitative and qualitative approaches, determined by the purpose of the assessment, the availability of resources and time, geographic scale, the number and type of stakeholders involved, economics and governance needs to be considered as the assessment is conducted. In order for adaptation and disaster risk reduction strategies to be effective, assessment findings must be shared with communities and policy-makers. Messages must be tailored to the audience, which will include different levels of government, the private sector, local communities and civil society groups all of whom have different perceptions of risk shaped by different beliefs, values and norms. These perceptions also determine the options for dealing with shocks. No single approach can address the challenge of assessing climate change vulnerability and designing adaptive measures.

Designing and implementing climate change adaptation and disaster risk reduction strategies should not only reduce risk in the short-term but also avoid vulnerability and exposure in the long-term. Strategies should not be maladaptive. Thus, embankments can reduce flood risk in the short term, but may increase risk in the long-term by fostering a false sense of security. The 2008 breach in the Koshi River embankment in Nepal inundated a large area that was supposedly protected, leading to huge loss of property, lives and livelihoods (Dixit, 2009). Similarly, groundwater pumping can meet immediate irrigation needs but if the rate of extraction is higher than that of aquifer recharge, it will only be useful in the short term because the strategy will eventually lower the groundwater table.



Source: Lavell and others, (2012)

and others 2006). Some studies have attempted to estimate the magnitude of the potential impact of climate change on landscape and biodiversity (Klausmeyer and others, 2011; Fitzpatrick, 2008; Loarie and others, 2008) but only a few provide practical guidance for ecosystem vulnerability assessment. For a region like the PMER, this task is complicated by:

I. The role of climatic stress;
II. the role of non-climatic stress; and
III. the link between adaptation and development.

Climatic stress: Climate is a major determinant of the PMER ecological and social systems. Although measurements are limited, it can be stated with some confidence that micro-level details regarding meteorological and hydrological parameters in the PMER such as temperature, rainfall, humidity, evaporation, wind and solar radiation are varied. Because of this, any assessment of the influence of climatic drivers on ecosystems and their services is based on extrapolated triangulation of historical climate trends, local perceptions and the results of global circulation models (GCMs). Although it is difficult to downscale GCM results to make them relevant to the PMER, extrapolated results suggest that the region will experience higher temperatures and more erratic precipitation in future. Local communities also report increased forest fires, thunderstorms and hail. An increase in temperature and rainfall and changes in the number of rainy days may accelerate soil erosion and soil fertility loss, thereby reducing agricultural and ecosystem productivity and increasing mass wasting and other climate-related hazards.

Non-climatic stresses: The PMER also faces significant non-climatic stressors in the form of human interventions such as road construction and urban growth. Growing tourism is expected to increase the number of hotels and restaurants, vehicular traffic and the consumption of wood and fossil fuel. While tourism will make a positive contribution to the local and national economy, it could also have adverse environmental impacts such as pollution. There will be increased pressure on ecosystem services as a result of increased demand for natural resources and higher pollution loads on natural systems. Stresses at the sub-watershed level in the PMER may have serious consequences downstream, especially for the Harpan Khola and Phewa Lake.

Adaptation and development: A recent study identifies the following climatic and non-climatic stresses on ecosystems in Nepal (Thapa and others 2011):

a) overexploitation of natural resources due to population growth and developmental pressures;
b) changes in land use and land cover;
c) migration and urbanisation;
d) biodiversity loss;
e) the spread of invasive species;
f) climate- and human-induced disasters; and
g) forest fires.

The first four of these drivers are non-climatic and the rest are climatic (Thapa and others 2011). The same drivers are at work in the PMER and are likely to produce changes in its ecosystems and their services such as hydrologic characteristics and moisture regime. These changes will alter water yields from springs and downstream water availability. Streamflow could lower and people would not have enough water to meet drinking, irrigation and other needs. There could be increased landslides, floods and forest fires that would damage tourist trails, roads, bridges and hotels as well as valuable flora and fauna. These events will also create risks for the tourism sector, which depends on the integrity of the landscape and rich biodiversity.

Local ecosystems and communities adapt to both climatic and non-climatic stresses with varying degrees of success. The increasing pace of change reduces the time available to adapt while at the same time increasing the pressure to do so. Interventions for building resilience and adaptation can reduce the risks of climate

BOX 3: Stresses on Phewa Lake

Phewa Lake faces a range of non-climatic stresses, including pollution (Acharya and others 2012), poorly built roads and a profusion of local infrastructure and human settlements (Pokharel 2009). The stresses are most evident along the eastern side of the lake and along the Firke Khola, where squatter settlements are burgeoning. The degradation of the lake is being accelerated by the rapid and haphazard urbanization of the Pokhara Municipality area and the discharge of untreated waste. An increase in the number of hotels and other tourist activity such as boating has altered land use along the lake.

The lake's storage capacity was augmented in the early 1960s with the construction of a dam at the outlet at Pardi. In 1975, the dam suffered structural failure and had to be rebuilt. The new dam became operational in 1982. Following the dam's failure and exposure of land along the lake, landowners exerted political and other pressure to register the land in their names. Once a cadastral survey of the area confirmed ownership, lands previously under public ownership (as part of the lake itself) were made private. People other than the landowners, also encroached on land parcels. The upper reaches of the lake where the Harpan Khola enters, have also been encroached upon, encouraged by annual sediment deposits creating new land.

The streams draining the sub-watershed and feeding the lake possess high sediment-transporting capacities; any material they pick up in their upper reaches is transferred downstream. This dynamic has major implications for Phewa Lake which is the repository of all these transported sediments. The result is a progressive reduction in its storage capacity. The alluvial deposits have turned the upper reaches of the lake into flat marshland, reducing their area from 0.58 km^2 in 1981 to 0.44 km^2 in 2001 and 0.40 km^2 in 2012 (MDO 2012). The reduction in the lake area is not directly correlated with changes in its volume. Fleming (1985) estimated the annual sediment inflow into Phewa Lake at 403 902 m^3 in 1980. Later studies put the sedimentation rate at 175 000-225 000 m^3 per year (Sthapit 1995) and estimated that at this rate the lake's life would be between 135-175 years. The reason that the latter estimate is roughly half that of the earlier one might be because of natural resource management activities in the Phewa Lake watershed from the 1980s to the mid-1990s.

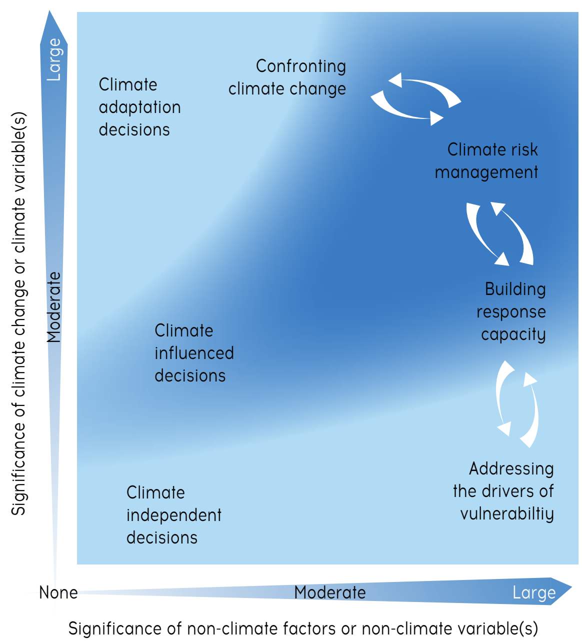
Despite conservation initiatives, both the area and depth of the lake are decreasing. In 1971, the lake had an area of 6.7 km^2 and a maximum depth of 20 m. In 1995, the area of the lake was estimated at 5.23 km^2 with a mean depth of 7.5 m and a maximum depth of 24 m (Rai and others 1995). A study in 2000 reported the lake had a surface area of 4.43 km^2 and a maximum depth of 23 m[19]. A subsequent assessment arrived at a similar value of 4.4 km^2 (JICA/SILT 2002). The 2012 MDO estimate cites an area of 4.43 km^2, a mean depth of 8.6 m and a maximum depth of 19 m. The volume of the lake varies from 40 million m^3 in the dry season to 53 million m^3 during monsoon. When the water level is high, as it is during the summer monsoon season, turbulence aerates the water, oxidizing nutrients that do not get deposited on the lake bottom (Rana 1990).

Tal Barahi temple in Phewa Lake is a site of popular pilgrimage.

change in the PMER. It is expected that the context and nature of the risks will be different in the future as climatic and non-climatic drivers continue to affect ecosystems and their services at ever-increasing rates. For example, weak governance and unsustainable natural resource use, such as mining stones and sand, will worsen the degradation of the PMER's ecosystems.[20] The declining population of rural youth and the resulting feminization of the agriculture and natural resources sector, will threaten local multi-cultural wealth as the socio-political context is transformed.[21] Measures to enhance resilience and build climate change adaptation capacity need to be implemented within existing regimes of governance and social relations. Adaptation is not an isolated activity but a continuous process that should be implemented along with development.

Distinguishing between the influences of climatic and non-climatic stresses on ecosystem services is a challenge. It is hard to define where development ends and where adaptation begins. Willows and Connel (2003) have developed a two-by-two matrix with X- and Y-axes representing climatic and non-climatic change variables. Each axis contains three calibrations of significance: low, moderate and high, delineating the following three possible decision making domains: climate-adaptation, climate-influenced and climate-independent decisions. McGray and others (2007) identified four tasks broadly mapping on to these three domains: confronting climate change, managing climate risk, building response capacity and addressing the drivers of vulnerability (see Figure 9). However, none of these approaches provide clear operational guidelines for differentiating between the decision-making domains. Given the uncertainty of local climate change scenarios, it is impossible to define the boundary marking the end of development and the beginning of adaptation (Dixit and Moench 2010). The two must be viewed as two ends of a continuum rather than as separate and isolated tasks.

FIGURE 9 Conceptualizing the adaptation-development continuum with climatic and non-climatic drivers related to ecosystem function



Adapted from Willows & Connel (2003) & McGray et al., (2007)

The assessment framework

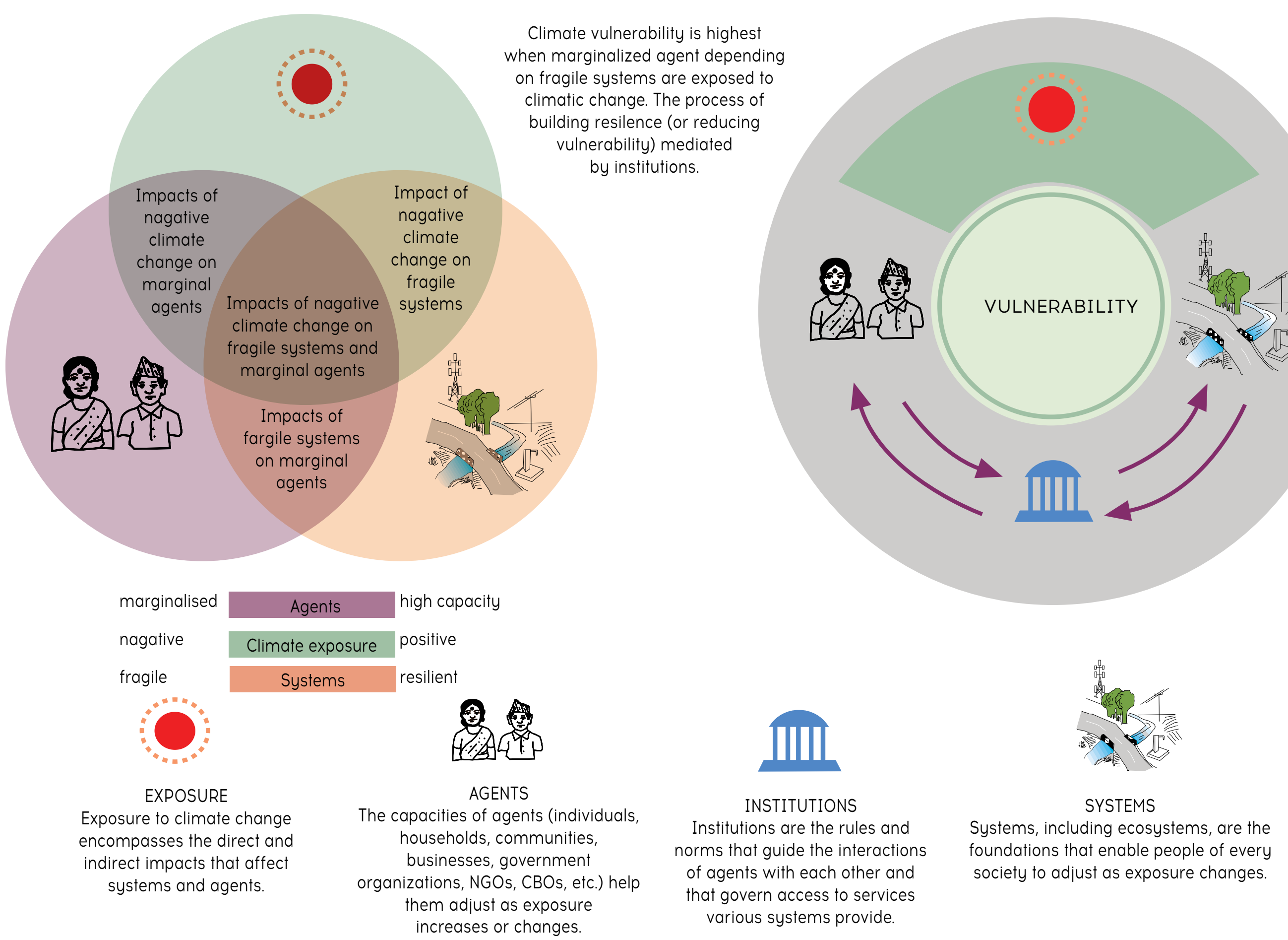
The above discussion highlights the challenge to a VIA designed to recommend ecosystem resilience-enhancing measures in the PMER. An effective VIA approach must include both natural science (hazard-based) and social science (socio-political circumstance-based) approaches to fully understand the PMER ecosystem vulnerabilities. The location of the ecosystem, human settlements as well as local livelihoods and exposure to both HPLI and LPHI all matter need to be considered while conducting a VIA. Some analysts have attempted to bridge the gap between the natural and social perspectives on vulnerability by using the concept of a "vulnerability of place" where biophysical exposure intersects with political, economic and social factors to generate specific configurations of vulnerability (Cutter 1996, Cutter and others 2000).

These insights helped develop the Climate Resilience Framework (CRF) (see Figure 10) based on the relationship between systems, agents, institutions and exposure (Tyler and Moench 2011, Dixit and Khadka 2013). The CRF views resilience as the characteristic that helps ecosystems including human built systems deal with climate change induced impacts. Another requirement for enhancing resilience is the ability to respond quickly to a shock while at the same time preserving well-being. Institutions have a key role in building resilience and choosing technology and management options.

According to Thompson (1994) technological flexibility helps enhance resilience and work towards the goal of sustainable development. To enhance resilience, procedures need to be put in place for timely and effective recovery from the impact of disruptive events.

The CRF is useful for assessing ecosystem vulnerability in the PMER and identifying strategies to build resilience and adaptive capacity. The CRF draws on and expands on the IPCC vulnerability assessment framework by reformulating the three factors of vulnerability, exposure, sensitivity and adaptive capacity, into four, systems, exposure, institutions and agents. The CRF integrates elements from the Livelihoods Framework, research by the Resilience Alliance and the perspectives of Amartya Sen, C.S. Holling and Elinor Ostrom (Sen 1981, Ostrom 1990, Dreze and others 1995, Twigg 2001, Gunderson and Holling 2002, Zolli and Healy,2012). The framework considers the ecosystem as the foundational element of adaptive capacity and applies lessons learned from designing local adaptation plans of action (LAPA) in Nepal, particularly the idea that systems are gateways to services (Dixit and others 2011, GoN 2011,, Dixit and Khadka 2013). It suggests that ecosystems

FIGURE 10 Climate-Resilience Framework (CRF)

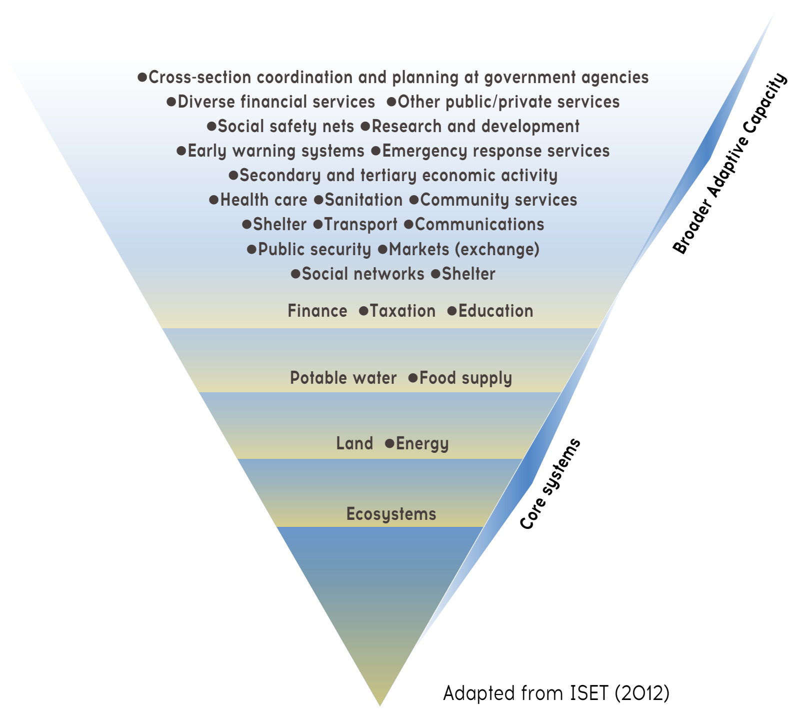


Adapted from ISET (2012)

and other human systems function as gateways to services (see Figure 11) much like an Internet router serves as gateways to the World Wide Web and global online knowledge.

