ICIMOD Working Paper 2019/5

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The socioecological system of Parsa National Park: Insights for an adaptive management using the ecosystem approach

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ICIMOD gratefully acknowledges the support of its core donors: the Governments of Afghanistan, Australia, Austria, Bangladesh, Bhutan, China, India, Myanmar, Nepal, Norway, Pakistan, Sweden, and Switzerland.

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The socioecological system of Parsa National Park: Insights for an adaptive management using the ecosystem approach

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International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, September 2019

Published by
International Centre for Integrated Mountain Development (ICIMOD)
GPO Box 3226, Kathmandu, Nepal

ISBN 978 92 9115 621 4 (electronic)

Production team
Shanuj VC (Consultant editor)
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Dharma R Maharjan (Graphic designer)

Photos: Jitendra Bajracharya: Cover; Luzmila Mercedes Rosales Richard: All others

This publication is available in electronic form at www.icimod.org/himaldoc

Citation:
Rosales-Richard, L. M., Bhattarai, N., Karky, B. S., Bhattarai G. P., Ram, A. K. & Windhorst, K. (2019). *The socioecological system of Parsa National Park: Insights for an adaptive management using the ecosystem approach*. ICIMOD Working Paper 2019/5. Kathmandu: ICIMOD.

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Acknowledgements

This research was developed in the framework of the REDD+ Initiative of GIZ/ICIMOD. We want to express our thanks to the REDD+ Initiative team for their comments and discussions on the preliminary findings of the research. In addition, we gratefully acknowledge Shashank Poudel from NTNC, without whose support this work would never have been possible. Finally, we express our sincere gratitude to all the participants from DNPWC, PNP, RCMP, NTNC, ZSL, WWF-Nepal, BZUCs, and FECOFUN for attending the interviews and the workshop in Parsa; they were extremely liberal with their time, patience, and valuable contributions.

Abbreviations and acronyms

BZCF	Buffer Zone Community Forest
BZUC	Buffer Zone User Committee
CICES	Common International Classification of Ecosystem Services
CNP	Chitwan National Park
DEPROSC	Development Project Service Center
DNPWC	Department of National Parks and Wildlife Conservation
DoFSC	Department of Forests and Soil Conservation
DoR	Department of Roads
EDA	Ecosystem Diagnostic Analysis
EWH	East-West Highway
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
HN	Himalayan Nature
ICIMOD	International Centre for Integrated Mountain Development
IUCN	International Union for Conservation of Nature
MAB	Man and the Biosphere Programme
MARISCO	Adaptive MAnagement of vulnerability and RISk at COnservation sites
MoFE	Ministry of Forests and Environment
NRCTC-N	Natural Resource Conflict Transformation Center-Nepal
NTNC	National Trust for Nature Conservation
OECD	Organisation for Economic Cooperation and Development
PA	Protected Area
PNP	Parsa National Park
PWR	Parsa Wildlife Researve
RCMP	Rastrapati Chure-Madhesh Programme
RCTMDDC	Rastrapati Chure Terai Madhesh Conservation and Development Committee
REDD IC	REDD Implementation Centre
REDD+	Reducing Emissions from Deforestation and Forest Degradation in Developing Countries
SES	Socioecological System
SNV	Netherlands Development Organisation
TAL	Terai Arc Landscape
VTR	Valmiki Tiger Reserve
WWF	World Wildlife Fund for Nature
ZSL	Zoological Society of London

Executive summary

Protected areas (PAs) are extensively used as one of the most important strategies for biodiversity conservation. They can contribute to maintaining or recovering biophysical structures, processes and functions of the ecosystems within the PA and even around it. However, the management of most PAs is facing a growing set of challenges due to climate change, unsustainable use of resources, and other socio-economic perturbations, especially in the surrounding landscape of the PAs. Therefore, it is crucial that the PA´s management know and understand the non-linear relationships and feedback loops affecting the socioecological system (SES) in which the PA is embedded.

This research selected Parsa National Park (PNP) in Nepal as a case study to analyse its SES, using the ecosystem approach. PNP, whose status has recently been changed from a wildlife reserve to a national park, is one of the 20 protected areas in Nepal and is located in the intersection of the Tarai and Siwalik physiographic zones. It has a very important socioecological role in facilitating the connectedness of different ecosystems – it enables the mobility of wild animals across these two zones – as well as in providing many ecosystem services such as the provision of non-timber products, carbon sequestration, control of erosion rates, buffering and attenuation of mass flows, micro and regional climate regulation, and water flow maintenance, among others.

The purpose of the study was to develop a systemic analysis which includes visualizing and describing the SES in order to identify the key elements, patterns, trends and complex relationships in the system and, based on that, to understand how the emergent properties of the system can arise and influence its sustainability. The method "adaptive MAnagement of vulnerability and RISk at COnservation sites" (MARISCO) framed the methodology that was applied. It included a systematic literature review of secondary sources, semi-structured interviews, and a validation workshop with the stakeholders.

This study confirms that PNP is clearly embedded in an SES which goes beyond the administrative boundaries of the PA. The interdependence and complexity of the relationships identified within the SES and with the surroundings suggest that cross-scale and multilevel perspectives need to be included in the PA´s management paradigm. The study has also identified that the main ecological dynamics that have been affected are those related to the hydrological system and the connectedness of the landscape. Even though climate change is altering precipitation and temperature patterns, the main drivers affecting the system dynamics are mainly attributable to human activities. This creates a set of challenges for transforming the development pathways in Nepal towards a more sustainable model. The results show the need to promote adaptive governance in order to frame the implementation of an adaptive management programme in PNP; this includes adopting a participatory approach whereby the ecological knowledge of the local population is taken into account, and also by promoting a culture of shared learning.

The present study lays the groundwork for future research to improve the understanding of the dynamics of the SES of PNP, to incorporate the ecosystem approach into PNP´s management, and even to scale it up to the entire landscape. Taken together, these findings have significant implications for the understanding of how the SES of a PA influences its sustainability in the short, medium and long terms.

Introduction

The Anthropocene is mainly characterized by human population growth and an increasing demand for land, infrastructure, and food production (Steffen, Crutzen, & McNeill, 2007). The emergence and the rapid development of human systems ("anthroposystem") have both influenced and altered the forces and patterns of ecosystems at the local, regional and global scales (Ibisch, Hobson, & Vega, 2010, p.20; Ibisch & Hobson, 2012, p.16). The last Fourth Global Biodiversity Outlook shows that despite some progress being made towards achieving the Aichi Biodiversity Targets, it is not sufficient to fulfil the targets set for 2020 (SCBD, 2014). Considering this context, PAs are one of the most important strategies for biodiversity conservation (Cumming, 2016, p.2) because, compared to other managed ecosystems, the PAs can offer some advantages such as "recognition (often legal); long-term commitment to protection; agreed management and governance approaches; and management planning and capacity" (eds Dudley et al., 2010, p.25). Simultaneously, the PAs contribute to maintaining or recovering the biophysical structures, processes and functions in the ecosystems which offer services such as providing food, clean water, medicines, protection from the impacts of natural disasters, and opportunities for ecotourism, among others (IUCN, 2016, p.9). Therefore, the PAs also support the livelihoods of local communities who, in many cases, are heavily dependent on them (Bhatta, Koh, & Chun 2010, p.157).