The CRF brings together practical knowledge, applied insights and a theoretical foundation in order to examine the dynamic interaction between climate exposure, the ecosystem, infrastructure, institutions and human behaviour. It promotes the integration of social and natural sciences, local and scientific knowledge, technical expertise and hands-on experience as well as opportunities for reflexive learning - a hallmark of all adaptive strategies. The CRF links analysis of ecosystem and human vulnerability and institutional and systemic dynamics with practical processes for planning and identifying solutions. This enables decision-makers to identify points of entry into existing policies, programmes and practices for implementing measures that help assess vulnerability and build resilience and adaptive capacity. It can be used as a tool to support decisions and overcome the limitations of linking specific or individual weather events to climate change. The CRF enables a holistic analysis of climate change vulnerability and adaptive capacities. Successfully applied in both urban and rural settings in Nepal, the framework has the potential to be used throughout the country as well as internationally to build resilience and adaptive capacity through an EbA approach. The CRF builds a case for an EbA approach by placing ecosystems and people at the centre of enhancing resilience.

FIGURE 11 The core systems and broad adaptive capacity of the CRF



Adapted from ISET (2012)

CHAPTER IV

THE ASSESSMENT PROCESS

The discussions in Chapter III leads to a number of important questions: How do analysts identify one risk area as more vulnerable than another? How does one identify the area most vulnerable to a particular kind of risk? Should the vulnerability assessment focus on systems, sectors or people? How is vulnerability measured? At what level should such an assessment be made: national, sub national, local or community? Answering these questions is difficult and requires information from multiple sources.

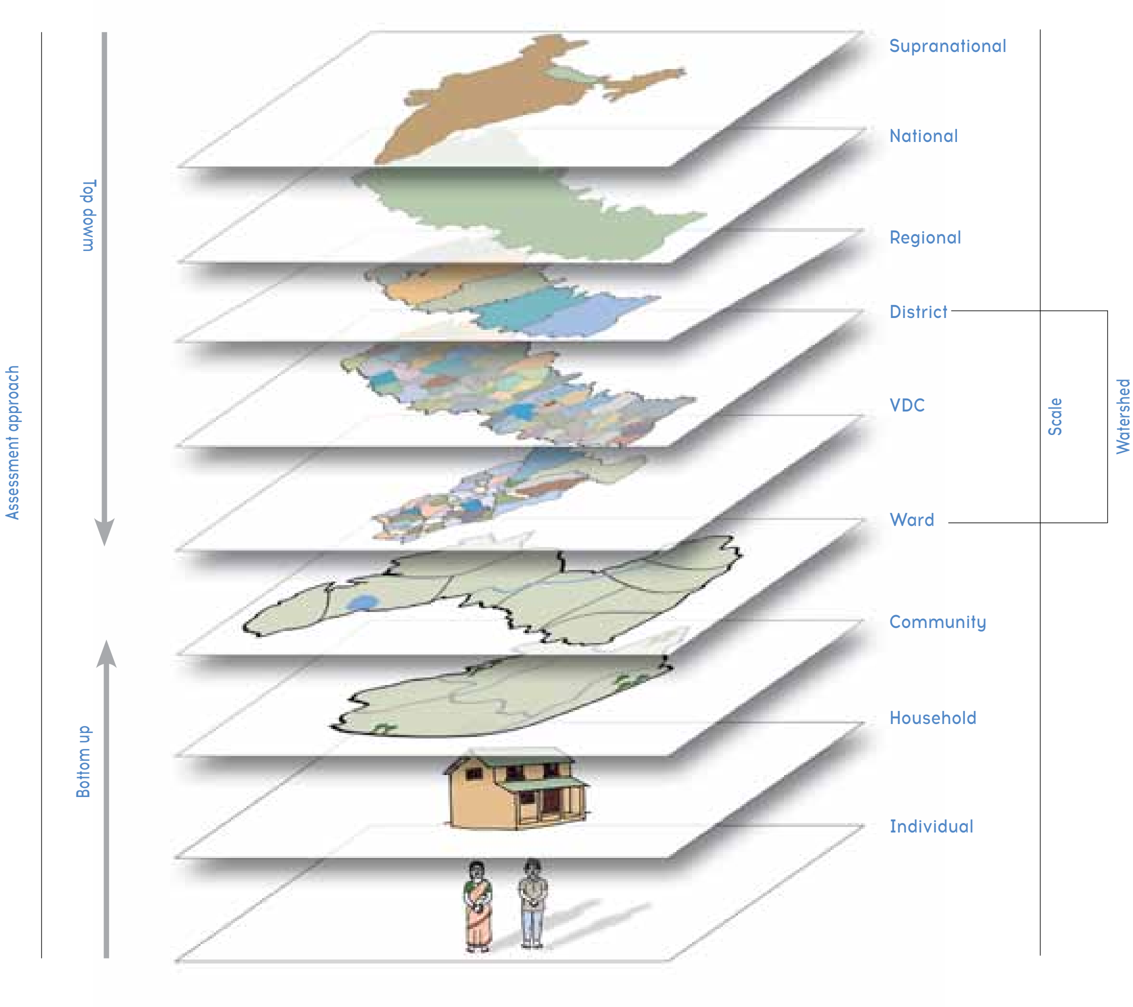
In Nepal, the scale of a VIA is an important consideration. Analysis can be done at the national, regional, district, watershed, VDC, ward, community or household level (see Figure 12). Maplecroft's 2011 analysis was conducted at the national level. Using 32 indicators, the assessment ranked developed and developing countries in terms of vulnerability to climate change. Nepal ranked fourth among the most vulnerable nations.[22] However this assessment of Nepal did not pinpoint the most vulnerable region in the country. An answer to this question requires assessment at smaller geographical levels.

How does one decide on a small geographical scale and determine a practical assessment method while working with divergent perspectives? To convert the theoretical scenarios discussed above into a practical tool, this study draws on the idea of risk areas developed by the National Oceanic and Atmospheric Administration (NOAA 2009) as follows:

> "Risk areas identify geographically (typically on maps) those areas most likely to be affected by a given hazard. People and resources located within the risk areas are considered to be at risk from hazards (exposed) and may or may not be vulnerable to hazard impacts. The vulnerability of the people and resources within the risk areas is a function of their individual susceptibility to the hazard impacts" (pp.10).

Vulnerability maps of districts in Nepal prepared by the MoSTE (NAPA 2010) are an example of the delineation of risk areas at the sub-national level. It is one example of a decision-support tool. Dixit and Khadka (2013) explain the ways CRF has been used as a top-down exercise to identify risk areas and assess vulnerability at the district, watershed, VDC and ward levels. This process was followed with a bottom-up effort that aimed to capture the social context of vulnerability.

FIGURE 12 Layers of vulnerability, resilience and adaptive capacity



The spatial scale of this assessment was 283 km² - the area of the 17 VDCs in the PMER. In a layered schema (see Figure 12) the PMER can be considered either as a cluster of VDCs or a cluster of sub-watersheds, making it possible to compare the vulnerability of both. There were four reasons why the indicators were chosen to compare wards rather than sub-watersheds. First, as the VDC is the lowest unit of governance in Nepal, it has data on some of the elements of the CRF. Second, identifying a vulnerable ward helps identify a fragile ecosystem, exposed hamlets, communities and marginalized households within that ward in a transparent manner. Third, VDC-level assessments can be aggregated to provide an assessment at the sub-watershed level. Lastly, budgets and financial resources transferred from central ministries to implement adaptive capacity-building options are channeled through VDCs.

This study first reviewed literature on ecosystems, resilience and development contexts and existing institutional arrangements. The study team then selected indicators to assess the current status of exposure, systems, agents and institutions within the PMER at the ward level. This assessment was then used to categorize the 153 wards in the 17 VDCs according to vulnerability to current hazards. This set of baseline information was then re-examined to identify future sources of vulnerability, keeping in mind climate scenarios for the WR. This top-down process was complemented by an iterative bottom-up assessment focused on assessing people's perceptions of the climatic and non-climatic drivers of change and their impact on livelihood-related ecosystem services in the PMER. Together, these processes helped identify options for building resilience and adaptation.

The specific methods used for the assessment included:

- a literature review
- regional and local level SLDs
- consultations with key informants in VDC clusters
- a questionnaire for all 153 wards

The following information was obtained: primary data on past hazardous climate events, historical climate trends from the Department of Hydrology and Meteorology and the MoSTE data as well as local perceptions. In addition, the literature review helped develop indicators for assessing ecosystem vulnerability, as did the preparation of social and natural resource maps and the assessment of hazards with local participants. All methods were participatory and aimed to derive indicators for assessing the vulnerability of linked human-environment systems. The data collected from key informant surveys were tabulated in Excel sheets for analysis. The primary (field-level) and secondary (literature review and consultation-based) data were screened, synthesized and analysed for assessing vulnerability.

The following steps were taken:

A literature review; meetings; idea sharing with experts and government officials; and preliminary field visits. It also involved discussions to clarify the conceptual framework. These processes resulted in the selection of indicators that identify vulnerability and resilience at the local level.

Shared learning dialogues (SLDs): Even if natural factors were responsible for changes in climate dynamics, it would still be difficult to make correct decisions about, for example, indicators to assess vulnerability. Decision-making in the complex context of human-induced climate change is much harder because there are many interconnected issues that need to be addressed simultaneously. No single person, agency, entity or group has all the information, knowledge or experience needed to solve the sub-problems that constitute the whole problem. The dynamism and fluidity of the socio-political context further impedes the ability to find a solution. As a result, the process of assessing vulnerability and building resilience and adaptive capacity to deal with climate change cannot be a one-off effort. It cannot also be done within the boundaries of a single discipline. Instead, the process of assessment of vulnerability and identification of options for adaptation must bring natural science experts and social scientists together. Decision-makers at different levels of government must be involved in the process. At the same time, the process must also involve civil society actors, community members and affected individuals.

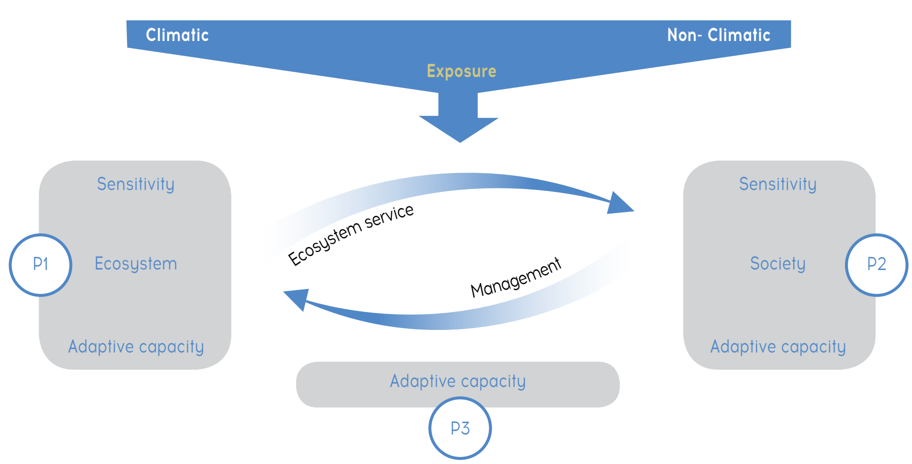
The SLD approach is characterized by mutual learning among participants. It fosters deliberation and the sharing of sector- and group-specific knowledge and experience as well as the knowledge of both local practitioners. This approach will generate insights that can help make effective decisions. It is useful in assessing vulnerabilities and building resilience and adaptive capacities because it ensures that knowledge from different perspectives is taken into account. The approach builds a shared understanding of the values that underlie positions, ideologies and interests. Used in conjunction with other social science methods, SLD incorporates attributes such as sharing, learning, dialogue, respect, fairness, feedback and evaluation (ISET 2012).

Indicators: An indicator refers to a policy-relevant (Astleithner and others 2004) quantitative or qualitative measure derived from observed data measurable over time and/or space that simplifies and communicates the reality of a complex situation (Freudenberg 2003). The measurements can take a variety of forms and aid comparison over a period of time, between government departments and projects and between performance and objectives or scales (Astleithner and others 2004). Dixit and others (2013) used for example, a set of indicators to assess the vulnerability of Nepal's food systems to climate change.

This study developed a set of indicators, keeping in mind the availability and scale of data and a number of questions: Where will the indicators apply? Who will use them? How will they be used? The selection of indicators involved discussion with key stakeholders at national, regional and local levels. This included district and VDC government agencies; user communities; the private sector; people in farming, tourism and other sectors that use the PMER's ecosystem services; and local NGOs and CBOs. The process aimed to incorporate data on different pressures being exerted on ecosystem services, including changes in land use and land cover and climate-induced hazards, as well as constraints to ecosystem resource management in order to increase resilience to climate change (Dixit and Moench 2010, Vignola and others 2009).

The loss of ecosystem services due to the degradation of the quantity and quality of productive forests, grazing land, fertile soil and the sensitivity of the system, like dependence on NTFPs and clean water for livelihoods, make human systems vulnerable. The availability of substitutes for lost medicinal plants, disadvantageous macroeconomic policies and fluctuating NTFP prices, determine the adaptive capacity of the human system to reduce the adverse impacts of the loss of ecosystem services through appropriate resource management. Unsustainable harvesting of products can increase pressure on and reduce the capacity of an ecosystem to adapt to new stresses. This would simultaneously reduce the capacity of local communities to implement adaptive measures. According to Locatelli and others (2008) (see Figure 13), the vulnerability of ecosystem services is partly due to historical climate variability and partly to socio-economic and developmental pressure. The recognition of this interdependence between socio-economic and climatic factors formed the basis of the study's identification of indictors for the assessment. Using criteria related to the exposure and sensitivity of the ecosystem that produces the services is one assessment approach. The study team identified a set of

FIGURE 13 Coupled human-environment system



Vulnerability of a coupled human-environment system to the loss of ecosystem services

Adapted from Locatelli and others (2008) indicators representing the four elements of the CRF – ecosystems/systems, agents, institutions and exposure.

Individual indicators were added to produce an aggregate index to measure vulnerability. This index is a useful tool for conveying the information needed for policy-making. Some researchers caution against this approach to assessing vulnerability because it fails to take into account the social, political and other heterogeneity, which occurs even at the smallest of scales, like a neighbourhood (Suarez and Ribot 2003). Researchers also advise keeping vulnerability analysis open to multiple interacting sources of harm (Ribot and others 1996).

This study adopted a strategic approach and considered vulnerability assessment as an exercise within the policy making domain. By adopting this approach the study allowed those concerned with an EbA strategy to ask questions about the assumptions, suggest alternatives and make revisions (Dixit and others 2013). This approach can help national and sub-national agencies in three ways: support local decision making, offer lessons to address gaps and guide reformulation of climate change adaptation and resilience-building policies. This approach can help decision makers and policy-makers synthesize information required to identify the effects of climate change on the drivers of vulnerability and take appropriate actions to reduce them.

The selection of indicators involved several steps and the holding of a SLD for each step, with analysts in formal settings as well as smaller informal groups. Special attention was given to identifying indicators representing ecosystems in their entirety, as available in the global literature. Two questions emerged during this process:

1. how many indicators should be selected and
2. would data be available to measure them?

In theory, the more indicators, the more nuanced the picture of vulnerability, but measuring more indicators involves greater effort and cost. The study carefully balanced costs with an estimation of the value that the measurement of each additional indicator would add, given the high degree of uncertainty associated with climate change as a stressor. A set of pragmatic indicators was selected that could be updated using an iterative process in order to capture vulnerability in all its dynamism.[23] This approach has already been used in Nepal with the national level Nepal Living Standard Survey. The approach is logical because building resilience and adaptive capacity means responding to external shocks by re-designing institutions, capacitating and supporting communities to assess their vulnerabilities and creating opportunities for new initiatives to respond to shocks. Accordingly, 32 indicators, eight related to the ecosystem and its condition, were chosen (see Table 8).

Regional stakeholder consultation: In May 2013, an inception workshop was organized in Pokhara to introduce the EbA and obtain feedback from key governmental, non-governmental and community-based organization stakeholders. Participants were identified through informal consultations, an examination of the roles of various agencies and based on suggestions by EbA project officials. Officials of the MoSFC, UNDP and Forest Department, VDC secretaries, members of the Panchase Conservation Council, forest users' groups and the MDO and the ISET-N research team took part.

ISET-N made a presentation on the EbA approach and methodology, introduced a sample questionnaire, cluster-level information-gathering tools and watershed-level information maps. This was followed by a discussion with stakeholders. The consultation focused on discussing the challenges of the assessment process and clarifying the use of EbA as a strategy to adapt to both climatic and socio-economic changes in the PMER.

Ways to enhance the role of ecosystem services and individual, household and institutional capacity to generate multiple benefits from these services were also reviewed. Local community

TABLE 8 | Indicators for assessing vulnerability

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 making 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 lighting, 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 well-being.
		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.

representatives advised that several factors needed to be taken into consideration when deciding trade-offs among options to enhance resilience and/or adaptive capacities including: the increasing demand on ecosystem services and that users have varied interests and compete for bigger shares of the benefits.

Cluster-level consultations: Four cluster-level consultations were organized to collect primary data using the SLD approach. Each involved 30-48 participants from several VDCs. The consultations were held at Pame in Kaski District, Chitre and Arthardandakharka in Parbat District and Bangefatake in Syangja District. Participants were broadly representative of the different spatial units of the PMER and included:

- VDC secretaries
- teachers and students
- youth
- farmers
- intellectuals
- social mobilisers
- local business people
- political party representatives
- civil society groups
- women's associations
- mothers' groups
- agricultural production associations
- dalit groups
- community forest users' groups
- cooperatives
- NGOs and CBOs

During the meetings, primary users and beneficiaries of the PMER ecosystem services offered views on the EbA strategy and on options to build resilience and adaptive capacities. The CRF puts ecosystems, people and their ideas at the centre of EbA strategies. It recognizes that different drivers of change exert pressure on ecosystems and people, affecting both human capacity and the quality and quantity of ecosystem services. Over a period of three days, each SLD refined methods for collecting data related to climate hazards, disaster risk reduction and adaptation.

Key informant surveys: Trained local enumerators conducted key informant surveys in selected wards of the 17 VDCs of the PMER. The informants included 1 683 community members, teachers, government and NGO representatives and older people. The survey was designed to gather information on: (i) people's perceptions about the vulnerability of the PMER ecosystems and their wards and VDCs, (ii) details about development challenges and opportunities, (iii) ward-level systems and (iv) traditional knowledge and good practices.

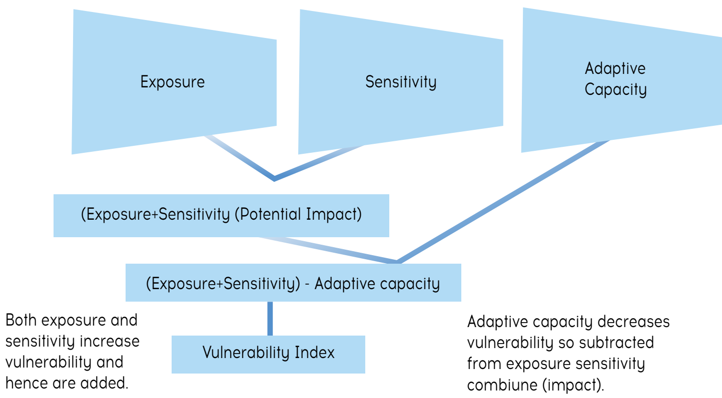
Resilience planning: This process involved soliciting suggestions during the SLD to identify options to build resilience to unknown future climate scenarios at the ward and sub-watershed levels.

Vulnerability index and categories current

Data on all 32 indicators were collected and composite values calculated to assess the vulnerability of all 153 wards. Vulnerability was assumed to be directly proportional to exposure and sensitivity and inversely proportional to adaptive capacity. Systems and agents exposed to hazards and sensitive to climate change, are likely to be vulnerable, but vulnerability would decrease if agents develop higher adaptive capacities through, for example, better access to benefits from systems (ecosystems or human-built). This relationship is shown in Figure 14.

The 32 indicators–eight relating to exposure and sensitivity and 16 to adaptive capacity–were weighted to calculate the vulnerability index of each ward. A joint value for exposure and sensitivity, weighted equally (up to 0.5, for a total weight of 1) was then calculated. Finally, ward-level composite values were estimated by subtracting an adaptive capacity value of up to 1 from the composite exposure and sensitivity (total vulnerability) value to yield a vulnerability index between -1 and +1. This process ensured that the range would remain constant even if the numbers of wards, sub-watersheds or indicators fluctuated. In the next stage, five categories of vulnerability, ranging from very high to very low were colour-coded.

FIGURE 14 Relationship among exposure, sensitivity and adaptive capacity



(0.61 to 1)	Very high vulnerable
(0.21 to 0.6)	High vulnerable
(0.21 to 0.19)	Moderated vulnerable
(-0.20 to -0.6)	Low vulnerable
(-0.61 to -1)	Very low vulnerable

The categories were presented graphically on a map of the PMER that showed potential locations of climate hazards (see Figure 15). The results were presented in two ways: a map of the least and most vulnerable wards (using ward-level data) (see Figure 16) and a map of the least and most vulnerable sub-watersheds (see Figure 17a) (using aggregated VDC-level data). In addition, we examined the spatial spread of ecosystem goods and services.

Wards: As the maps demonstrate, 31 of the 153 wards were identified as highly vulnerable to current variability.

Sub-watersheds: The ward-level vulnerability index helped determine VDC-level vulnerability, which in turn helped determine sub-watershed-level vulnerability. This step was necessary to identify areas at risk within the geographic composite and categorize vulnerability. As the PMER comprises headwaters of rivers that extend services beyond its geographical confines, it was also logical to examine the spatial availability, functions and values of such services. The exercise identified the Andheri Khola sub-watershed as the most vulnerable of the 13 PMER sub-watersheds (see Figure 17b).

Distribution of services: The availability of services in the PMER takes place at three spatial scales: the PPF,[24] the PPF buffer zone and a large outer region (see Figure 18) embedded within several simultaneous socio-economic processes of change occurring at these scales. These processes have implications for the integrity of the PMER ecosystems and the services these generate. In the same way, the direct or indirect beneficiaries of the services can be divided into (i) those dependent on PPF resources; (ii) those living in buffer VDCs; (iii) those living around Phewa Lake; iv) those living along the Aandhi Khola and Rati/Jare Khola outside the 17 PMER VDCs; and (v) the general public, especially residents of Kaski, Parbat and Syangja Districts as well as both Nepali and foreign nationals visiting the area and feeling gratified by valuing its existence.

The influence of PMER characteristics, particularly its ecosystems and the goods and services these generate, varies according to the spatial scale considered (see Figure 12).

All three sub-watersheds (Harpan Khola, Aandhi Khola and Rati/Jare Khola) produce freshwater, which is the key PMER service (see Table 10). The flow in the Harpan Khola sub-watershed is, however, the most important because it feeds Phewa Lake, which has a variety of functions, services and values for local, regional, national and international stakeholders. As a major tourist attraction, Phewa Lake is hugely important to the

FIGURE 15 Sources of climate-related hazards in the PMER

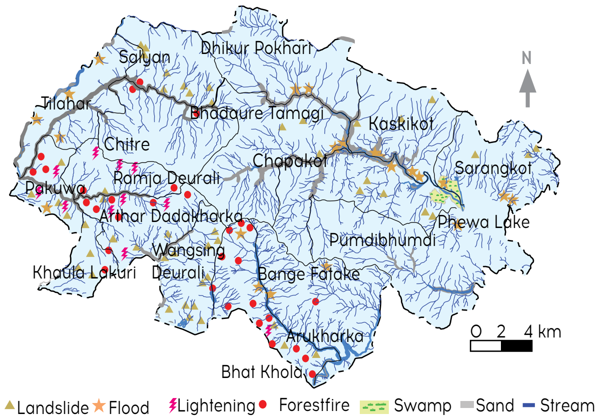


FIGURE 16 Vulnerability categories of the PMER at the ward level

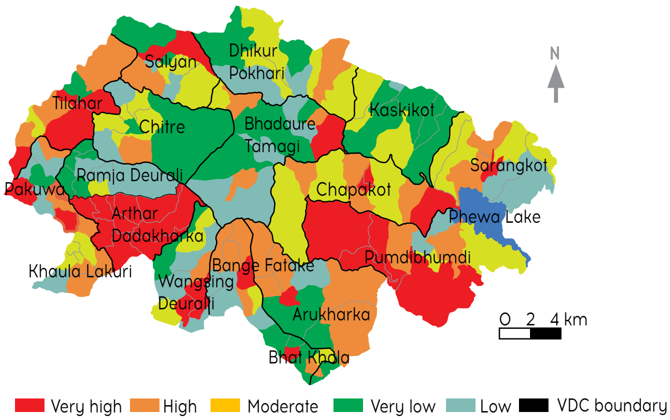
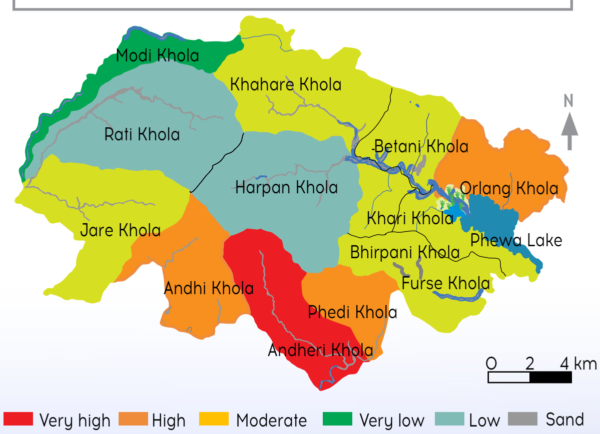


FIGURE 17a Sub-watersheds of the PMER

FIGURE 17b Vulnerability categories of the PMER at the sub-watershed level



Paddy straws are used for repairing thatched roof, and livestock feed.

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TABLE 9a | Ward level vulnerability ranking in PMER

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
Moderate	Sarankot	2,3	3.39
	Tilahar	2,4,9	6.35
	Wangsing Deurali	4	0.78
	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

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Livestock make substantial contribution to household livelihoods at Harpan Khola watershed.

TABLE 9b Sub-watershed level vulnerability ranking in PMER

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
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

local and national economy. The lake is already experiencing different non-climatic threats and the warming climate is likely to exacerbate the adverse effects. Extreme rainfall events have caused and will accelerate landslides and flooding, leading to increased sedimentation in the lake. It is, however, important to remember that one cannot predict the timing or the magnitude of extreme weather events, nor the risk thresholds for the sub-watersheds.

Future climate change scenario

As the database is limited and GCMs cannot predict the future at the scale of a ward or a sub-watershed, it is not possible to predict precisely what will happen to the PMER ecosystem. Instead, the risks must be acknowledged and at the very least preparatory action needs to be taken to minimize the impact of climate change on ecosystems, people, livelihoods and the availability of goods and services from the ecosystems.

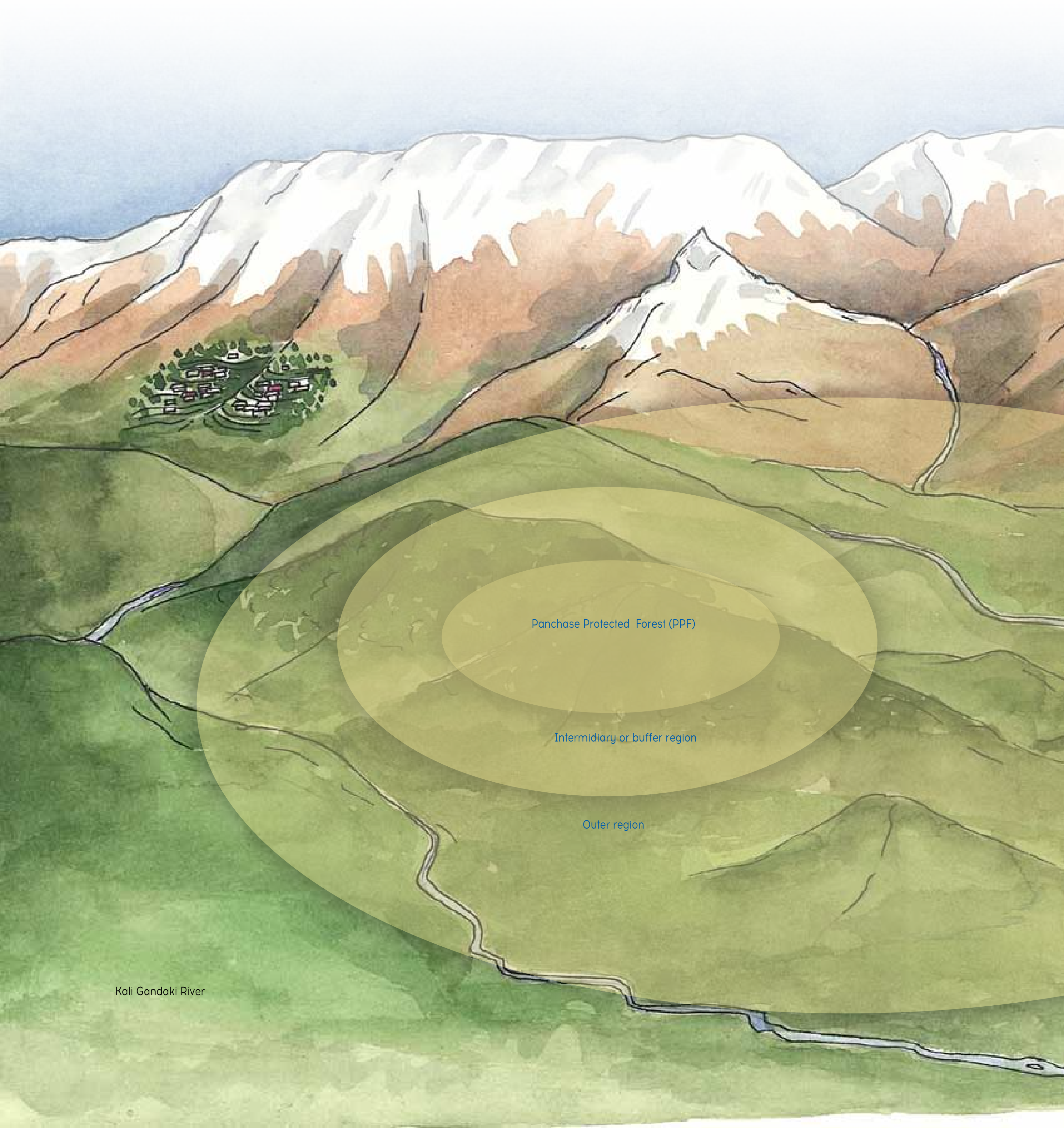
To answer the question of how current vulnerability will change in future and how climatic drivers will interact with existing systems and people, the study examined the climate context of the PMER using the following:

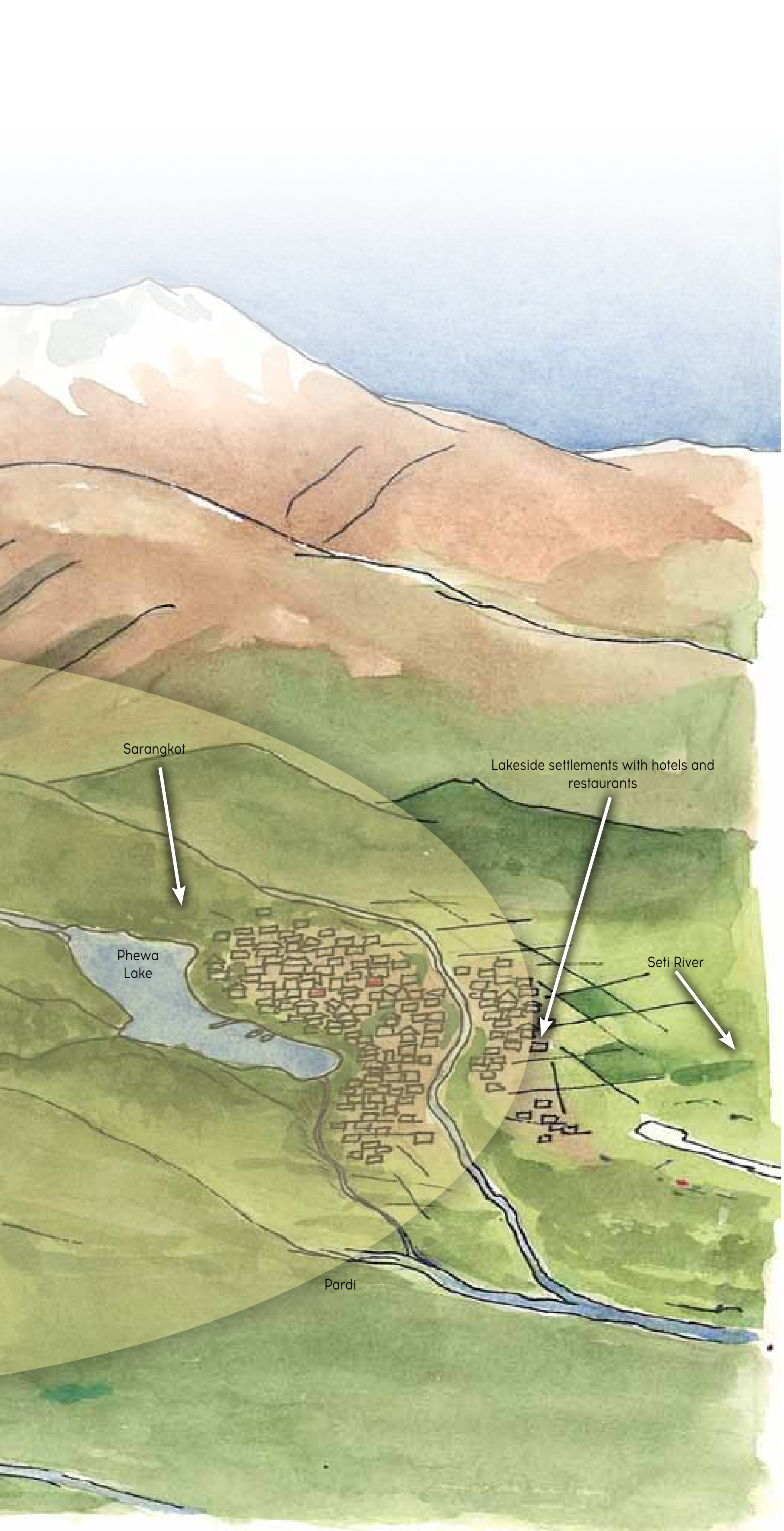
a) historical climate trends, particularly temperature and rainfall
b) global climate model scenarios for the WDR
c) perceptions of PMER residents of changes in temperature and rainfall

The climate context was used to envision future climate change in the PMER and identify new sources of vulnerability based on this scenario in order to select EbA options to build resilience and adaptive capacity.

Historical trends: Analysis of recorded climate data in Nepal shows that temperatures are increasing. Indeed, as the concentration of greenhouse gases increases, the temperature has risen consistently

FIGURE 18 Geographical schematization of ecosystem services from the PMER





Degradation of Phewa Lake is a major threat to fishery.

Phewa Lake possesses socio-economic and cultural values.

Tourism generates revenue that can be used to help maintain the PMER ecosystem.