However, the PAs´ management is facing a growing set of challenges due to climate change, unsustainable use of resources and other socio-economic perturbations, especially in the surrounding landscape of the PAs. In fact, despite efforts to integrate the PAs into a wider landscape, most of these areas are still managed as islands within a degraded territory (Palomo et al., 2014, p.181). In addition, many of the PAs exhibit some weaknesses in their management, especially regarding community benefit programmes, availability of financial and human resources, and management effectiveness evaluation (Leverington et al., 2010, p.685). This shows the necessity to move away from traditional solutions towards solving cause-effect problems, and developing strategies that attempt to address the complex issues of non-linear relationships and the feedback loops associated with human disturbances (Ibisch & Hobson, 2014).

Nepal has an enormous wealth of biological and cultural diversity (Bhatta et al., 2010, p.157). Formal conservation started in the country in 1973 through the establishment of wildlife reserves and national parks (Shrestha et al., 2010, p.283). Currently, according to the Department of National Parks and Wildlife Conservation (DNPWC, 2017), Nepal has 20 PAs, including 12 National Parks, 1 Wildlife Reserve, 6 Conservation Areas, and 1 Hunting Reserve; it covers 80 of the 118 ecosystems that have been identified in the country. However, Bhatta et al., (2010, p.182) point out that the PAs in Nepal are dealing with various constraints on social mobilization, local access to natural resources, and institutional arrangements. Likewise, Shrestha et al., (2010, pp. 282, 292) argue that the location of conservation sites in Nepal has mostly been chosen for socio-economic and aesthetic reasons, instead of biological ones; thus, some geophysical and biological features are not adequately represented.

Parsa National Park is part of a big natural corridor in the intersection of the Tarai and Siwalik physiographic zones in Nepal. In 2015, its status was upgraded from a wildlife reserve to a national park. PNP has a very important socioecological role. On the one hand, it allows for the connectedness of different ecosystems, thus ensuring the mobility of wild animals; on the other, the forest ecosystems provide many services, such as the provision of non-timber products, carbon sequestration, control of erosion rates, buffering and attenuation of mass flows, micro and regional climate regulation, and water flow maintenance. These ecosystem services contribute to human well-being, providing the basis for livelihoods of the people living in the buffer zone and around it. However, as will be explained in this document, PNP – like other PAs in Nepal – is dealing with many challenges such as people–park and human–wildlife conflicts; as well as several threats like deforestation and habitat degradation, the presence of invasive species, encroachments, unplanned infrastructure, and logging.

Considering the social and ecological relevance of PNP and the challenges it is facing, the research "Situation Analysis of Parsa National Park (foremerly-Parsa Wildlife Reserve) and its buffer zone, based on the development of a systemic conceptual model" was developed as part of the Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (REDD+) Initiative of the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and the International Centre for Integrated Mountain Development (ICIMOD).

This working paper presents the findings of the research using the MARISCO method as the tool for analysis. These findings are focused on the dynamics and relationships between the ecological and social systems within which PNP is embedded. They were developed based on literature review, interviews, and a validation workshop with the stakeholders.

First, an Ecosystem Diagnostic Analysis was developed to get a comprehensive understanding of the state of health of the ecosystems and to identify human-related impacts. This diagnostic analysis was made by assessing landscape patterns and the behaviour and distribution of its inhabitant species. Then, based on that information, a conceptual model of the socioecological system of PNP was developed to analyse the dynamics and relations between the elements of the system. The results of the study can be an entry point to incorporate adaptive management practices into PA management and even to scale them up to the entire landscape.

Research rationale and objectives

During the last few years, due to the relevance of PAs in biodiversity conservation and the challenges they are facing in a more complex world, they have started being studied from the perspective of socioecological systems. Several existing frameworks provide theoretical guidance for the analysis of these SESs. One of those frameworks is the ecosystem approach, based on the systems theory and ecological research which have improved our understanding of ecosystems (Ibisch & Hobson, 2014, p.17). It means that PAs are part of nested structures which are in constant interaction, generating emergent properties and dynamics leading to a whole that is not equal to the sum of its parts (ibid.).

The ecosystem approach requires the development of "systems thinking" in order to establish an adaptive management paradigm. On the one hand, systems thinking provides "a language, questions, and techniques for thinking through the self-organizing aspects of the system" (Waltner-Toews, Kay, and Lister 2008, p.7); it implies an understanding of the source and role of transformational changes that are economic, ecological, social, and evolutionary, ranging from local to global scales (Gunderson & Holling 2002, p.99). On the other hand, adaptive management encourages systematic learning from errors in order to build more efficient and resilient systems; it is a new way of dealing with knowledge management (Ibisch & Hobson, 2014, p.30). However, for many of the organizations involved in the management of PAs, it is still a challenge to introduce new pathways to look at the whole picture, and they usually do not include social, cultural and political factors in their management practices.

Therefore, to apply the ecosystem approach in PA management, it is necessary to look through the lens of systems thinking (Waltner-Toews et al., 2008). It implies, first, to generate a description of the system and to identify the most relevant relationships which define the system (Waltner-Toews et al., 2008, p.12). As a next step, to develop a description of the dynamics of the situation and synthesize the understanding gained from the first two phases into scenarios describing how the situation could develop in the future (ibid.).