Phewa Lake draws a lot of tourists

Phewa Lake shoreline serves as landing-pad for paragliders.

Poorly maintained shoreline infrastructures affects Lake's aesthetic quality.

(Shrestha and others 1999, Agrawala and others 2003, Cruz and others 2007, NCVST 2009; ICIMOD 2009). The average rate of increase of 0.04°C – 0.06°C per annum is higher than the global warming rate (Shrestha 2009). According to Practical Action (2009), winter temperatures are higher in western Nepal than in the eastern part of the country. The temperature trend in the PMER is broadly similar to the rest of the country (see Figure 19a). All 11 stations studied showed that temperatures were increasing and that there was a significant inter-quartile range of maximum and minimum monthly temperatures. The data at Pokhara Airport is typical of this warming and variability (see Figures 19b and 19c). The mean monthly temperature varied on a monthly and seasonal basis. The increase in the average winter temperature was slight, particularly in January (see Figure 19d) and this was also the case with the average increase of summer temperatures. Pokhara Airport witnessed the greatest temperature increase in May, when the rate of increase was 0.04°C per year (see Figure 19e).

TABLE 10 | Summary of ecosystem services provided by the PMER

	Provisioning services					
Sub-watershed	Hydropower	Irrigation	Drinking water	Fishery	Wildlife	Livelihood
Harpan Khola	Installed capacity of 1 000 kW. In 2012/2013 the plant produced 2.082 GWh energy that was supplied to Integrated Nepal Power System.	A canal from lake to irrigate 350 ha of land.	Hotels, restaurants and other uses along the banks of Phewa lake and lakeside region draw water from the lake. This amount is largely unmonitored.	About 100 cages have been installed on the lake for fish farming.	Vulture, *Kalij*, Monkey, Owl, *Titra*, Eagle, *Baaj*, Himalayan Black Bear, Leopard, *Ratuwa*.	About 200 families are dependent on boating as source of livelihood.
Andhi Khola	5.1 MW Andhi Khola hydropower plant produces 38 GWh energy in a year fed to Integrated Nepal Power System.	Water from Andhi khola is diverted to irrigate land in Syangja District.	Local agriculture and domestic uses.	Mostly local types. Andhi Khola dam has a small reservoir where some fish farming is done.		NTFP and medicinal plants (Chiraito) used as a source of livelihood, Aloevera, *Tej pat*.
Jare/Rati Khola	Upstream of the confluence of Jare Khola with Modi Khola lies Modi Khola hydropower plant. Modi Khola feeds into Kali Gandaki. Very little influence on downstream region.	Irrigation facilities for adjoining settlements.	Agriculture and domestic uses in adjoining communities.	Mostly local but unquantified.		Medicinal plants Pasture for buffaloes, people sell milk, ghee and young male buffalo to earn income.

There were no discernible trends in rainfall but average annual rainfalls at all stations (Kaski, Parbat, and Syangja in figures 20a, 20b and 20c, respectively) do show some increase. The large difference between the average amounts of rainfall in the wettest and driest months is a reflection of significant inter-annual variability. At the same time, the date of withdrawal of monsoon is being delayed. On the basis of analysis of 63 years of data between 1951 and 2013, Gautam and Regmi (2013) found that both the onset and the withdrawal of summer monsoon are delayed. After 1997, the withdrawal date has shifted by 10 days (statistically significant at 5 per cent whereas the onset days is statistically insignificant) (Gautam and Regmi 2013). Figure 20d presents the inter-quartile monthly rainfall range over the period 1977-2009 for Pokhara Airport and other stations around the PMER. At Pokhara Airport, the intensity of hourly rainfall in 2012 and 2013, showed a slight increase (see Figure 20d). The maximum hourly rainfall recorded was on June 10, 2013; the total was 107.8 mm. Although no station experienced a significant decline in total annual rainfall between 1977 and 2009, stations in both Parbat and Syangja districts experienced reductions in winter rainfall even though summer rainfall increased (see Figure 20f).

Cultural services		Supporting services	Regulatory services	Remarks
Recreation	Religion	In situ value	Ecosystem flow	
Tourists visiting Pokhara use boating as recreational activity. The number of tourists enjoying boating is large but unrecorded. Other type of recreation common along the banks of Phewa Lake is paragliding. The gliders jump start in Sarangkot hills and land on the bank of Phewa Lake in Pame VDC. Micro light flight also offer view of Phewa Lake.	Tal Barahi temple situated in Phewa Lake is popular site for pilgrimage.	The lake has intrinsic value and helps modulate the microclimate of the area but this aspect cannot be scientifically validated.	Ponds store water and provide some moderation impact. Area under forest helps in modulation of local climate though unquantified.	There are uses like water mills and other unquantified context.
Insignificant		Local	Ponds store water and provide some moderation impact. Area under forest helps in modulation of local climate though unquantified.	Water mills and other unquantified uses
None	Temple of Srawan Kumar and Panchase Lake are sites for religious pilgrimage for the people of the area during Balachaturdashi in November.		Ponds store water and moderate hydrological extremes. Area under forest helps in modulation of local climate though unquantified.	Other unquantified uses

Global climate model scenarios for the WDR: In Nepal, a number of national climate projections, mostly based on GCMs, have been prepared (NCVST 2009). While it is widely agreed that no global or regional model can predict Nepal's future climate accurately due to the extreme physiographic variations in the country, these projections, including the down-scaled ones, indicate that temperature trends are only upward and rainfall is becoming more erratic. Analyzing the consequences of concentration of greenhouse gases in the Ganga Basin, Mirza and Dixit (1997) found that the mean annual temperature would rise by 2.7°C by 2100 but with high regional variation. In Nepal within the basin, for example, the study could make predictions but with much less confidence. A 2003 analysis, subsequently confirmed by other models, indicated significant and consistent increases in temperatures in Nepal between 2014 and 2030 and beyond to 2050 and 2100, and that these increases would be greater in winter not summer (Agrawala and others 2003). NCVST (2009) shows that temperatures will increase more in western and central Nepal than in the East and that the greatest increases will be in the western mountains. A later study by McSweeney (2010) suggests that the temperature increase by the end of the century is likely to be between 2°C and 5°C. The temperature scenario for central Nepal suggested by NCVST (2009) is valid for the PMER.

Results from rainfall modelling are less clear although all projections indicate that annual precipitation will increase throughout the country (Agrawala and others 2003, IPCC 2007). In general, pre-monsoon and monsoon rainfall will increase and winter rainfall decrease with marked regional variations (Bartlet and others 2011). These results suggest that winter precipitation will decrease in western Nepal but increase by 5-10 per cent in the East. In contrast NCVST (2009) projects that monsoon and post-monsoon rainfall will increase in most parts of the country and that winter rainfall will decrease. The monsoon months in particular will bring 15-20 per cent more rain across much of the country, except western Nepal.

FIGURE 19 Trends in surface temperatures in the PMER

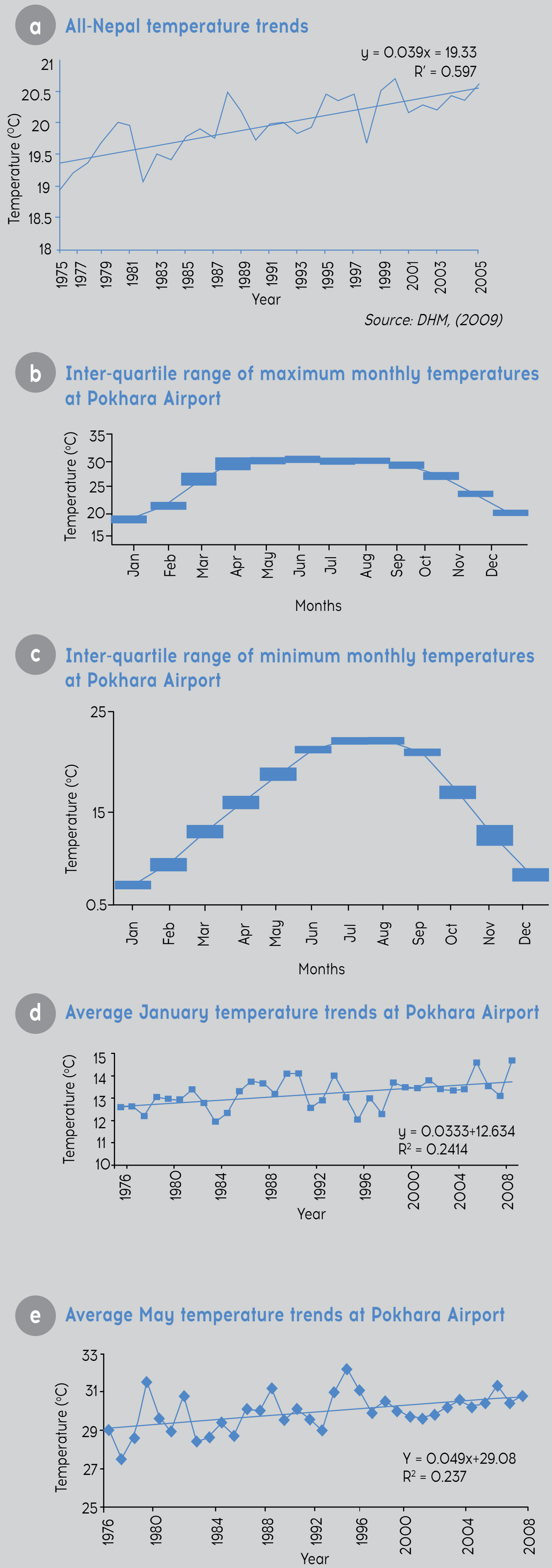
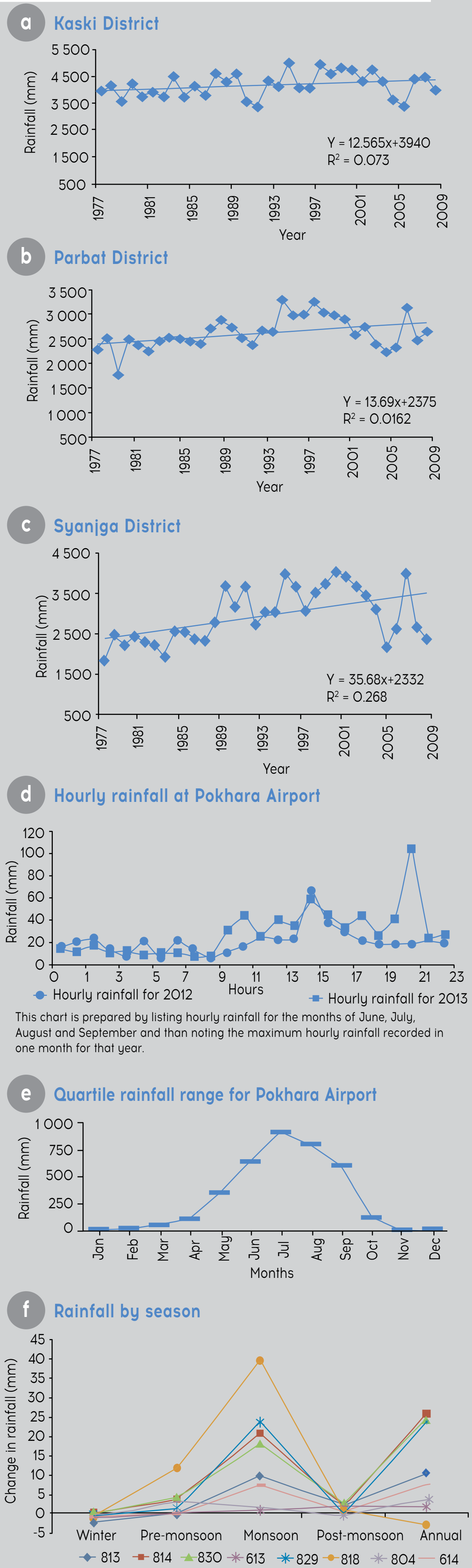


FIGURE 20 Rainfall trends in the PMER



While Nepal is likely to receive more rainfall, spatial and temporal trends are difficult to predict. An increase is expected in extreme weather events such as droughts and flash floods brought about by a prolonged rain-less period followed by sudden heavy rainfall. Precipitation variability will no doubt increase though we may not be able to accurately define its future spatial and temporal character. This level of uncertainty is a stress multiplier and presents a fundamental challenge to devising adaptation strategies.

Temperature and precipitation changes will affect local hydrology and local ecosystems. Water is essential for human well-being and it is, therefore, important to understand potential changes in flow dynamics. At the sub-watershed level, spring and streamflows depend on a large number of processes such as infiltration, inter-flow, percolation and groundwater recharge, as well as site-specific conditions, including topography, geology and vegetation. In mountain sub-watersheds, rainfall contribution to groundwater tends to be low with most rainwater running off and adding to streamflow. As run-off is rapid and concentrated, flash flood-level flows are common.

Prediction is not easy because local hydrological parameters are not systematically monitored. There is not enough data to estimate the mean annual flows of rivers, let alone monthly flows or year-on-year trends. It is, therefore, uncertain how climate change will affect the hydrological characteristics of medium-sized and small watersheds such as those that drain the PMER. Since ecosystem-level scenarios in the PMER have not been studied, changes in the PMER have to be inferred from analysis of adjoining catchments, yielding results that are only indicative of what will happen in the PMER.

Babel and others (2013) analysed the potential hydrological impact of climate change on Nepal's Bagmati River basin using down-scaled temperature and precipitation outputs from GCMs. Their results suggest an increase in the intensity

TABLE 11 | **Temperature scenarios in degrees Celsius in relation to 1970-1999 as projected global climate model projections**

Time Period	Annual (°C)	Pre-monsoon (MAM) °C	Monsoon (JJA) °C	Post-monsoon (SON) °C	Winter (DJF) °C
2030s	1.4 (0.8-2.0)	1.8 (0.8-2.1)	1.4 (0.5-2.2)	1.1 (0.5-2.0)	1.5 (0.7-2.8)
2060s	2.8 (1.9-3.8)	3.0 (2.2-4.4)	2.3 (1.4-3.3)	2.6 (1.8-4.0)	3.4 (1.7-4.5)
2090s	4.9 (3.7-5.9)	5.3 (4.0-6.5)	4.4 (2.8-5.9)	4.3(3.3-5.5)	5.6 (3.7-6.2)

Source: NCVST (2009)

TABLE 12 | **Precipitation scenario for mid-century (2039-2069) compared to baseline (1961-1990)**

Season	Precipitation change per cent		Temperature change °C	
	West	East	West	East
Winter	-0.6	-9.6	2.2	2.1
Pre-Monsoon	1.0	-2.1	1.7	1.8
Monsoon	-8.4	-18.1	2.1	1.9
Post-Monsoon	5.7	-5.9	2.2	2.0
Annual	-4.1	-13.2	2.0	1.9

Source: DHM/APN/GCISC (2007)

of monsoon precipitation, which might affect the hydrological characteristics of the basin. These changes, together with inadequate management capacities and increased resource use and other stresses, will increase the vulnerability of medium-sized river basins of Nepal (Pandey and others 2010). It is likely that the PMER water resources will face similar challenges and the rivers flowing through it will see changes to their sediment hydrology. According to MoPE (2004) a more than 20-per cent addition to precipitation is likely to increase the rate of sedimentation of a basin. If the land surface is exposed due to intense cropping or overgrazing, that rate will increase further.

Local perceptions: To assess people's perception of climate change, participants were asked about their experiences with temperature changes and extreme rainfall events in the PMER. Participants were then informed about the findings of NCVST (2009), which suggest that the average temperature in the Gandaki (Narayani) basin area will rise by 1.4°C by 2030, 2.8°C by 2060 and 4.9°C by 2090. Participants were asked to reflect on changes in temperature and precipitation over the past 10 years in each of the country's four seasons, namely pre-monsoon, monsoon, post-monsoon and winter. Five trends were identified:

- a delay in the onset of the monsoon
- an increase in the frequency of extreme rainfall events
- an increase in the intensity of extreme rainfall events
- longer dry periods
- an increase in hailstorms and thunderstorms

The perceptions are summarized in Table 14.

Stakeholders were also asked to reflect on the impact these changes were likely to have in each of the 17 VDCs on landslides, floods, forest fires, pests and disease, water, agriculture, forests and invasive species. They identified seven main changes (see also Table 15):

- The range of wildlife and plant population will shift and/or the phenology or composition of forest species will be altered; and/or there will be a fragmentation or loss of biotic interaction in habitats.

- Changes in forest composition may impact the productivity of ecosystems and agriculture.
- Changes in local hydrological regimes will alter the availability of water in terms of both volume and time distribution of flow.
- Reduced stream flows will lower the capacity of the ecosystem to provide services to the local population, creating more push factors for migration and undermining community cohesion.
- Overgrazing of forest and grassland will put further stress on these resources.
- To compensate for declining food production, more chemical fertilizer will be used.

These changes are likely to increase vulnerability as well as the interdependence between the provisioning and regulating services of the ecosystems in each VDC. PMER residents were asked about their assessment of the climate change vulnerability of the various PMER sectors and systems. They felt that in almost all VDCs, drinking water, forests and agriculture were in the moderate-to-highly vulnerable category. Local stakeholders were less certain about the vulnerability of specific ecosystems because of their lack of in-depth knowledge of systems and their behavior. The perceptions are summarized in Table 16.

Synthesis of future climate change: All three levels of analysis–historical trends, GCM scenarios and people's perceptions–indicate that temperatures in the PMER will increase; that rainfall characteristics, such as timing, frequency, duration and intensity, will change; and that extreme rainfall events will be more intense and frequent.