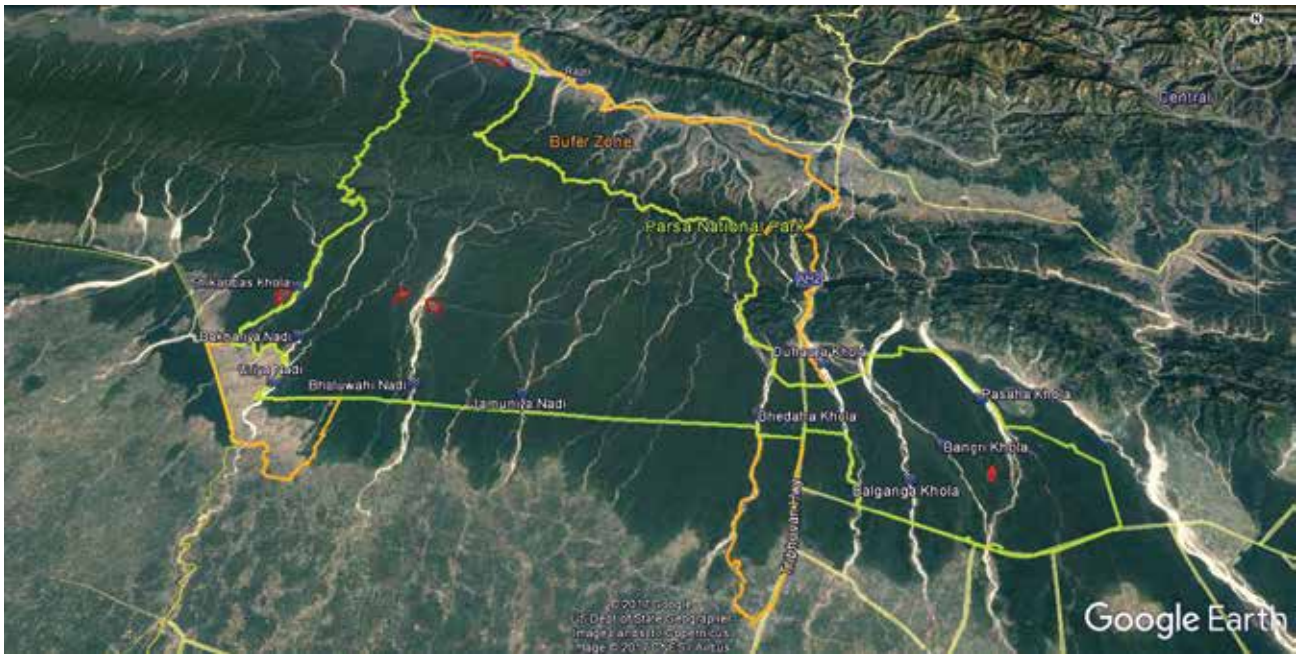
In this regard, the research objective was to develop a systemic analysis which included visualizing and describing the SES in order to identify the key elements, patterns, trends and complex relationships in the system and based on that, to understand how emergent properties can influence the system's sustainability. .

Considering that there has been no previous systemic research on PNP – only compartmentalized information – the research results analysed in this document can contribute to a better understanding of the socioecological system where the PA is embedded and help establish efficient adaptive management practices.

The study area: Parsa National Park

Parsa National Park (Figure 1) covers 627.39 km^2 of core area and 285.30 km^2 of buffer zone (DNPWC, 2017). It has an altitude between 88 and 837 masl (ICIMOD, 2017), and is located in south-central Nepal. Besides, it is part of the Tarai-Siwalik landscape which is dominated by tropical forests; at the same time, it is a densely populated area in Nepal. According to the new federal structure established by the Constitution of Nepal which was approved in 2015,[1] PNP is located within province 2, in the districts of Parsa and Bara, and province 3, in the district of Makwanpur.

Figure 1: **Parsa National Park and its buffer zone**



Source: Illustration based on the kmz file proportioned by ICIMOD, 2017

In the past, this area was a vacation site for the Rana rulers of the country (WWF-Nepal, 2014, p.7). Until the 1960s, the Tarai was mainly inhabited by indigenous ethnic groups, but after the eradication of malaria in that area, the Government of Nepal initiated a settlement programme promoting movement from the hills to the Tarai (Ghimire, 1992). The construction of the East–West Highway (EWH) in the early 1970s and the promise of new land also contributed to the migration processes (ibid.). This context created a complex society – multilingual, multireligious, multi-ethnic, and multicultural – comprising some indigenous groups and migrants from the hills of Nepal and from the Nepal–India border (Pravat & Humphreys, 2013, p.50). Some of the ethnic groups[2] which can be found in the buffer zone are Tharu, Musahar, Majhi, Magar, Gurung, and Dalit (Karki, 2017, pers. comm., 22 August). Over the last few decades, population growth in the Terai and the high demand for timber have adversely affected the quality and quantity of the Terai forests, resulting in the degradation and fragmentation of landscapes and also posing threats to both biodiversity conservation and local livelihoods (Gurung et al., 2015, p.2). To deal with this situation, the government established PAs in the 1970s and some sal (*Shorea robusta*) forest subsequently came under strict protection (Timilsina, Ross, & Heinen, 2007, p.224).

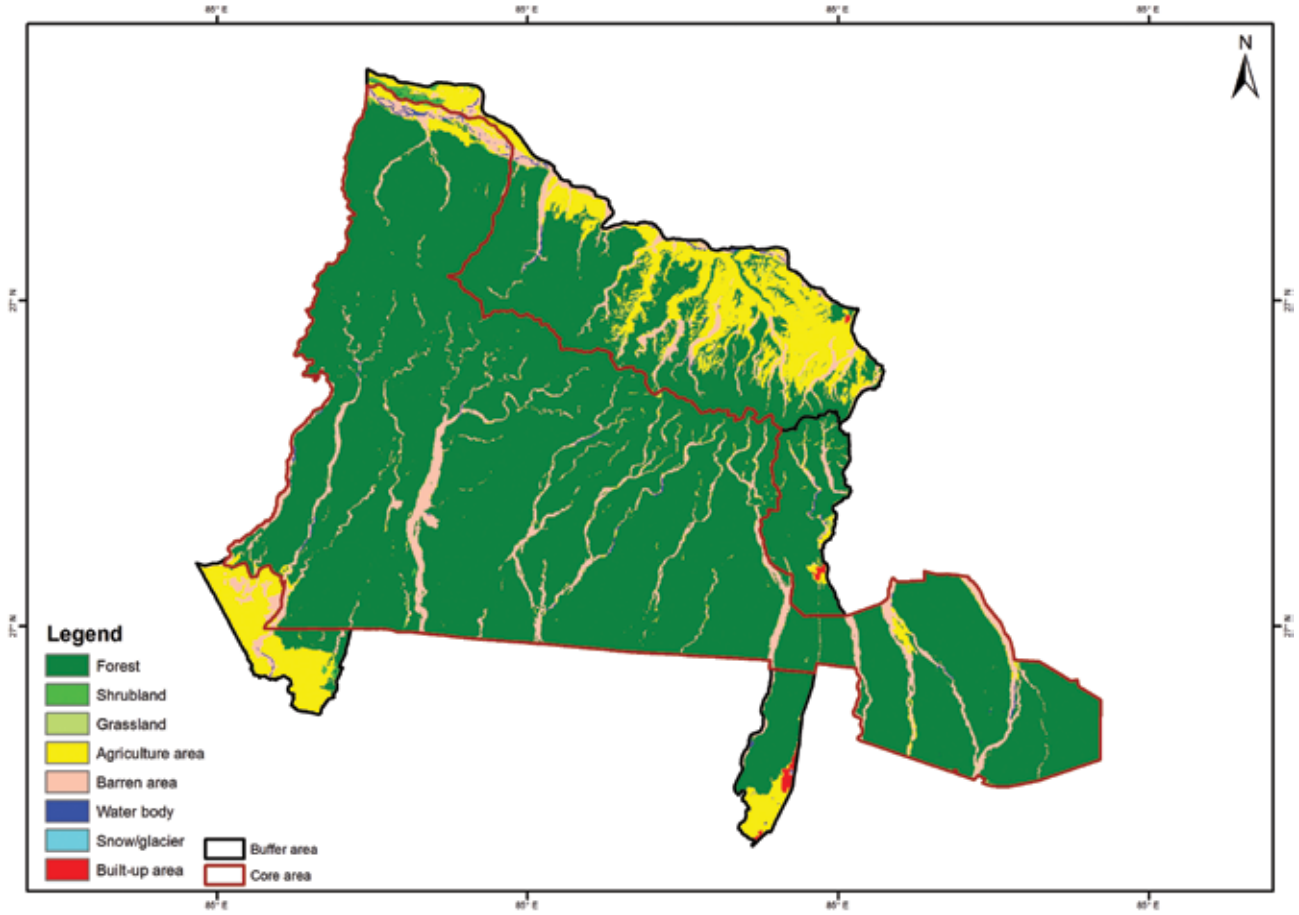
In 1984, PNP was gazetted as a wildlife reserve to preserve the habitat for the wild Asian elephant (Elephas maximus), tiger (*Panthera tigris*), gaur (*Bos gaurus*), and other fauna (Thapa, 2016, p.42). The buffer zone of Parsa Wildlife Reserve (PWR) of 285 km^2 was declared in 2004 and at the end of 2015, the core zone was extended

[1] Constitution of Nepal in English: http://www.lawcommission.gov.np/en/documents/2016/01/10272.pdf
[2] This list of ethnic groups was also validated during the workshop in Parsa.

by 127 km^2 into the district of Bara (Lamichhane et al., 2017, p.2). In 2017, the status of PWR was changed to a national park in order to be able to promote the development of tourism infrastructure and to provide access to natural resources to the local communities in the buffer zone. In addition, there was access to the local communities in the buffer zone though it was a wildlife reserve, considering that those resources were necessary for their subsistence. Under the International Union for Conservation of Nature (IUCN, 2017) categories for PAs, the changed status also implied a shift in the focus of conservation. As a wildlife reserve, the PA was in category IV which aims at the conservation of a particular species or habitat. Currently, as a national park, it falls under category II which aims to fully conserve functional ecosystems.

In addition, the farming system in the buffer zone consisted mostly of agricultural activities (Figure 2) and livestock practices in the forest and grasslands. Although grazing activities were not allowed in the core zone, sometimes the villagers would go illegally into the forest for the same, especially in the northern side of the park, according to the interviewees.

Figure 2: **Land cover in Parsa National Park (2010 Landsat data)**



Source: ICIMOD, 2017

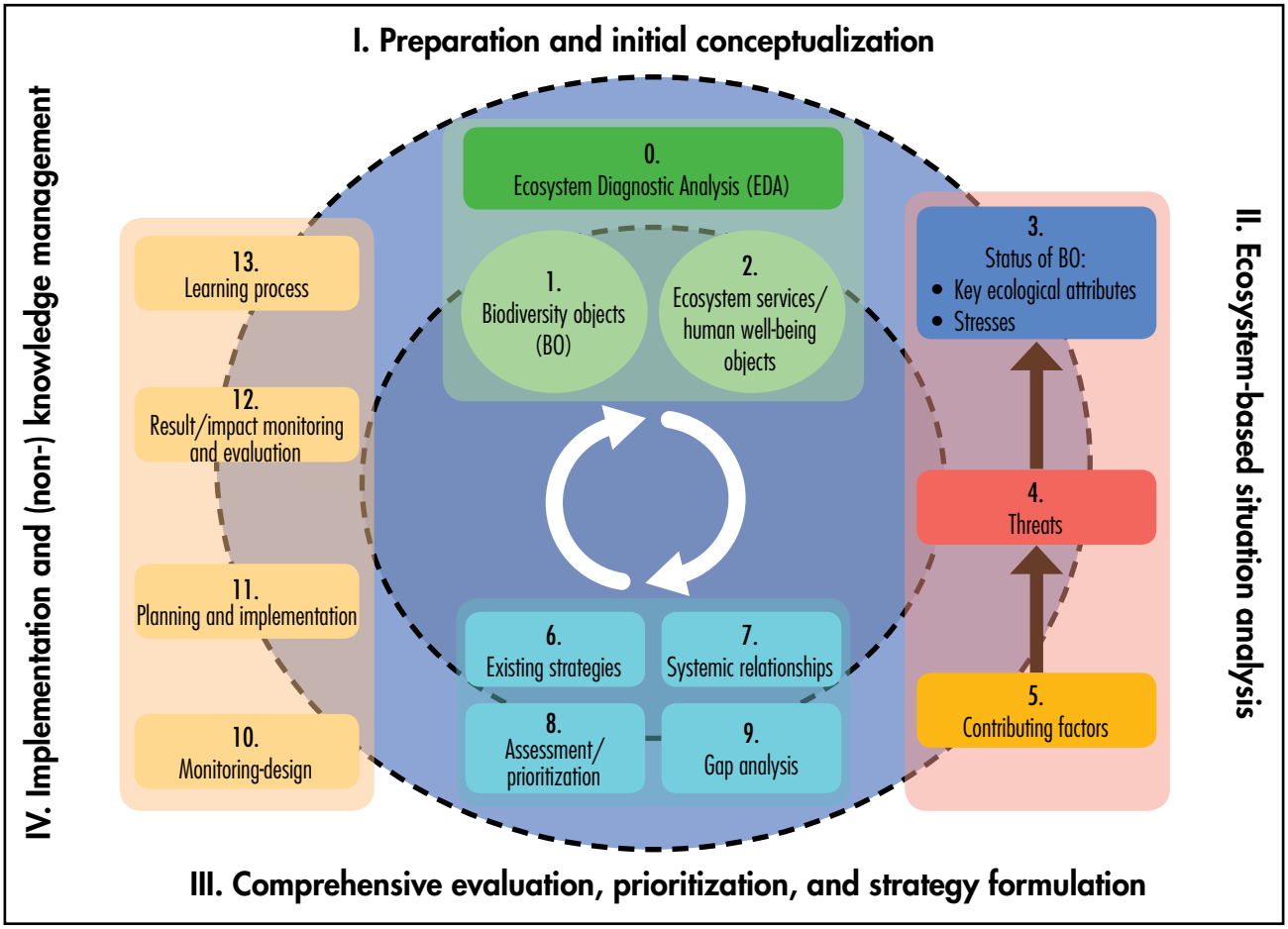
Methodology

The field research was conducted between June and August 2017 through a desktop study, a series of interviews, and a validation workshop. Later, the qualitative analysis of the results was based on the theoretical framework of the ecosystem approach (Waltner-Toews et al., 2008). The methodology applied was framed by the MARISCO method developed by the Centre for Economics and Ecosystem Management; it has been implemented in other Asian countries like China, Malaysia, and Uzbekistan, as well as in other countries around the world. The method is based on an ecosystem-based approach to strategic conservation management with a focus on the functionality of the ecological systems which provide the base for human well-being (Ibisch & Hobson, 2014, p.17–42).