These changes are likely to exacerbate climate hazards and increase risks to the ecosystems and communities. The impact will be magnified because altitude changes are extreme. Part of the predicted impact has already been observed and is threatening food security, biodiversity, wildlife habitats, water and tourism. The agriculture, forest, livestock, disaster and health sectors are likely to be adversely affected and people accustomed to steady weather patterns will find it hard to deal with greater and accelerated climate variability. By the 2030s, the temperature will have risen a degree or two and while total annual rainfall will be more or less the same, rainfall will be intense and its seasonality more pronounced. Because of the fragility of slopes and vulnerability of riverbanks to erosion, the frequency of floods and landslides, already a serious concern in the PMER, is likely to increase. The consequences of greater climate variability and associated disaster events on the ecosystem services of the PMER are shown in Table 17.

It is important to assess the implication of these changes for the PMER wards and sub-watersheds because building resilience and adaptive capacity must start from small units and be aggregated up to watershed and river basin scales. The study developed a scenario for the 2030s by synthesizing historical trends, GCM scenarios and people's

TABLE 13 | Global climate model-based estimates of temperature and rainfall for Nepal

Season	Temperature			Rainfall			Snowfall			Hail stone			Mist			Fog			Storm			Forest fire		
Pre-monsoon		I		D			D					S			S			S		I			I	
Monsoon		I		D					S			S		I				S			S	D		
Post-monsoon		I		D					S			S		I			I				S			S
Winter		I		D			D					S	D					S			S		I	
Annual		I		D					S			S		I				S			S		I	

I = increasing, D= decreasing, S= same

Source: SLD (2013)

TABLE 14 | VDC-level impact matrix based on community perceptions

District	VDC	Regulating				Provisioning			
		Land-slide	Flood	Forest fire	Pests & Diseases	Water source	Forest condition	Invasive species	Agriculture production
Parbat	Arthar Dada khark	I	-	I	I	-	D	I	-
	Pakuwa	I	-	I	I	-	-	I	-
	Chitre	S	-	D	I	D	S	-	D
	Tilahar	S	-	-	I	-	S	-	D
	Khaula Lakuri	I	-	D	I	-	-	I	D
	Ramjha Deurali	D	D	S	I	-		I	-
Syangja	Bhat Khola	D	-	I	I	-	S	I	D
	Bange Fatake	I	I	D	-	-	-	-	-
	Arukhark	I	-	S	-	-	S	-	-
	Wangsing Deurali	I	-	I	-	-	-	-	D
Kaski	Bhadaure Tamagi	I	I	D	I	-	D	-	D
	Dhikur Pokhari	D	-	D	I	D	I	I	D
	Kaskikot	I	-	D	I	-	I	-	D
	Sarangkot	D	S	D	I	-	S	-	D
	Salyan	I	-	S	I	D	-	-	D
	Chapakot	D	-	D	I	D	I	-	D
	Pumdi-bhumdi	D	-	D	I	D	I	I	D

Note: I= Increasing, D= Decresing, S= Same *Source: SLD (2013)*

perceptions of climate change. Both ward and sub-watershed levels were considered. The year 2030 was chosen because participants felt most worried about the near future. The Harpan Khola was selected as the pilot because it flows into the Phewa Lake. Participants were asked what the rise in temperature and extreme rainfall events in the watershed would mean for the services generated by the sub-watershed. They were reminded of the 2009 NCVST findings, which suggested that the average temperature in the Gandaki basin would rise by 1.4°C by 2030 (see Table 11).

It is difficult to predict the likely magnitude of an extreme daily rainfall event. The maximum daily rainfall ever recorded in Nepal was 540 mm in July 1993 (NCVST 2009) and the maximum hourly rainfall of 107 mm was recorded at Pokhara Airport on 10 June 2013. Daily or hourly future rainfall values cannot be predicted, as more information is needed. However, if the Harpan Khola sub-watershed receives extremely high hourly or daily rainfall, landscape-level processes would be affected and sediment yields would be likely to increase. Figure 21a shows the distribution of grazing, terrace, scrubland, forestland and gullies in the sub-watershed. Ward-level maps of erosion rates and landslide hazards (see Figure 21b) were also prepared for this sub-watershed. These two maps were used together to present a vulnerability scenario for an increase in rainfall intensity (see Figure 21c).

TABLE 15 | Matrix of vulnerability perceptions

District	VDCs	Drinking water	Forest	Agriculture	Irrigation	Transportation systems	Indicative endangered	Electricity	Other energy sources	Communication	Grazing area	Land and ecosystem
Parbat	Khaula Lakuri	5	5	5	5	4				4		
	Ramja Deurali	4	4	5	5	5	1	4	4			1
	Chitre	4	2	4							5	
	Tilahar	5		5	4	4						
	Artha Dandakharka	3		5	2	4	2	4		4		3
	Pakuwa	5	5	5	5	3	2					
Kaski	Chapakot	2	2	3		5	2	2		1		
	Pumdibhumdi	4	3	5		4	3	5		3	2	
	Kaskikot	5	1	3		3	5		2			
	Sarangkot	3	2	3		5		3		1		
	Dhikur Pokhari	3	2	4		2	4		3	1		
	Bhadaure Tamagi	3	2	4		2		4	1	3		
	Salyan	5	4	4		4						
Syangla	Bhat Khola	5	4	3			4					
	Bange Fatake	4	2	5		4		5		2		
	Arukharka	4	1	3		5						
	Wangsing Deurali	5	4	4		4	4					5

Very low = 1 , Low = 2, Moderate = 3 , High = 4 , Very high = 5

The scenario developed suggests that the various ecosystems in the PMER are likely to be negatively affected. The likely drying up of springs vital for drinking water and irrigation, will add to the stress, as will increased forests fires. It is likely that the PMER will experience a moderate loss of habitat, a high rate of ecosystem fragmentation due to human and animal pressure and moderate-to-high vulnerability to temperature stress. All this will exacerbate adaptive constraints.

TABLE 16 | Climate change scenario, consequences for and vulnerabilities of ecosystem services in the PMER

Ecosystem type	Dependent livelihood	Possible changes	Vulnerability	Risks
Hill farming system	Agriculture and food production	Increase in frequency of heavy downpours during monsoon	Increase erosion and landslides, debris floods affecting water storage and damaging farm land. Environmental degradation and damage of water systems.	High
		More rainfall in shorter duration: extreme events will increase	Similar events more frequent	Moderate
		Defecit monsoon rainfall	Less water available for growth of paddy	Moderate
		Low pre-monsoon and winter rainfall	Reduction in production of crops like maize and wheat	Moderate
		Changes in crop growing season, reduced grazing period	Changes in crop calendar and reduction of production Reduced livestock population affecting milk and meat production	Low
Water stored in ponds, springs and wetlands	Drinking, irrigation and gender consideration while fetching water	Higher temperature leading to drying up of springs and ponds	Reduced water for drinking and irrigation	Moderate
		Reduced rainfall and reduced stream flow	Reduced water available for Andheri Khola, Pardi and Kali Gandaki	Moderate for Pardi Dam Low for Aandhi Khola and Kali Gandaki hydropower dams
		Extreme rainfall leading to flash floods	Higher sedimentation and loss of lives and assets	Moderate
		Uppredictable rainfall means unavailability of timely water supply for ponds, wetlands and springs	Changes in local hydrology with implications for dependent systems	Moderate
Community forestry	Timber, fuelwood, compost and fodder	Reduction in variety of species	Loss of biodiversity and negative consequences as reduced household entitlement to natural assets	Moderate
	NTFP and MAP uses	Dry winter and pre-monsoon season, and soil moisture (without rains, land can become drier, increasing the chances of forest fire	Loss of assets, livelihoods, forest products and degradation	Moderate
		Decline in local vegetation	Loss of income	Moderate
Range pasture land and grazing	Livestock farming	Reduced grazing land and fodder and increased diseases	Reduced livestock numbers and delivery of products. Increase in diseases and expense for treatment with lowered quality of life	High to moderate
National forest and related ecosystems	Collection of NTFPs and MAPs	Decline in varieties of trees medicinal plants, herbs and fruits	Loss of livelihood and family income	Moderate
Natural landscape	Ecotourism	Overall landscape becoming drier and losing aesthetic appeal	Tourists less inclined to visit with consequences for household incomes	Moderate

Stresses caused by climate variability are likely to have an adverse impact on biodiversity, water, tourism and agriculture, and coupled with the increased frequency of extreme weather events, are likely to make local communities more vulnerable. This scenario broadly matches community perceptions of the local climate and its changed dynamics.

To assess the context, it was assumed that the status of vulnerability as listed in the watershed-level Excel database would change, new values were worked out for the indicators and vulnerability categories re-evaluated. The results showed that sub-watersheds would become highly vulnerable by 2030 (see Figure 22), in particular the Harpan Khola. In both practice and theory, assessment should involve working on the sub-watersheds identified as the most vulnerable. Assessments should form the basis of decisions about resilience-building measures and consider prioritizing the most vulnerable. The later stages of this study assessed the vulnerability of the sub-watershed and developed reports on resilience planning in the PMER.

Presentation in GIS Format

The activities undertaken produced three outputs, which were integrated in a GIS-based platform: 1) vulnerability category maps of the 153 PMER wards and the three PMER sub-watersheds, 2) maps depicting the presence of social and natural systems in all 153 wards and 3) a future vulnerability scenario at the ward and sub-watershed level. These maps provide only a snapshot of current and future scenarios and the scenarios are subject to change. Instead, the maps serve as useful visual texts for dialogue and negotiation. When new assumptions, indicators or criteria are adopted, new scenarios will be generated and new spatial representations will be made. The study has created a tool to assist in the assessment of vulnerability and making of EbA decisions.

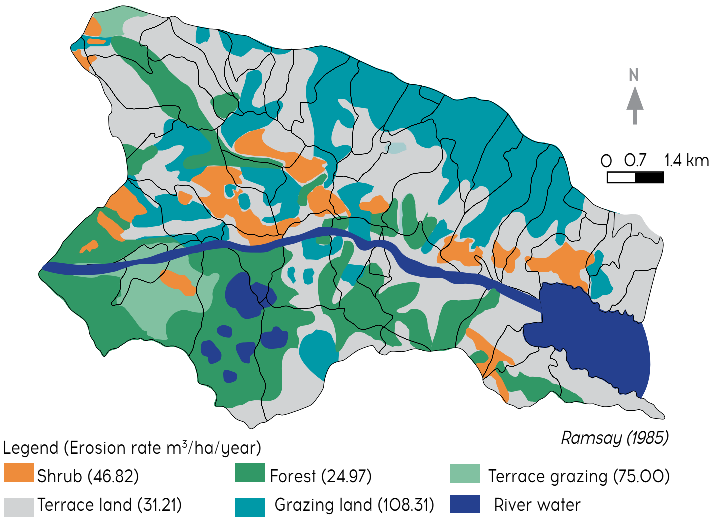
Distribution of services

As discussed earlier, climate change dynamics will affect the distribution of ecosystem goods and services at local and sub-national levels. The dynamics will play out in all sub-watersheds with varying consequences on livelihoods and economies. What will changes in the Harpan Khola sub-watershed mean for the main ecosystem services in Phewa Lake, for example. A warming climate will alter the local hydrology, resulting in high and low flows, thereby increasing sedimentation rates and intensifying stress on water resources. As water and sediment flow change, new sources of vulnerability will emerge (see Figure 23) and affect water-related processes (listed in Table 17). These changes are likely to place the lake under additional stress when it is already affected by pollution, waste, nutrient run-off and physical encroachment.

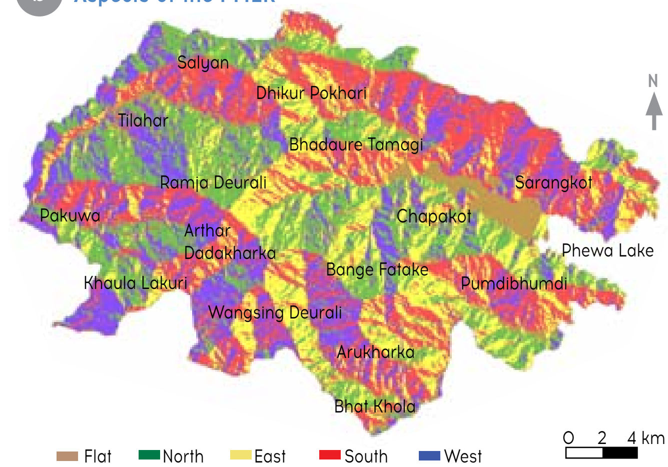
Scenarios developed for each sub-watershed create the stage for identifying preliminary sets of EbA options for the PMER.

FIGURE 21 Hazards maps for the Harpan Khola sub-watershed

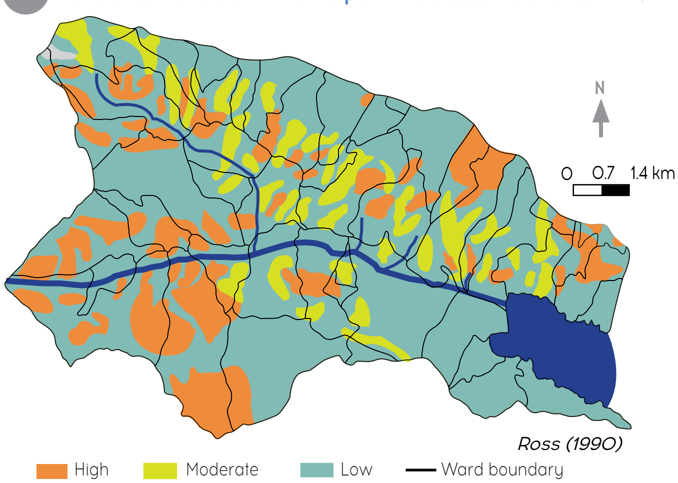
a Distribution of grazing land, terrace, scrubs, forestland and gullies in the Harpan Khola sub-watershed



b Aspects of the PMER



c Landslide hazards in the Harpan Khola sub-watershed



d Landslide scenario in Harpan Khola sub-watershed due to higher intensity rainfall

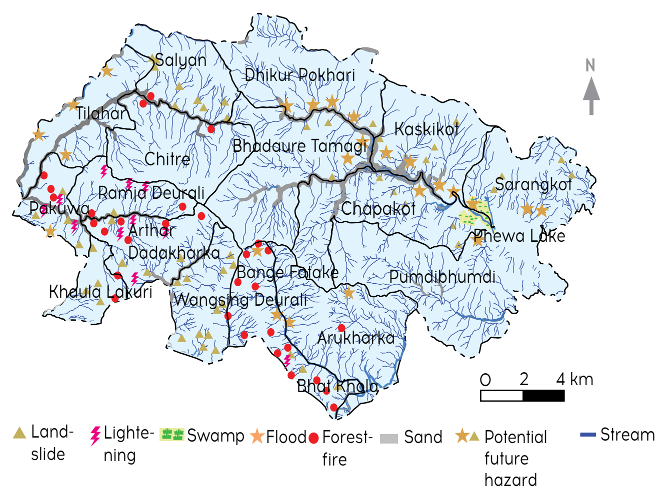
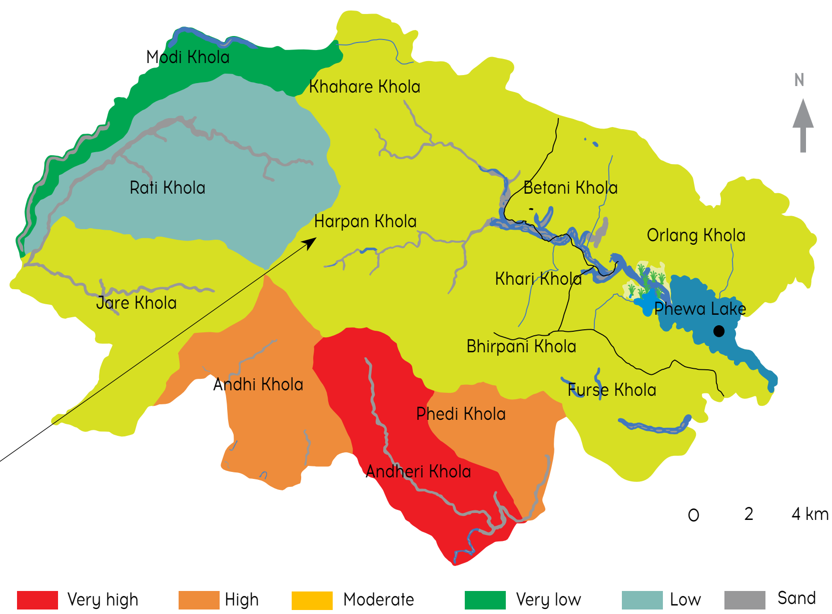


FIGURE 22 Vulnerability scenario of the PMER at the sub-watershed level



In figure 17b the current vulnerability of Harpan Khola sub-watershed was ranked low. In future, if climate change induced hazards become more extreme, this ranking will change. In one scenario the sub-watershed will become moderately vulnerable as shown.