The method comprises four phases as shown in Figure 3; each phase has a set of sub-products that are the base for the next phase. It is a cyclical process under the adaptive management approach. Therefore, phase IV is not an endpoint; regular reviews and modifications are needed in the conceptual model that is developed as well as the in the strategies that are implemented. This research applied only phases I and II which are shown in a darker colour in Figure 3.

These phases provide enough results to adjust, for example, the management plan of the PA and to assess the strategies that the park management is implementing. The other two phases can be applied during the implementation of the conservation strategies, along with a monitoring system, in order to complete the cycle of adaptive management.

Figure 3: **Phases of the MARISCO method**



Source: Adapted from Ibisch & Hobson (2014, p.15)

The Ecosystem Diagnostic Analysis (EDA) is the main result from phase I. It includes the identification of the key ecosystems and its ecosystem services as well as its relationship with the provisioning of human well-being in the local area. An EDA is a process of characterizing and evaluating land-use change patterns (Ibisch & Hobson, 2014, p.57). The purpose of this rapid assessment tool is to get a comprehensive understanding of the ecosystem's state of health, by assessing landscapes as well as the behaviour and distribution of its species (ibid.). Additionally, this kind of analysis can generate information about the risk status of a certain area, and thus ideally, potential pressures and drivers behind them can be identified (Ibisch & Hobson, 2014, p.64).

The conceptual model is the main result from phase II. It helps to visualize the context within which the PA is operating and, in particular, the major forces that are influencing the biodiversity in the conservation site (FOS, 2009, p.1). This context is expressed in a diagram (the conceptual model) which contains the elements that can be seen in Figure 4. The logic behind this is that human well-being depends on the ecosystem services provided by the biodiversity objects which, in turn, have a set of key ecological attributes to maintain the functionality and adaptability of the system. However, different factors can contribute to generating threats which impact on the ecosystems, creating stresses that show the degradation of key ecological attributes. Thus, the conceptual model allows for analysing the scales, structures and the dynamic cause-effect relationships between the various contributing factors and threats that influence the vulnerability of the biodiversity objects which also affect human well-being (Ibisch & Hobson, 2014, p.74).

Figure 4: **Elements of the conceptual model**

Source: Own elaboration based on the MARISCO method

To develop the conceptual model, the following key concepts were used:

Biodiversity objects are "all elements of biodiversity falling within the geographical scope that merit conservation attention and strategically implemented action to: increase their functionality and viability, reduce existing and imminent threats, and reduce their vulnerability against probable disturbances and changes" (Ibisch & Hobson, 2014, p.54). They must be logically listed according to the landscape ecosystems and with the included nested objects (ibid).

Ecosystem services are "the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as the regulation of floods, drought, land degradation, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious and other non-material benefits" (Ibisch & Hobson, 2014, p.56).

Key ecological attributes "are best described as integral elements and properties of ecological systems that maintain its function and provide the necessary adaptation and resilience to cope with perturbations" (Ibisch & Hobson, 2014, p.74).

Human well-being objects "describe the recognizable human benefits derived from biodiversity through ecosystem services and the social services" (Ibisch & Hobson, 2014, p.55).

Conservation objects are "those elements of nature that have recognisable functional importance in maintaining the integrity of an ecosystem and that also provide very real benefits in terms of goods and services for people" (Ibisch & Hobson, 2014, p.54).

Stresses "describe the symptoms and manifestations of the degradation of key ecological attributes, in other words they describe a certain state, reaction or symptoms of a system or any of its components to anthropogenic threats whose impacts will lead to shifts or changes in the system" (Ibisch & Hobson, 2014, p.75).

Threats are considered to be any human-induced forcing or pressing factor that is likely to directly or indirectly have an impact on the natural structure and dynamics of an ecosystem; they represent processes of change that negatively affect biodiversity objects by causing stress and increasing vulnerability (Ibisch & Hobson, 2014, p.75).

Contributing factors are best described as a human action or activity that directly or indirectly results in the emergence of a threat, which then induces a stress or stresses in one or a number of the components in an ecosystem (Ibisch & Hobson, 2014, p.75).

The sources of information for this research come from a desktop study, semi-structured interviews, and a validation workshop.

The desktop study was based on a systematic review of literature from secondary sources. These included technical reports, scientific papers, maps, and satellite imagery (Google Earth). The type of collected information consisted of maps of land use and land cover, hydrology and bioregions; biodiversity information (habitat types and species); information about the use of natural resources and biodiversity as well as of ecosystem services in terms of how they benefit the local people; and information about socio-economic, political and legal circumstances, among others.

To complement the desktop study, impressions and knowledge were obtained from semi-structured interviews with the stakeholders; these were conducted in Kathmandu, and in Parsa during a visit to the study area in July 2017. The interviewees[3] were chosen from different projects and programmes related to the park and its surroundings, based on the desktop study. For this process, a wide variety of participants were identified from research and public institutions, as well as from international agencies and civil society. The interviews were divided into three sections:

- Open questions related to the management of the park; local participation; patterns of land use and land change; threats and their causes; and the activities and programmes that institutions carry out in PNP. These questions were formulated according to the type of interviewee.
- Revision of diagrams of Biodiversity Objects and Human Well-being. The diagram of Biodiversity Objects was developed as a draft based on the desktop study; meanwhile, for the Human Well-being dimensions, two diagrams were shown to the interviewees: one from the Organisation for Economic Cooperation and Development (OECD)[4] and the other from the Millennium Ecosystem Assessment.
- Selection of ecosystem services which are provided by the ecosystems in PNP and its surroundings, based on the list of ecosystem services from the Common International Classification of Ecosystem Services (CICES)[5].

In addition, after processing all the collected information and to develop a draft of the conceptual model, new interviews were conducted with experts to confirm some information and to enrich the model.

The draft of the conceptual model was validated with local actors in the field through a validation workshop which was conducted in Parsa on 31 August and from which new elements for the analysis emerged. The workshop had consecutive translation between Nepali–English–Nepali, and in the same way, the cards of the conceptual model were written in both languages, Nepali and English.

[3] For further information, see Annex 1: List of interviewees
[4] For further information about the OECD framework for human well-being, see: http://www.oecd.org/statistics/measuring-well-being-and-progress.htm
[5] For further information about CICES, see: https://cices.eu/

Socioecological system analysis of Parsa National Park

Based on the desktop study and interviews with the stakeholders, this section presents the main results which have been organized into five subsections:

- **Relevant stakeholders**: It gives a brief overview of the institutions and organizations that are linked to PNP to a greater or lesser extent.
- **Key ecological attributes**: It provides an ecological description of the study area and its surrounding landscape in order to define the key ecological attributes that support the ecosystems.
- **Ecosystem services and human well-being**: It explains the interrelations within the SES, focusing on the relevance of ecosystem services to human well-being.
- **Drivers influencing the dynamics of the SES**: It presents and analyses the context and main trends in order to explain how they are influencing the main dynamics in the SES.
- **Challenges and opportunities**: It presents a set of challenges, but also opportunities, based on the interrelations and drivers identified within the SES.

Relevant stakeholders

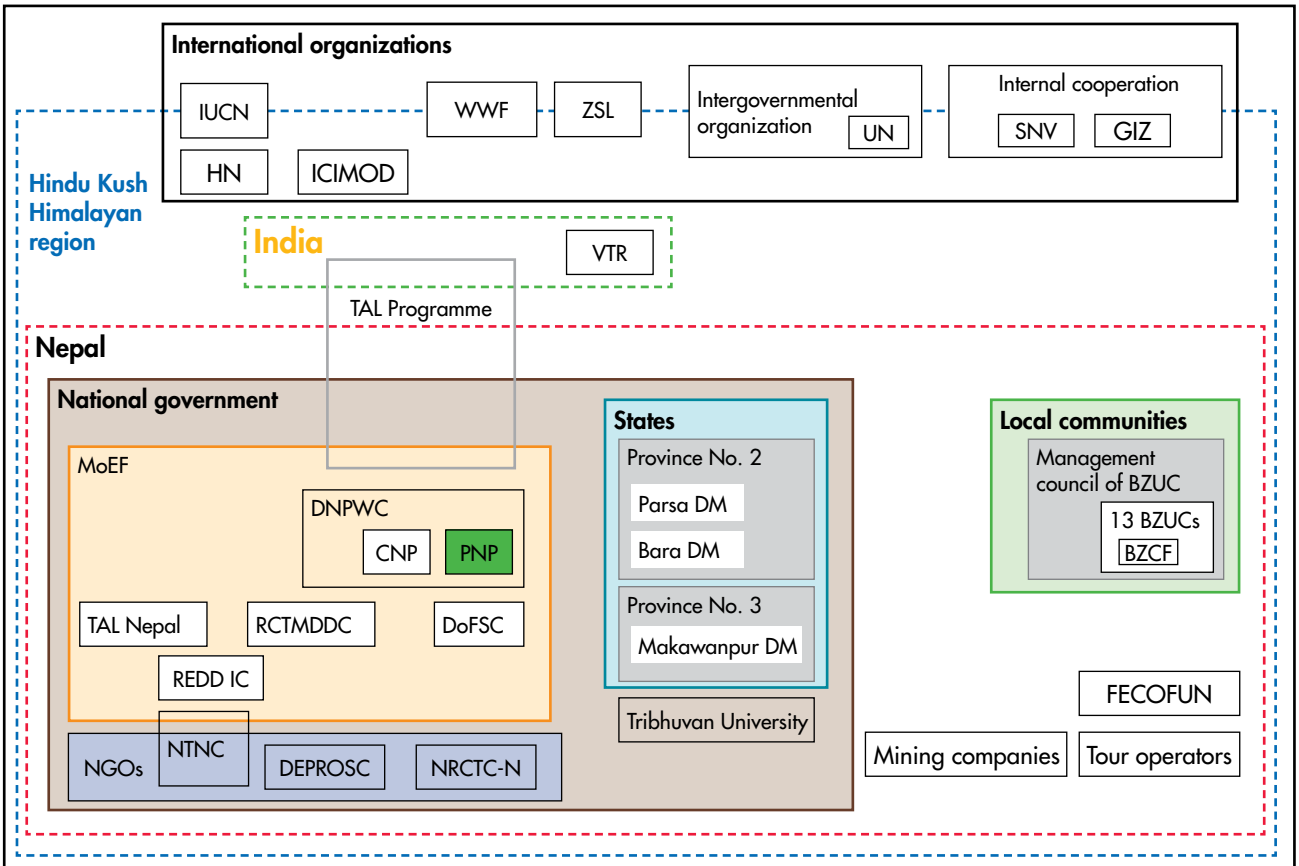
The study has identified a set of stakeholders[6] linked to PNP, to a greater or lesser extent, from international, regional, national and local levels. Figure 5 helps to visualize the nested social subsystems and its interrelations within the study area.

Under the new federal structure of Nepal, PNP is part of the Department of National Parks and Wildlife Conservation (DNPWC) which is a wing of the Ministry of Forests and Environment (MoFE). This ministry also incorporates the Department of Forests and Soil Conservation (DoFSC) which is the authority in charge of the collaborative forest outside the park. Furthermore, under the same ministry, there are two programmes working in the landscape within which PNP is located; they are the Rastrapati Chure-Madhesh Programme (RCMP) and the Terai Arc Landscape (TAL)-Nepal. Besides, TAL-Nepal is part of the TAL programme which includes nine PAs of India and six of Nepal (MFSC, 2015, p.3). In addition, the REDD Implementation Centre (REDD IC), under the MoFE, is working in the surrounding landscape of the park, specifically in Chitwan National Park (CNP).

Meanwhile, academic institutions like Tribhuvan University also contribute to the development of scientific knowledge in PNP. Likewise, the National Trust for Nature Conservation (NTNC), together with international organizations, such as the Zoological Society of London Nepal (ZSL Nepal), the World Wildlife Fund for Nature, Nepal (WWF Nepal), and the International Centre for Integrated Mountain Development (ICIMOD), include nature conservation in their projects with the aim to promote the sustainable development of local communities. NTNC was created by the Nepalese government in 1982 as an autonomous and not-for-profit organization and it has a field office in Parsa from where it works closely with the PNP management. Besides, WWF supports the TAL programme under a landscape approach, supporting the governments of Nepal and India, and involving a large number of partner organizations. Similarly, other international organizations, such as the Netherlands Development Organisation (SNV), the German Corporation for International Cooperation (GIZ, by its German acronym), and the United Nations (UN), among others, have supported PNP through national or regional programmes focused on biodiversity conservation, capacity building of park staff, community mobilization, human–wildlife conflict mitigation, etc.

[6] For further information, see Annex 3: List of stakeholders

Figure 5: **Diagram of the main stakeholders linked to Parsa National Park**



Acronyms

BZCF	Buffer Zone Community Forest
BZUC	Buffer Zone User Committee
CNP	Chitwan National Park
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DEPROSC	Development Project Service Center
DM	District Municipality
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FECOFUN	Federation of Community Forestry Users Nepal
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PNP	Parsa National Park
RCTMDDC	Rastrapati Chure Terai Madhesh Conservation and Development Committee
REDD IC	REDD Implementation Centre
SNV	Netherlands Development Organisation
TAL Nepal	Terai Arc Landscape Nepal
TAL Programme	Terai Arc Landscape Programme
UN	United Nations
VTR	Valmiki Tiger Reserve
WWF	World Wildlife Fund for Nature
ZSL	Zoological Society of London

Source: Based on desktop study and interviews with stakeholders

In addition, there are some institutions, like Himalayan Nature (HN) and the Development Project Service Center (DEPROSC) Nepal, which, although they don not have a direct link with PNP, are working in the surrounding areas of the park and in significant fields such as sustainable livelihoods and microfinance. Also, organizations like the Natural Resource Conflict Transformation Center-Nepal (NRCTC-N) are working on topics linked to the challenges faced by PNP. Moreover, there are other PAs in the same natural corridor, like CNP and Valmiki Tiger Reserve (VTR), with common conservation goals with PNP, such as in the area of tiger conservation.[7] All these institutions could be considered as potential partners of PNP in exchanging knowledge or establishing other collaborations.