FIGURE 23 Phewa Lake as a recipient of ecosystems goods and services from Harpan Khola

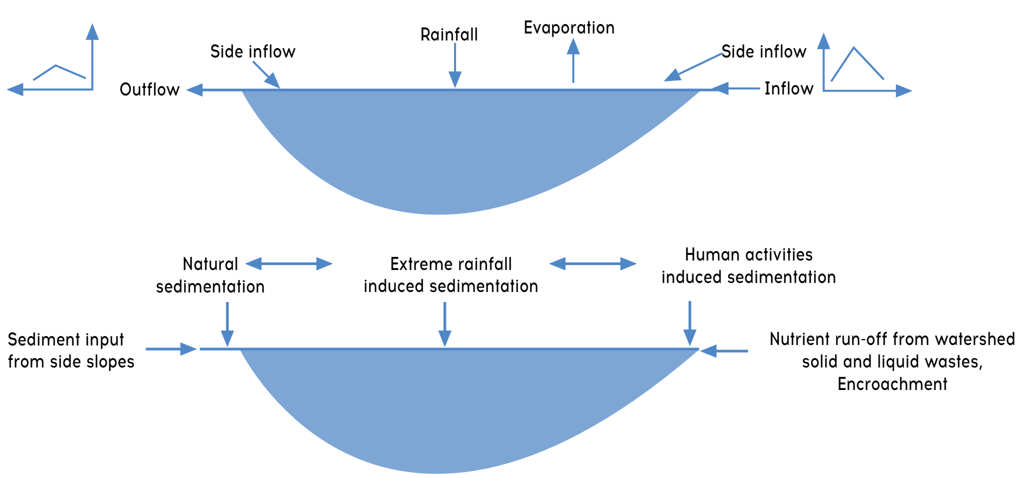


TABLE 17 | Linkages among water-related ecosystems and human well-being as conditions change in the PMER

Human well-being impacts

Pressures	State changes	Human health	Food security	Physical security	Socio-economic
Rivers, Streams and Floodplains					
Changes to input from precipitation changes Flow modification (withdrawal) Sediment budget modification Temperature Eutrophication Pollution (organic, microbial, persistent organic pollutants, solid waste) Invasive species	▲ Water residence time ▲ Ecosystem fragmentation ▲ Disconnection of river - floodplain connectivity ◀▶ Tropic structure ▼ Habitat	▼ Quantity of freshwater ▼ Natural purification processes, water quality ▲ Incidence of water-borne diseases ▲ Malnutrition from drought ▲ Fish contamination	▼ Fish stocks ▲ Flood damage ▲ Crop reduction from drought ◀▶ Crop reliability and change ◀▶ Species distribution from temperature change ▼ Flooplain cultivation ▼ Livestock health	▼ Flooding ▲ Drowning ▲ Community displacement	▼ Tourism ▼ Fisheries ▼ Livestock ▲ Poverty ▲ Property damage ▲ Irrigated agriculture ▲ Allocation ▼ Cost of water treatment
Lakes					
Infiling, drainage Eutrophication Pollution Overfishing Invasive species Temperature changes	▲ Nutrients ◀▶ Trophic structure ▼ Habitat ▲ Algal blooms ▲ Anaerobic conditions ▲ Alien fish species ▲ Water hyacinth ▼ Storage capacity	▼ Natural purification process, water quality ▲ Fish contamination ▲ Chronic disease	▼ Fish stocks ▼ Livestock health	▼ Flood prevention	▼ Tourism ▼ Fisheries ▲ Displacement of communities ▼ Livelihoods Poverty
Conversion, infilling, drainage Change in flow regime Water withdrawal Change in fire regime Overgrazing Eutrophiction Pollution Invasive species If forested, conversion through tree-felling	▼ Habitat and species ▼ Flow and water quality ▲ Algal blooms ▲ Anerobic conditions ▲ Threat to indigenous species ▼ Carbon storage ▲ Soil erosion ▲ Degradation of water resources	▼ Water inflow and storage ▼ Natural purification processes, water quality ▼ In available water quantity and quality		▲ Flash flood frequency and magnitude ▼ Flood mitigation ▼ Drought mitigation	▼ Buffering of flow extermes ▼ Livelihoods

▲ Increasing ▼ Decreasing ◀▶ No change

Adapted from Athurton and others, (2007)

CHAPTER V

EBA STRATEGIES

EbA is an emerging approach to addressing climate change vulnerabilities and has replaced earlier approaches such as "ecosystem-based management" and "ecosystem management". The latter was based on the philosophy of maintaining natural protected areas through cooperative management and developing management responses to complex demands and pressures. EbA proposes to integrate the use of ecosystem services into an overall strategy to help people adapt to climate change (IUCN 2009). It also aims to secure livelihoods threatened by climate change (Jones and others 2012). The key principles of EbA include (Andrade and others 2011):

(1) promote multisectorial approaches;
(2) operate at multiple geographic scales;
(3) integrate flexible management structures that enable adaptive management;
(4) minimize trade-offs and maximize benefits of development and conservation goals to avoid unintended negative social and environmental impacts;
(5) use the best available science and local knowledge and foster knowledge-generation and diffusion;
(6) promote resilient ecosystems and use nature-based solutions to provide benefits to people, especially the most vulnerable; and
(7) embrace equity and gender issues in a participatory, transparent, accountable and culturally appropriate manner.

EbA embraces both natural and social systems. It recognizes the existing interaction and feedback mechanisms between human and ecological systems with the objective of optimizing the flow of benefits from those systems (World Bank 2010). It recognizes the pressing need for approaches that help mitigate the decline in ecosystem services so that the costs to society, measured in terms of increased vulnerability, are minimized. The principles articulated by IUCN for EbA in Nepal are shown in Table 18.

EbA ensures that any approaches to minimizing vulnerability maintain the integrity of the PMER and its resilience to multiple pressures, including climate change and changes in interlinked socio-ecological systems, in ways that enhance ecological processes and services generated. Strategies are needed to manage ecosystems so that their services help reduce the vulnerability of socio-ecological systems and increase their resilience to both climatic and non-climatic risks (Colls and others 2009). EbA helps achieve this objective by emphasizing ecosystem services that underpin human well-being or promote adaptation to climate change.

TABLE 18 | Principles of EbA

Principle	Requirements
Promote resilient and healthy ecosystems	• Modelling of projected climate change • Systematic planning • Protected area systems design • Involve local communities in restoration and management • Adjust management programmes and actions
Maintain ecosystem services	• Valuation of ecosystem services • Determine climate change impact scenarios • Identify options for managing ecosystems or managing use • Involve local communities in adaptation action • Trade-off analysis
Support sectoral adaptation	• Include approaches in national adaptation plans • Incorporate ecosystem services in land management frameworks • Influence sectoral development plans - e.g. agriculture; water supply
Reduce risks and disasters	• Restore key habitats that reduce vulnerability • Catastrophic fire – fire-adapted forests • Water security- Watersheds • Involve vulnerable communities in restoration efforts
Complement infrastructure	• Dam re-engineering – maintain ecological flows in rivers • Dams, levees – Restoration of flood plains • Reserviors – restoration of forests and watersheds
Avoid mal-adaptation	• Improve analysis of impacts from adaptation activities • Reduce negative impacts on natural enviornment • Avoid inadvertent impacts on natural ecosystems and communities
Generate multiple and co-benefits	• Social and cultural • Biodiversity • Economic • Mitigation
Cost effectiveness	• Low cost, small scale investment • Mobilize local resources • Integrate both soft and hard approach

Soruce: IUCN (2014)

To reduce the vulnerability of ecosystems and communities dependent on them, the health and well-being of both need to be improved. Sustaining ecosystem services can help reduce the exposure, sensitivity and vulnerability of coupled human-environment systems. If adaptation is to be seen as an activity addressing the impact of climate change, one needs to attribute the impact to the cause, which in this case, is the warming climate. Attributing a specific local impact to global climate change processes is almost impossible because of a lack of adequate understanding about the relation between the monsoon and the Himalayan mountain systems, the nation's lack of hydro meteorological data base and the limitations of GCMs. Researchers still lack the tools to down-scale GCMs to develop local scenarios. The 2009 NCVST study of GCMs clearly highlights the extent of the limitations of the models in projecting a future precipitation scenario for Nepal. It concludes that when applied locally, these models would show monsoon precipitation varying from a 52 per cent reduction to a 135 per cent increase (NCVST 2009).

It is not possible to predict the response of local climate dynamics to global climate change and the new sources of vulnerability it will introduce. This uncertainty makes it difficult to know how to proceed, how to define the relationship between adaptation and development and where development ends and adaptation begins. A detailed examination of the nature and influence of all the drivers of change, including both climate and non-climatic drivers, must be undertaken in order to ensure that strategies to enhance resilience and adaptive capacity are effective.

EbA for the PMER aims to identify and integrate options to reduce the vulnerability of ecosystems and communities dependent on their services in order to enhance the resilience of the natural-human system. It is expected that EbA options will minimize the negative impact of climate change, namely higher temperatures, changing patterns of precipitation, increased crop failure, pests and disease and greater presence of invasive species. The options identified will be implemented by building on existing projects such as the management of the PPF. These strategies aim to promote green development by rehabilitating ecosystems, improving connectivity between patches of wetlands, forests and pastures, including those in conservation and protected areas and increasing buffers for vulnerable communities and ecosystems. These efforts should generate jobs and improve the resilience of the local infrastructure in and around the PMER. The measures should also be low-cost and flexible, help alleviate poverty and promote sustainable development.

Two factors drive an individual's attempt to adapt to shocks. Firstly, an individual takes action to deal with the constraints and opportunities that emerge over time. Secondly, he or she makes adaptation decisions depending on his/her capacity, perceptions and priorities. Continuous adoption of new skills and technologies, reform of institutions and nurturing of social relationships foster actions that minimize climate change threats. However, these actions will not automatically achieve the objectives of reducing vulnerability, building resilience and achieving social equity. In reality these actions often separate those who are at an advantage by virtue of their education, wealth or location leading to competition across generations and marginalized sections of society thus reinforcing entrenched social, ethnic, class and caste divisions. The result is limited adaptation.

Building on the CRF, this study proposes the following EbA framework focusing on people and ecosystems. It has two pillars:

- Pillar 1: management of key ecosystem sectors using community-based strategies and conservation of biodiversity resources, including NTFPs; and
- Pillar 2: building the resilience of core and broader systems that serve as gateways to services.

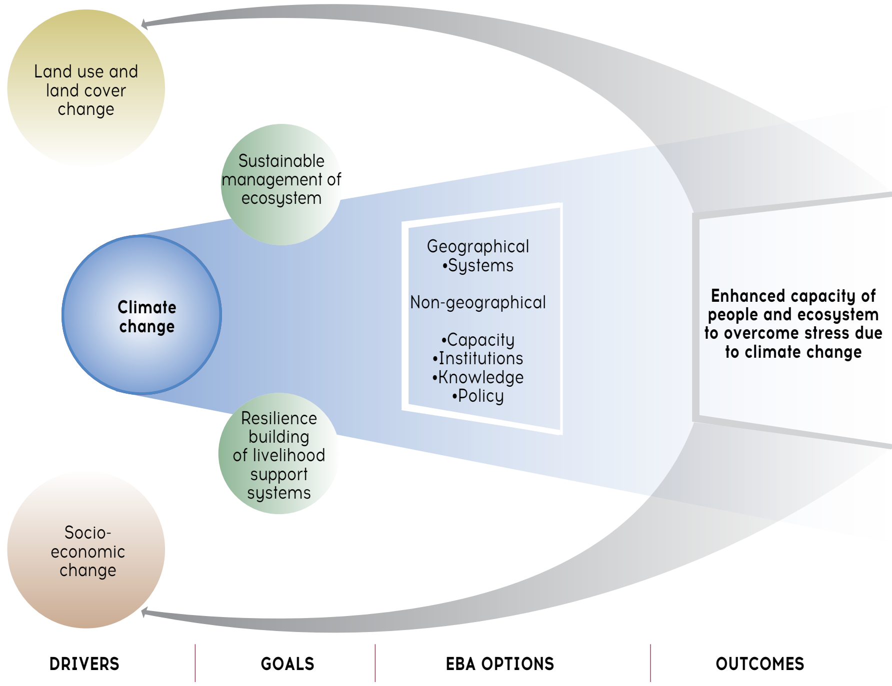
These two pillars will help EbA address three climate and non-climatic change drivers–changes in land use and land cover, socio-economic development and climate change–which affect the nature-human system. Formulating the EbA strategy is difficult because it is almost impossible to attribute local impact to climate change alone. To overcome this limitation, the climate change driver is used as the one entry point into existing approaches and from there we can propose biophysical measures to successfully address the other two change-drivers (see Figure 24).

The PMER ecosystem services support diverse sectors: agriculture, horticulture, floriculture and animal husbandry, water, wetlands, springs and rivers, forestry, NTFPs and biodiversity, rangeland and landscape roads, trails. It also supports community infrastructure: institutions and organizations: government, non-government and community-based and private sector entities. Investments to maintain the integrity of the PMER ecosystems will produce diverse benefits at local, regional and national levels and affect differently the natural and human systems inside and outside the region.

Not everyone dependent on ecosystem goods and services will receive an equitable share in the benefits of EbA. Different community groups categorized by gender, ethnicity, caste and socio-economic class, are the primary and secondary users of ecosystem services. The benefits to each group will depend on the minimum amount of goods and services available in and outside

FIGURE 24 Framework for developing EbA strategy

Climate change vulnerability is conceived as the entry point in proposing options (Geographical and Non-geographical) for EbA. When implemented they will bring about changes in land use, land cover and socio-economic context to achieve the EbA goals.



the PMER, the rights to the services assigned and benefit-sharing arrangements. Differences in benefits are attributable to the fact that government, non-government and community-based organizations and private sector entities function under different governance regimes, pursue different property right regimes and have different risk perceptions. To overcome these differences, it is important to link the costs borne by different actors within the PMER to the direct and indirect benefits they receive. These organizations are important actors in implementing EbA options.

Private sector tourism, particularly around Phewa Lake, is a major beneficiary of ecosystem services in the Harpan Khola sub-watershed. Though immediately outside the boundary of the PMER, the quality and value and integrity of Phewa Lake depend on two things: the quality and quantity of water flowing into the lake from the PMER catchment and its sediment hydrology. The forest in the sub-watershed maintains the water yield of the Harpan Khola, thereby helping to provide the water necessary for irrigation, drinking, hydroelectricity, fishery, tourism, recreation and cultural and religious practices in and around the lake (see Table 19).

Identification of EbA options

Some EbA options identified are likely to be geographical, for example, a drinking water system serving a particular settlement, while others will be non-geographical such as policies and institutions applicable to the PMER in particular and Nepal in general. Some options may not address the biophysical system directly but involve roads, energy generating systems or communication networks such as telephone, radio and Internet. As mentioned in Box 4, these types of activities are being implemented autonomously in the PMER. By improving mobility and access to new knowledge and creating alternative livelihoods, these systems can serve as a foundation for building resilience and adaptive capacity.

TABLE 19 | The vulnerability scenario for Phewa Lake

Drivers	Parameter	Trend	Response
Climatic	Temperature	Go up	Planting more trees but it may increase forest fire hazards without local mitigative measures.
	Rainfall	Become more erratic	Rainwater harvesting and promotion of conservation ponds.
	Humidity	Go up in summer	Plantation of suitable vegetation species on the lake shores to buffer the effects.
	Run-off	Seasonal scarcity may increase	Preservation of existing ponds and building of new conservation ponds to store water. Conserve forest and other biophysical system.
	Sediment flow	Increase	Reforestation and terracing with focus on reducing sediment generation.
	Thunderstorm and lightning	Increase	Provide lightning arrester in houses and other structures.
	Wind	More erratic unknown	Development of wind breaks and wind resistance design in homes and structures.
	Evaporation	High in summer and dry months	Vegetation plantation in Phewa shore area.
	Invasive species	Increase	Promote resistant crops and use natural methods of mitigation.
	Nutrient loss due to excess rainfall	Increase	Contouring, terracing, developing grassed waterways
Non-climatic	Solid and liquid wastes	Increase	Managing and improving awareness, monitoring of production and proper disposal.
	Nutrient loss due to excess application	Increase	Monitoring, organic farming and building awareness.
	Water extraction from lake	Increase	Monitoring regulation and building awareness.
	Washing clothes	Continue	Build awareness and provide alternative washing places and sources.
	Tourism	Continue	Develop code of conduct, awareness building and regulation
	Religion	Continue	Develop code of conduct, awareness building and regulation

The creation of alternative livelihood opportunities and encouraging their adoption by those dependent on natural resource-based livelihoods would reduce pressure on the stock of the PMER's ecosystems. This would help achieve the goals of the EbA project, namely to enhance the resilience of PMER ecosystems and services in order to deal with climate change vulnerabilities. These types of interventions may enhance the quality of both ecosystems and their services and modulate the local climate. However, given the scale of the region and the limitations of data sets within the PMER, it has not been possible to establish a cause-impact relationship. Continuous efforts are needed to clarify the relationship.

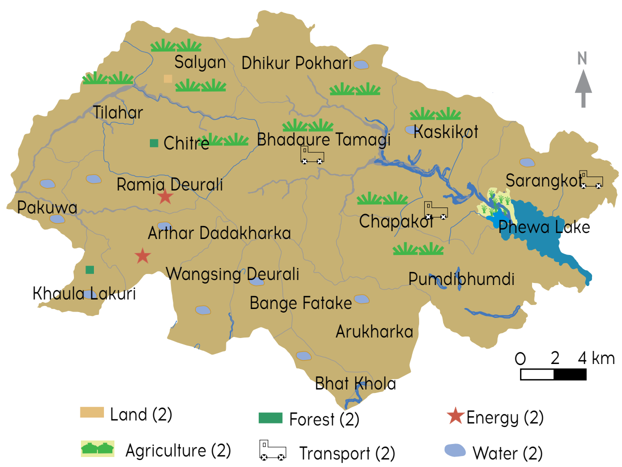
The first EbA options identified and located on the PMER map were based on one cycle of a repeated assessment process that categorized the wards and sub-watersheds. The options identified were expected to help pilot the EbA to improve national capacities to strengthen ecosystem resilience, in particular mountain ecosystems and to reduce the vulnerability of communities (UNDP 2011). Community forests, watershed conservation, biodiversity, landscape and local community institutions are important building blocks in achieving this goal. While identifying EbA options, this study sought to link these with ongoing national and local climate change-related programmes to avoid duplication and ensure the EbA complemented other efforts. Some trade-offs were involved as PMER stakeholders identified different benefits from the same ecosystem processes and individual choices often competed with the choices of others. During the initial SLDs, participants proposed, identified and ranked EbA options, prioritizing the top six shown in Figure 25 and listed in Table 20. Each option is expected to strengthen elements of core systems and should, therefore, enhance well-being.