Local people are important stakeholders since they can – consciously or unconsciously – use, exploit, change, protect and rehabilitate ecosystems for their own or somebody else's benefits (Bennett et al., 2015, p .80). In this regard, the park is also linked to the local communities through the Management Council of the Buffer Zone User Committees (BZUCs). Simultaneously, according to the new federal structure of the country, the park could work more closely with the municipalities of three districts – Parsa, Bara, and Makwanpur – in provinces 2 and 3 respectively. Meanwhile, the Federation of Community Forestry Users Nepal (FECOFUN) is another important stakeholder from the civil society. This organization is a formal network of forest user groups dedicated to promoting and protecting their rights.

Finally, there are some companies in the buffer zone of PNP and its surroundings that use the natural resources of the area. For example, in the northern part of the buffer zone, some companies are extracting sand and gravel. Likewise, there are mining companies extracting groundwater. Furthermore, because of the change in status of the PA, it is expected that more tour operators would be working within the park.

All the various types of stakeholders mentioned above are also related to each other in some cases. In addition, they are operating at different scales and have specific and different motivations, preferences and access to the ecosystem services provided by the ecosystems in PNP and its surroundings. Thus, all these stakeholders can – directly or indirectly – benefit from the park, and can also simultaneously influence the ecological and social systems in which PNP is located. For instance, the international network supports the conservation of TAL because it represents the protection of ecosystems and species of global relevance. On the other hand, the Government of Nepal has different motivations, such as the protection of tigers because of international treaties, the safeguarding of forests with high economic value in TAL, the promotion of tourism, etc. Meanwhile, at the moment, for the local people, the forest represents the main source of energy and timber, an area for grazing, and also where land is available.

Key ecological attributes

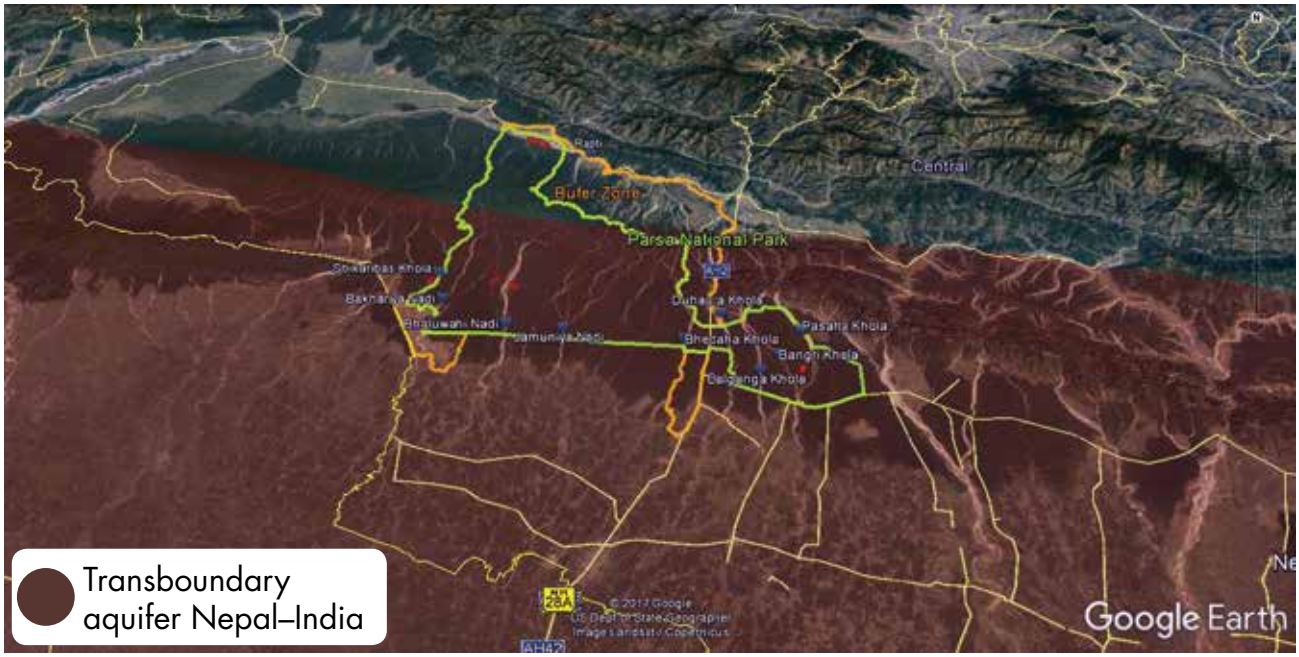
PNP occupies part of the Siwalik (or Churia) zone and part of the lowland Terai (or Madhesh). The Churia hills are the most recent mountain system of the Himalayan orogeny and tectonically one of the most active mountain ranges in the world (Ghimire & Basnet, n.d., p.4). These hills play an important role in the recharging of groundwater in the Tarai (MFSC, 2002, p.34); however, they have been facing high rates of deforestation and land degradation over the last five decades (GoN & MFSC, 2014, p.19).

As can be seen in Figure 6, according to the 2015 Transboundary Aquifers of the World map (IGRAC & UNESCO-IHP, 2015), a big part of the Terai area of PNP lies on a transboundary aquifer (brown area in the map) between Nepal and India. It confirms the importance of the Siwalik in recharging the low parts, and also highlights the importance of transboundary water management in terms of ground and surface water.

Besides, PNP is located between two river basins: the Gandaki (also known as Narayani) and the Bagmati (WECS, 2002). The Gandaki is a transboundary basin lying north–south in the central Himalayan region and it extends from China, through Nepal, to India (Dandekhya et al., 2017, p.1). The downstream of the basin goes through CNP and

[7] Nepal signed the St Petersburg Declaration on Tiger Conservation in 2010, with the aim to prevent the extinction of tigers and to double their population (based on the population of 2009) by 2022. Further information in: http://cmsdata.iucn.org/downloads/st_petersburg_declaration_english.pdf

Figure 6: **Transboundary aquifer Nepal–India**



Source: Elaboration based on the kmz file proportioned by IGRAC and UNESCO-IHP, 2015

the river Rapti on the northern side of PNP (ibid.). The Bagmati originates from the hills in the north of Kathmandu and flows to the plains of the Terai in the Nepal–India border (Babel et al., 2014, p.640). The western zone of the basin runs near the eastern border of the extended area of PNP.