The SLD process was useful but did not provide details about chosen options. Nor did it build on what the assessment process had revealed, namely that Andheri Khola was the most vulnerable watershed followed by the Orlang Khola. It would be logical to begin identifying options for building resilience in these two sub-watersheds and focus on the most vulnerable households or groups. For this reason, a second round of SLDs was held in both sub-watersheds to discuss earlier findings and identify EbA options. A similar process was undertaken in Harpan Khola because of its direct link to Phewa Lake. The process will be replicated in the remaining sub-watersheds. This will bring together all stakeholders trying to reduce vulnerabilities and build resilience in the PMER. It would dovetail the EbA options into both planned and autonomous adaptation measures in the PMER and complement ongoing works such as the Hariyo Ban which is funded by the United States Agency for International Development (USAID) and implemented by the World Wildlife Fund for Nature, CARE-Nepal, National Trust for Nature Conservation and Federation of Community Forest Users Nepal (FECOFUN). Another example is the PPF being implemented by Nepal's Regional Forest Directorate in collaboration with the district forest offices in Kaski, Parbat and Syangja districts. Care must be taken to avoid previous oversights: implementing adaptation and resilience building efforts should not lead to fragmentation and poor coordination.

TABLE 20 | List of EbA options identified

S. No.	Options	Number of responses by clusters/types
1	Conserving existing drinking water sources together with rehabilitation of infrastructure and improvement of management to enhance resilience of existing drinking water and irrigation systems.	12
2	Improving agriculture production through crop diversification, off-season and climate-smart crop production system.	9
3	Conserving and managing forest, biodiversity and wildlife with the objective of improving livelihoods and reduction in people-wildlife disputes.	2
4	Rehabilitating and reclaiming degraded land and promoting measures to control landslide, soil erosion and similar forms of land degradation.	1
5	Building and rehabilitating roads with due consideration of changes in the local hydrology, especially surface drainage, likely from prevailing construction practices. As an alternative, promotion of technology and practices for climate resilient road-building, based on the lessons of green road was mentioned.	3
6	Promoting the use of clean, carbon-neutral energy sources and information and communication facilities.	2

FIGURE 25 Mapping of options identified



The implementation of EbA options can enhance ecosystem services in the PMER that support the functions and productivity of diverse sectors: agriculture (horticulture, floriculture and animal husbandry); water (wetlands, springs and rivers); forestry (NTFPs, biodiversity, rangeland and landscape); and local roads, trails and community-based systems. Undertaking EbA options will involve government, non-governmental and community-based organizations as well as the private sector and their managers. The lessons learned will benefit EbA stakeholders such as local communities, local government agencies, high-level government agencies, policy and decision makers, researchers, planners and academics, the private sector and civil society. Effective communication will promote a sense of local, regional and national ownership and support successful implementation of the EbA. This effort will also help clarify confusion over the difference between EbA and community-based adaptation by projecting EbA as part of a broader adaption strategy and by implementing EbA options through community-based approaches.

Over 80 per cent of Nepal's population of 27 million depends upon agriculture and paddy is the major crop.

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Lake in PMER has high insitue value


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Landscape and diverse vegegation

CHAPTER VI

KEY INSIGHTS

This study used a systematic approach to assess vulnerability to climate change impacts in the PMER. It generated the following insights:

Climate system

1. The PMER faces temperature rises and unpredictable changes in the character of precipitation.
2. These changes may alter the behaviour of the region's ecological systems, putting severe stress on some species when their tolerance thresholds are surpassed and may become endangered. The cycle of change triggered would follow an adaptive cycle broadly characterized by loss of resilience and reorganization. Holling's four-stage model of ecosystem dynamics–growth, conservation, disturbance and reorganization (1986)–might help explain ecosystem behavior in the PMER.
3. The incidence of thunderstorms is increasing in some VDCs in the PMER, including Pumdibhumdi, Sarangkot and Dhikur Pokhari. The incidence of hailstorms in the Harpan Khola sub-watershed has also increased, damaging food crops such as paddy, wheat, maize, millet and vegetables every year.
4. There is no natural disaster early warning system in the PMER. A few VDC residents are trained to use early warning systems but they lack access to such systems.
5. The many PMER microclimates, which support diverse vegetation, are important for implementing the EbA. The relationship between climate events and their effects in the PMER is neither linear nor clear because many factors operate simultaneously. Such interdependence makes it difficult to differentiate between cause and impact, especially because the local impact of climate change cannot be directly linked to global change processes. The existence of multiple variables also gives rise to differing worldviews, behaviour interests and strategies for dealing with impacts and vulnerabilities. Every element of this complex ecological region needs to be unpacked if EbA strategies are to succeed.
6. Developing a climate scenario involves four basic elements: collection of base-line data, its assimilation into a forecasting model, projecting the base-line state into the future and the application of the forecasts to real-

world situations (Du 2007). Uncertainties are introduced during each step, including instrumental and human errors when data is collected. When the real world is reproduced in mathematical models, errors are introduced by assumptions, discontinuity of data sets, mathematical limitations and approximations. Different interpretations by forecasters and users further accentuate these uncertainties, especially when data is deficient and PMER societies face rapid social and political changes.

Biophysical systems

7. A variety of invasive species, mainly *Eupatorium adenophorum, Ageratum houstonianumaa, Gleichenia gigantea, Rubus ellipticus* and *Biden spilosa* flourish in the PMER. Local grassland species are threatened by both natural and anthropogenic risks, such as landslides, floods and erosion as well as development activities, overgrazing, fire and encroachment (Sharma and others 2013).
8. Extreme rainfall, hailstorms, drought and changing wind patterns as well as various kinds of diseases, insects and pests cause damage to crops. Farmers identify four main problems: the lack of reliable irrigation, acidic soil, difficulty in obtaining fertilizer and the lack of agricultural implements.
9. Water is a crucial PMER component with a high *in situ* value. It provides services and contributes to the microclimate of both the PMER as well as the region outside it, although to a lesser extent. The Harpan Khola illustrates this. The spatial and temporal interaction within the local hydrological system is complex: pressure exerted at any one place or point in time in the system will cascade through it. Any cascading in future will affect all three spatial scales of the ecosystem functioning-the PPF, the buffer zone and the outer region which is dependent on the ecosystem services from the PMER.
10. Springs, rivers, lakes, ponds and wetlands meet local water demands used for drinking, bathing, household cleaning and livestock feeding. But few PMER inhabitants purify drinking water with potassium permanganate, SODIS or by boiling and filtering. Improving awareness and changing behaviour will bring health benefits and enhance adaptation capacity.
11. The PMER aquatic ecosystem comprises deep and shallow water bodies and the wetland system includes swamps and marshlands along the floodplains of the streams draining the PMER. Most wetlands have been converted into paddy fields or are open grazing areas. A few small patches of grassland are privately owned (IUCN 2013).
12. Immature trees are cut indiscriminately by locals, ignoring dead, fallen, malformed and diseased trees. The young shoots and leaves of orchids are used as cattle fodder and uncontrolled cattle grazing is a major threat to terrestrial orchids. A large number of fauna are at increasing risk because of illegal poaching.

Socio-cultural systems

13. The majority of PMER residents are agricultural workers but others are wage labourers, have government jobs or work in cottage industries. On average, local agricultural production meets the community food needs for only six months.
14. Agroforestry is an integral part of the local farming system. To control erosion, farmers practice minimum tillage and mulching, cover legume crops and level terraces. Crop diversification and intercropping are practiced to increase income and reduce risk. There is some commercial-scale agriculture and livestock production and a few farmers are using gully control measures. These activities are autonomous efforts to minimize the impact of erratic rainfall.
15. Preference for hybrid seeds may reduce the use of local seeds, which may disappear without preservation efforts.

16. Animal husbandry is an important source of livelihood in the PMER. Buffalo, cow and goat livestock rearing can be broadly categorized into commercial, semi-commercial and domestic. About 85 per cent of families raise livestock solely to meet household consumption needs of milk and meat and to produce farm manure. Livestock and its products play a key role in generating cash for households and providing food and helping maintain farm productivity. Some households also cultivate and sell vegetables.

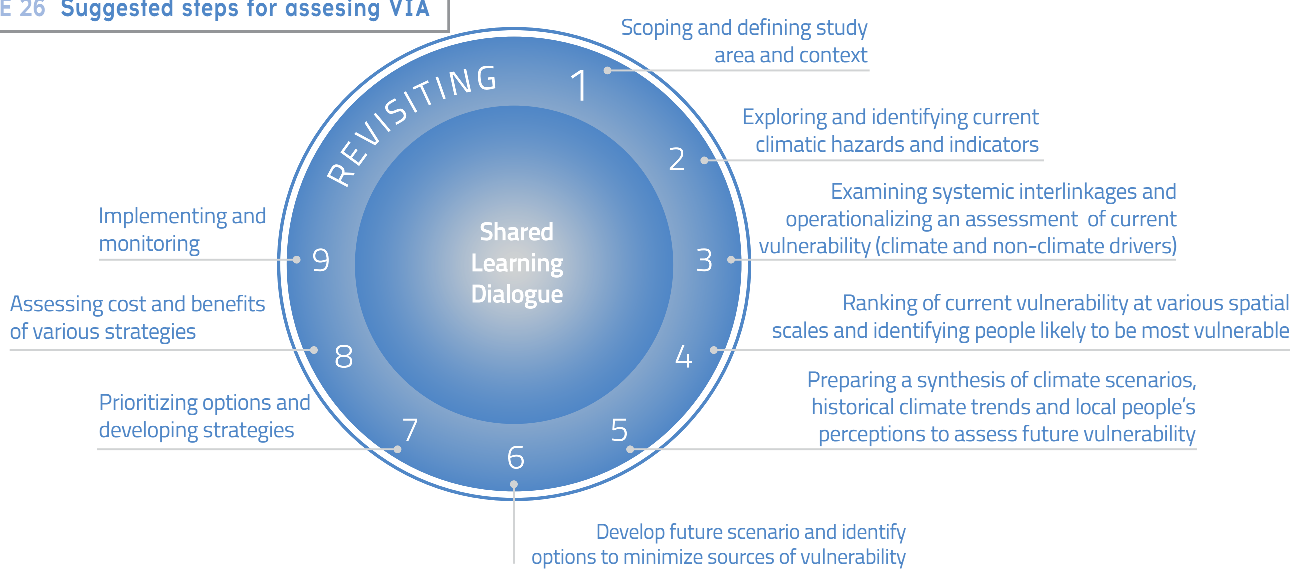
Vulnerability assessment

17. A VDC ward has different levels of vulnerability to climate hazards, depending on exposure, ecosystem condition, availability of local human built systems and the services they provide and local capacity to access these services and deal with external shocks. Institutions have an equally important role in determining the responses, which can be supportive or obstructive.
18. This assessment captures prevailing conditions, develops future scenarios and depicts the outputs in a GIS platform. The exercise created a base-line for envisioning future vulnerability. This method enabled consideration of different types of exposure, including forest fires, extreme rainfall, soil erosion and landslides.
19. The method proposed provides opportunities for iteration and assists in making decisions about strategies by providing evidence-based decision making. The method needs to be replicated and gaps and limitations identified. Those limitations should be addressed through adjustments and the method needs to be re-applied after adjustments.
20. It is not possible to differentiate climatic from socio-economic, political and other sources of vulnerability of local communities and ecosystems in the PMER either conceptually or in practice. For this reason, the proposed EbA strategy takes a holistic approach and aims to build capacity to respond to both climatic and non-climatic drivers of change.

Knowledge systems

21. Several PMER characteristics, including vegetation, erosion, landslides, watershed management and lake dynamics have been

FIGURE 26 Suggested steps for assesing VIA



studied, producing a wealth of information, but this has not been combined and clearly reviewed for any insights into how these could support EbA.

22. The inhabitants of the PMER have access to forests as well as grazing and other common land, meaning that they also have access to ecosystem products such as fuel, fodder and water. The services these ecosystems provide contribute to household and community economies but as the quality of ecosystems decline, access to their services will become more limited. Dependent households will find themselves deprived of resources and, as a result will become increasingly more vulnerable.
23. There is limited knowledge about the interdependence between PMER ecosystem characteristics and its climate because there are very few monitoring stations in the region and very little local-level data specifically monitoring the impact of climate on different vegetative species. The local and scientific knowledge necessary for designing, implementing and monitoring EbA interventions is not yet developed.
24. Phewa Lake faces multiple threats, including those from a warming climate. Efforts to minimize these threats and improve the quality of the lake have so far not produced desired results.
25. The PMER and communities within it are vulnerable to different types of shocks and pressures – both climatic and non-climatic. This requires generation of knowledge from continuous dialogue between climate scientists, development practitioners, local communities and professionals involved in the design and management of EbA strategies.

Stock and flows

26. PMER ecosystem services are available at three spatial scales, namely the PPF, the buffer zone and the outer region that is dependent on its goods and services (mostly those provided by Harpan Khola). The integrity of the PMER ecosystem is crucial for the well-being of these three areas.
27. A number of organizations are involved in PMER ecosystem management. These include state organizations as well as national and local NGOs involved in the management of natural resources excluding wetlands and water bodies such as ponds. State agencies mostly involved in agricultural, forest, wetland and water body management are implementing policies, regulating and managing resources, providing technical support and coordinating provision of services at the local, district and regional level. A few NGOs are involved in the management of livestock and pastureland ecosystems. Very few local organizations are involved in the management of wetland and water body ecosystems.

Local infrastructure

28. The road network linking PMER settlements is being expanded. Roads promote mobility between the residence and place of work, thereby helping people overcome challenges such as floods that climate change and other stressors impose. Roads also improve access to open markets. Road construction is haphazard and because there is minimal regard for local ecosystems (IUCN 2013), can have a highly negative environmental impact, including on surface and groundwater systems. In many areas, discharge from springs is being depleted this.

CHAPTER VII

RECOMMENDATIONS

The lessons learned from implementing the EbA in the PMER will be useful for shaping climate change policies and practices by providing local evidence of their success or failure. The following recommendations can help develop a knowledge base for policy making.

Systemic perspective: A systemic view of the ecosystem and its services and the links between its functions and human and social behavior is needed to maintain the health and balance of the PMER's integrity. In Nepal, public policies related to ecosystem management should be the starting point for identifying approaches to stabilizing ecosystems and the services they generate and building resilience. A range of interventions are needed to support community capacity-building, develop disaster risk reduction strategies, spread risks through financial or other mechanisms and provide alternative livelihoods that support adaptation. Community and household measures, both autonomous and planned, can help achieve objectives that support sustainable, targeted interventions and build healthier ecosystems and more resilient communities.

Capacity-building: The success of efforts to improve the adaptive capacity of the sectors and stakeholders involved in EbA depends on the maintenance of key ecosystems and their services. EbA strategies should be based on the principles of ecological integrity, good governance, community participation and ownership. These principles already underpin community forestry, drinking water management and community-based practices in Nepal. These ongoing community-based practices need to be strengthened to reduce the vulnerability of forest and agriculture-dependent ecosystems by minimizing human interference such as indiscriminate grazing and extraction of NTFPs and other products such as MAPs.

Knowledge base and synthesis: Local people have knowledge and experience of ecosystem response to endogenous and exogenous pressures through their practices. This information needs to be harnessed and supported by monitoring hydrological and other natural processes in the PMER. Systematic and continuous data on critical ecosystem characteristics and their services must be collected through innovative techniques (DST 2009). The following steps are recommended:

a. Species most at risk from a warming climate and other non-climatic changes need to be identified. Knowledge of PMER vegetation needs to be augmented by examining species at various altitudes. Local fauna and flora varieties should be promoted to foster biodiversity. This can be done partly by species documentation and preserving the gene pool. This will require close collaboration between botanists, foresters, hydrologists, climate change analysts and other professionals.

b. Climate stations, including rain gauges that monitor rainfall intensity, must be installed in the PMER and surrounding areas. To capture micro-scale characteristics of climate information, stations should be installed in different zones of the PMER. As these zones vary by elevation, an altitude-based criterion should be adopted, as well as deciding whether these are located on the windward side of a hill slope or the rain shadow face of the sub-watershed. These stations should measure multiple variables, including temperature, humidity, solar radiation and wind speed. Studies of watershed-scale run-off, erosion and sediment flow should be supported by a deeper analysis of lake dynamics, including sedimentation characteristics.

c. All measurements should be linked to an examination of the local vegetation response to climate change. Phewa Lake must be monitored annually to assess both climatic and non-climatic risks. Data on variables such as water inflow, volume, depth, quality (including oxygen content) and sedimentation rates need to be collected. Isotope methods should be used to assess the age of the lake, past and future hydrological scenarios, vertical mixing, stability and temperature response.

d. Monitoring should result in the determination of threshold values for parameters such as temperature and rainfall and the tolerance of vegetation species. These approaches must be guided by high-level scientific knowledge and linked to civic initiatives involving community groups in the monitoring of parameters such as rainfall, temperature and vegetation growth. The data should be used for an in-depth analysis of the interdependence of ecosystems and their services.

e. The data obtained from such assessments must be synthesized and made widely accessible so that the insights they provide can be communicated to stakeholders. The information can then be used to support action. All communication material must be based on local and scientific knowledge to promote better understanding of developing ecosystem resilience using EbA strategies.

f. Early warning systems are needed to prepare for both LPHI and HPLI climatic events. The former can have widespread impacts on ecosystems, their services and dependent communities while the latter expose ecosystems, their services and dependent communities to new vulnerabilities. Both events add to ecosystem insecurity. Early warning systems, transmitting of information on temperature, rainfall, pests and other risks, can enhance ecosystem resilience. Local radio stations can disseminate advance warnings.

Learning and innovation: The PMER can be a knowledge platform to develop and test EbA methodologies for a better understanding of the relationship between the changing climate and local ecosystems, particularly in mountain regions, and provide a basis for continuous learning. Lessons learned in the PMER should be used to promote regional and international collaboration for increasing knowledge about EbA. The method used for assessing vulnerability will need to be replicated and the gaps and limitations identified and overcome through adjustments. The process must be re-applied, further developed and updated.

Building resilience: PMER ecosystems are located within overlapping systems and if a component is disturbed and the energy input changes, the system can become unstable. It is, therefore, important to understand how these components are connected and recognize the thresholds at which these can no longer withstand climate and other changes that make them become vulnerable to collapse. The diversity and flexibility that enhances the resilience of ecological and human systems must be continuously promoted. Particular attention must be focused on developing resilience indicators for local transport and water drainage infrastructure such as roads, culverts, drainage systems and check dams. Bio-engineering measures can be beneficial.

Autonomous adaptation: For generations, the people of Nepal and the PMER inhabitants have autonomously adopted a variety of strategies to deal with biophysical and socio-economic constraints by utilizing niche ecosystem products and services (see Box 4) with some success. The key elements of these practices must be studied to formulate appropriate policies for an effective EbA. Policies to build resilience and adaptive capacity need to recognize autonomous adaptation and support local institutions and individuals to respond to new constraints that emerge as climate change accelerates. The policies must ensure that local people have access to financial, technical and information resources needed to initiate the response to climate change. It is important that EbA strategies augment local decision making capacities, diagnose problems and vulnerabilities and support learning and action. Efforts to enhance climate resilience and adaptive capacity through EbA must be twinned with capacity-building. When it comes to developing resilience, PMER residents are constrained by system fragility, service inaccessibility and social marginality.

Livelihood diversification: To enhance ecosystem resilience, interventions to manage natural resources should also be sources of income. At the same time, efforts must be made to create new employment for PMER residents by taking into account the influence of on going social and political changes. Access to alternate energy platforms can provide opportunities to meet local needs and create alternative livelihoods. PMER inhabitants are already seeking alternative livelihood opportunities outside the natural resource base through migration and other channels.

BOX 4: **Autonomous adaptation in Panchase**

The absence of a bridge over the Harpan Khola severely restricted the access of the residents of Chapakot VDC of Kaski District to the local market, VDC office and health post. Students found it difficult to go to school, as they had to wade across the river and carry an extra set of clothes.

To solve the problem, the 600 households of Chapakot raised about NRs 55 000 and agreed to contribute free labour to build a bridge over the river. The district administration office and VDC together contributed NRs 175 000. The resulting footbridge has made it easy to cross the river, even by motorcycle.

Policies to build resilience and adaptive capacity need to recognize and support local initiatives like this. Local populations must have access to the financial, technical and information resources they need so that they can implement such initiatives to promote their well-being. The capacity of local communities to make decisions, diagnose and document problems, and act upon learning, must be enhanced. Any effort to build climate resilience and adaptive capacity must be tailored to meet these objectives.

Adopted from www.ekantipur.com

Student crossing the newly built trail bridge

What lessons does this shift away from natural resource dependence offer for EbA? Further analysis is required to fully answer this question. Action at a national level requires government agencies to focus on improving the core and broader systems that serve as gateways to services. The government should ensure that local populations have access to key services such as drinking water, health, education, energy and communications. The service and industrial sectors should be developed to provide livelihood diversification opportunities, including through promotion of niche enterprises and high-value agriculture. Donor and funding agencies should allocate resources to promote transformative change that addresses the underlying sources of vulnerability.

Trade-offs and cross-cutting issues: Trade-offs are likely among alternative land uses (e.g. short term service delivery) that avoid harm and different types of ecosystem services based on stakeholders' needs, preferences and priorities at different geographical locations and points of time. EbA must consider cross-cutting themes, including knowledge management, local and national policies and regulations, gender, institutional constraints and governance. Emerging lessons from research on climate change adaptation suggest that the resilience of ecosystems relies on a healthy local ecosystem and diverse livelihoods, access to energy, banking and communication services, and information about weather and technology (Moench and Dixit 2004). Social networks and safety nets mitigate the negative impacts of a warming climate, in conjunction with diversity in agricultural systems and natural vegetation.

Institutions and incentives: While the PMER has both rural and urban areas, it is likely that the rural population will become more urbanized with increased transport links, private and public vehicles, mobile phones, Internet, education, access to modern communications and diversified and monetized livelihoods created by migrant remittances. These changes will have major implications for the incentives which different groups dependent on the ecosystem and its services, may (or may not) have to manage or pay for those services (DST 2009). EbA strategies need to recognize the changing socio-economic landscape and consider appropriate incentives for mediating competing demands for services and the pressures these exert on ecosystems. Strategies for implementing EbA should generate positive incentives and eliminate those that create negative externalities or mal-adaptation. Local communities must be empowered for effective implementation of EbA strategies: they must secure ecosystem tenure, develop organizational capacity and access new sources of financing. As livelihoods are diversified, mobility improves and communication expands. This will lead to new questions about the viability of community-based approaches that is the hallmark of natural resource management strategies in Nepal. EbA strategies need to address these questions and take measures that will effectively maintain the integrity of ecosystems.

Creatively engaging stakeholders: There are different perceptions about the effects of climate change on ecosystems, goods and services; likely vulnerability; and future environmental and livelihood challenges. Everyone involved in this study is aware of the nature and value of ecosystems, the need to conserve them and is willing to share the costs of preserving them in order to enjoy the benefits. The different perceptions about ecosystems and their services will, however, result in diverse responses and adaptation strategies. It is important to understand the links between different ecosystems and the services they generate and sources of vulnerabilities. To be effective, EbA activities should acknowledge perspectives of local communities, private enterprises, government agencies and donors. EbA strategies must recognize diverse perspectives; adopting a strategy based on a single perspective will not build resilience or adaptive capacity.

There are at least four perspectives to consider: government, private sector, community-based groups and farmers. Government agencies view ecosystems as resilient but only up to a point and believe that official experts should manage the adverse impact of climate change on ecosystem services. The private sector views ecosystems as being able to become resilient without external support. Community-based organizations and community groups view ecosystems as inherently unstable and highly vulnerable and needing to be handled with sensitivity. Farmers view ecosystems as unpredictable and subject to random changes.

These four perspectives emerge from a number of factors such as where an agent is located in the ecological landscape, his or her view of nature (Douglas 1992) and his or her perception of risks. Creatively engaging stakeholders ensures that all perspectives are taken into consideration. This type of engagement is imperative for implementing EbA in the PMER; a successful strategy is dependent upon the recognition of all perspectives and public engagement with different stakeholders. Promoting creative discourse about EbA strategies ensures that all stakeholders will have some incentive for buying into the strategy because it will serve some of their interests.

EbA platform: Since both the spatial and the socio-economic dimensions of the ecosystems and services in the PMER must be considered, it is essential to increase the understanding of how ecosystems span different VDCs, users' groups and districts. This understanding will help identify both constraints and opportunities. For example, whether floodplains in the Harpan Khola sub-watershed, especially along its banks, can be restored to minimize floods, erosion and sedimentation and sustain water flow into the lake, will depend on how the upper catchments are managed and improved. To a certain degree, the ecosystem services of Phewa Lake depend on how well the Harpan Khola sub-watershed is maintained.

Responses to reduce vulnerability and maintain the integrity of the PMER must create opportunities for continuous engagement with different stakeholders. Communities in the PMER; those living near Phewa Lake, including the hotels and restaurants that serve the tourist market; enterprises that provide recreational services; those responsible for maintenance of religious sites; national and local government agencies; and donors-all need to come together to maintain the health of the PMER. The EbA strategy must consider all embedded systems and stakeholders through the establishment of a multi stakeholder platform that emphasizes how the strategies will support lives and livelihoods and promote the well-being of PMER communities.

The EbA platform must foster collaboration among government agencies, the private sector, civil society actors and donors with the objective of pooling resources, knowledge and skills for responding to the common challenge of maintaining the ecosystem integrity of the PMER. The platform needs to pursue a shared vision and maintain dialogue in order to promote a charter for sustaining the integrity of the PMER. Stakeholders who pursue their own interests, will adopt different approaches to achieving the shared goal of preserving the PMER. With discussion, it will be possible to devise a strategy that meets at least some of the collective interests. This approach will need to be sustained over time to help realize the transformative potential of communication, information, innovative technologies and knowledge, to maintain the integrity of the PMER and thereby improve the well-being of PMER residents and their capacity to deal with external shocks, including those associated with climate change. The aim of a platform like this is not about creating a consensus on values, meanings and strategies, but about creating a forum that promotes mutual respect, legitimacy and gives credibility to diverse interests and perspectives.[25]

Harvesting of knowledge: The fragmented knowledge about PMER ecosystems needs to be collated and used to design a strategy for maintaining the integrity of the PMER while building resilience and adaptive capacity. Future research must build on these insights and be focused and targeted. Graduate students need guidance in developing suitable hypotheses and in conducting research on different aspects of ecosystem stability, climate science, adaption, resilience thinking and strategies to deal with increasing climate related uncertainty in Nepal generally and in the PMER specifically. Research-based knowledge must be made available to all stakeholders (DST 2009).

Mainstreaming EbA: The EbA should be mainstreamed into the local planning process. It can be linked with land use and biodiversity conservation planning by integrating climate change risks and adaptation approaches. EbA-influenced strategies should focus on conserving and restoring natural habitats, protecting ecosystem hotspots and key species, rehabilitating and protecting aquatic resources, promoting climate-smart farming practices and establishing early warning systems. They should also develop a mechanism that fosters the continual improvement of management policies and practices by promoting learning from outcomes. In addition to building synergy with the programmes mentioned above, the EbA process needs to link to other programmes, such as the Nepal Climate Change Support Program (NCCSP), which operationalizes CRF-based LAPA framework (Regmi and Karki 2010, Dixit and others 2011, GoN 2011, Chaudhury and others 2014). The process must place the well-being of PMER residents at its centre and ensure that they are beneficiaries as well as custodians of efforts to ensure the integrity of the ecosystems. In Nepal, there are many precedents for such processes: dependent communities have been entrusted with environmental stewardship, particularly in the management of community forests and the buffer zones of protected areas.

BOX 5: **Ecosystems that are better abe to accommodate change**

Often, characteristics that are the opposite of what makes systems vulnerable to change, might make certain species, communities, and ecosystems more accommodating to change. Ecosystems better able to accommodate change include the following:

- Species that are currently increasing
- Species with a wider ecological range of tolerances
- Species with greater genetic diversity
- Species and ecosystems adapted to disturbances
- Species and ecosystems adapted to warmer, drier climates
- Species in the middle or northern extent of their range
- Diverse communities and species
- Habitats within larger, contiguous blocks

The above characteristics can help in designing EbA measures.

Source: Chris and others (2011)

CHAPTER VIII

CONCLUDING COMMENTS

Climate change is a complex problem that cuts across sectors and disciplines. The impacts also span administrative and political boundaries. Climate change impacts will make poor and marginalized people even more vulnerable and marginalized. It is certain that the warming climate threatens the ability of ecosystems to provide basic food, water, energy and livelihood services. Because the interaction among climate change, ecosystems and society is complex and cannot be explained precisely, it is difficult to define the direction and magnitude of the local impacts of climate change. Reducing vulnerability to climate change, whether using EbA or another approach requires innovative and holistic thinking.

To build resilience and adaptive capacity to climatic and other threats, it is necessary to recognize that various conceptual frameworks have been proposed to assess vulnerability and they do not give the same results. Vulnerability assessment should not attempt to achieve high-level precision as no method can capture vulnerability in its entirety (Patt and others 2011). To overcome this limitation, vulnerability assessment processes must be carried out in the domain of policy analysis, where assumptions and gaps are made transparent, discussed, debated and revised. Analysts and policy-makers at different levels of the government and those engaged in different professional activities need to recognize that every school of thought (vulnerability, resilience, adaptation, development, ecology, gender, social inclusion etc.) has its limitations and they should, therefore, remain open to revisions in the analysis as climate hazards and socio-political contexts change.

The EbA strategy developed in this study can be replicated across Nepal and elsewhere to enhance resilience and adaptive capacity to climate change-induced vulnerabilities. Drawing upon results in rural and urban regions in several countries of Asia, including Nepal, the strategy reconciles different schools of thought, recognizes the role of both climatic and non-climatic drivers and proposes a methodology for incorporating future climate scenarios, envisioning new risks and identifying measures to minimize them. The strategy is consistent with a community-based approach to management of forests, drinking water and sanitation systems and community electricity distribution that are already being practised in Nepal. These strategies have yielded procedural and substantive gains. The former include democratic deliberation, civic engagement, capacity-building and local institutional development. Substantive gains include maintenance of livelihood opportunities, effective service delivery using systems, and contribution to ecological restoration.[26] An important element of this approach is in how it creates space for dialogue among analysts, local communities and decision-makers at different levels. This kind of dialogue will remain a cornerstone for designing strategies to minimize climate change-induced vulnerabilities.

Community-based resource management practices in Nepal recognize the importance of obtaining benefits from natural resources in a sustainable manner. This makes these practices a useful entry point for EbA. Climate change induced vulnerabilities and risks will exert stresses on natural ecosystems and their services with implications for individual livelihoods and the well-being of households and communities. EbA will be an effective strategy to maintain ecosystems and the services they produce. When conceived as a holistic and continuous process that allows dialogue among practitioners, decision-makers and the local community, the approach has the potential to decrease climate change-induced risks and assist in the pursuit of development. In the process, EbA strategies will help integrate ecological, social and economic goals.

NOTES

1 According to LPR (2014) "Wildlife populations have dropped sharply, by 52 per cent between 1970 and 2010, especially freshwater vertebrate species, which declined 76 per cent".

2 This discussion is based on Lovins and others (2008).

3 According to CBS (2011) about two-thirds of Nepal's population of 27 million (about 17 million) are dependent on the use of natural resources.

4 Panchase Mountain Ecological Region (PMER) is the only officially declared protected area in the Mid Mountains; all other protected areas are either in the High Mountains or in the Tarai.

5 In the 1970s it was estimated that Nepal had 35 forest types, 5,833 flowering plant species, 185 mammal species, 847 bird species, 645 butterfly species and 170 fish species (Stainton 1972). More recently, Bhuju and others (2007) reported that there were 635 butterfly species (4.2 per cent of the global total), 185 freshwater fish species (2.2 per cent), 43 amphibian species (11 per cent), 100 reptile species (1.5 per cent), 860 bird species (8.5 per cent) and 181 mammal species (4.2 per cent).

6 For a discussion, see Bromley (1989).

7 The principle of equity in strategies for adaptation to climate change should aim to reach the most vulnerable. Nepal's climate change policy, for example, suggests that 80 per cent of the financial resources available to the country to tackle climate change will be allocated to the most vulnerable population. To meet these objectives, we need to learn from the country's natural resource management practices such as community forestry. For a discussion on the dynamics of Nepal's community forestry see Nightingale (2003), Ojha and others (2009) and Koirala and Wiersum (2013).

8 The mining and quarrying of sand and stones is one example. The governance of these resources includes a variety of government and non-government agencies working in the PMER, including the Regional Forest and Agriculture Directorate, district forest offices (DFOs), ranger posts, district agricultural development offices (DADOs), DADO service centers, DADO Contact Center ("Samparka Kendra"), district livestock service offices (DLSOs), DLSO service centers and DLSO sub-service centers, UNDP, IUCN, UNEP, Rural Water Supply and Sanitation Project in Western Nepal (RWSSPN) [Syangja and Parbat districts] and USAID. In varying degrees, all are involved in forest, agriculture and wetland and drinking water management in the PMER as well as planning, monitoring, providing financial and technical support and developing. Developing what? Is this sentence incomplete?

9 These are broad anecdotal trends in the PMER. For further detail, refer to MDO (2012) and Sharma and others (2013).

10 Some of these species are locally called Kande, Saur, Rewa, Suire and Fageta (Regmi and others 2009).

11 VDC is Nepal's lowest level administrative and political unit.

12 "Khola" means "river" in Nepali and is commonly used in place of river, even in English.

13 Available secondary sources give different values for the lower elevation of the PMER. According to the website of Forestry Nepal, it is 1,450 m above sea level, but a report by the Department of Forest gives 900 m as the lowest elevation. The difference may be attributable to differences in designating the elevation band between PMER and the PPF. The lower boundary of PPF is at a higher elevation than that of the PMER, which lies between 742 m and 2,581 m above sea level.

14 In this report data was analyzed from 11 stations as shown in Figure 4.

15 The rainfall was recorded by DHM in 2013.

16 Assuming the specific gravity of sediment is 2.5.

17 Measured at station close to the confluence of the Aandhi Khola with Kali Gandaki River.

18 IUCN has developed threat categories for species as follows: Extinct (Ex), Endangered (E), Vulnerable (V), Rare (R), Indeterminate (I), Insufficiently Known (K), Threatened (T) and Commercially Threatened (CT). Information about the total number of plant species in the PMER is not available although IUCN has published details on 237 plant species in Bhadaure Tamagi VDC. Of these, 33 are endangered (E). MDO (2010) reports 30 orchid species as endangered. Tree fern (Cyathea spinulosa), and aconite (Aconitum ferox), locally known as bish are endangered (IUCN 2013). The Nepalese hog plum (Choero spondiasaxillaris) or lapsi, is considered rare (R).

19 MDO (2012) cites this study by Lamichhane.

20 Governance includes activities of government and non-government agencies working in the PMER. See footnote 8 above for a partial list of those agencies.

21 These trends are seen in the PMER but evidence is only anecdotal. For details, refer to MDO (2012) and Sharma and others (2013).

22 A similar analysis by German Watch suggests that Nepal is highly vulnerable to climate-induced disasters. See Harmeling and Eckstein (2012) for details.

23 Decision makers could decide on the frequency of this type of assessment. We suggest once every two years.

24 The PPF is also called the Panchase Conservation Area (PCA).

25 Shannon (1987).

26 The idea of procedural and substantive gains is based on Ojha and others (2009).

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