In the south of PNP, other rivers flow through the core area, such as the Shikaribas Khola, Bakharilla Nadi, Uriya Nadi, Bhaluwahi Nadi, Jamuniya Nadi, Bedaha Khola, Duhaura Khola, Belganga Khola, Bangri Khola, and Pasaha Khola (ICIMOD, 2017). The distribution of the sub-watershed boundaries of the rivers and streams can be seen in Figure 7. However, most of these streams are seasonal and the water flow is pronounced during the monsoon, creating some floods (Gurung & Khanal, 1986–88, p.8). These annual monsoon floods maintain the grasslands and woodlands by reversing the successional process (Thapa, Wikramanayake, & Forrest, 2015, p.10). Meanwhile, during the summer season, the scarcity of water creates some very dry areas.

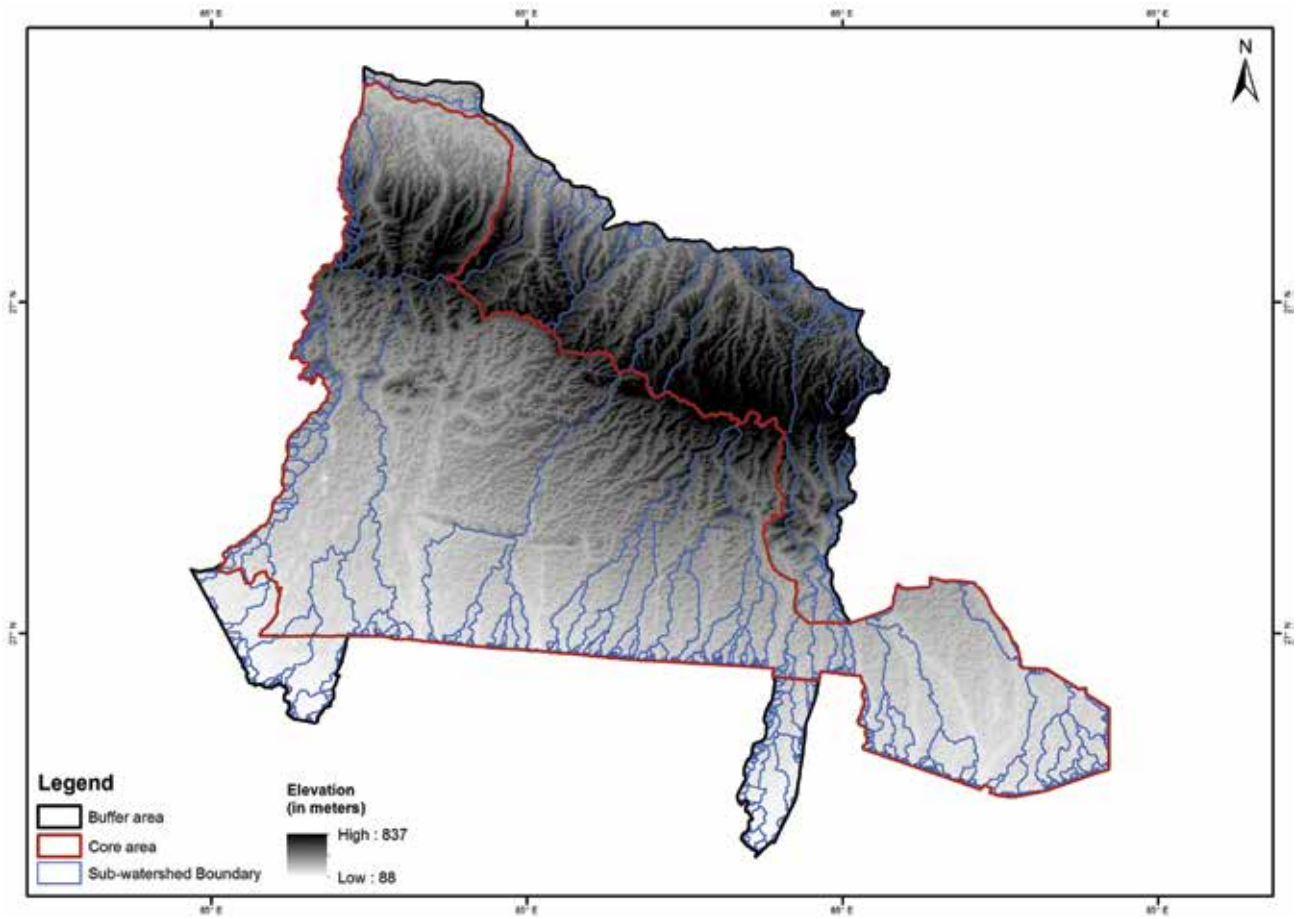
Significantly, the biophysical conditions make the watersheds of the Churia-Terai region extremely fragile and the ecological environment sensitive to human disturbance (Ghimire & Basnet, n.d., p.4). The type of substrate in PNP is one of the critical factors because the soil is primarily composed of gravel and conglomerates, making it susceptible to erosion (Bhuju et al., 2007, p.59). The hills present a very rugged face with numerous gullies and dry streambeds (WWF-Nepal, 2014). As the foothills are very porous, the water flows underground and surfaces at a distance of about 15 km from the park's hill base (Bhuju et al., 2007, p.59).

Another important aspect is the climatic zone of PNP. According to the climatic map of Nepal based on the Köppen–Geiger classification, PNP lies in the temperate climate zone with dry winters and hot summers (Cwa); however, a new climatic classification of Nepal proposes that the southern side of the park be classified as Tropical Savannah (Aw) and the northern side as of a temperate climatic nature with dry winters and hot summers (Cwa) (Karki et al., 2015, pp. 806–07).

The climate in the area where PNP is located is characterized by four distinct seasons (GoN & MoE, 2010, p.2):

- The pre-monsoon season (from March to May) is extremely hot; the temperature reaches up to 40°C (Sitikhu, 2015, p.2), and scarcity of water is the main characteristic; water availability is restricted to less than 70% of the total that could be available (Lamichhane et al., 2017, p.1).

Figure 7: **Sub-watershed boundary of Parsa National Park**



Source: ICIMOD, 2017

- The monsoon rainfall (from June to September) causes a little drop in the temperature and the average precipitation increases.
- During the post-monsoon season (from October to November), the temperature decreases and so does the average precipitation.
- During the winter season (from December to February), the temperature reaches its lowest value, 5.8°C (Sitikhu, 2015, p.2) and the average precipitation is between 40 to 60 mm (Marahatta, Dangol, & Gurung, 2009, p.12).

Regarding flora, the Terai plain possesses forestland dominated by sal (Shorea robusta), which is of high economic value. Besides providing timber and non-timber products, the Terai forests fulfil an important corridor function for wildlife and also provide environmental services such as protecting the foothills from floods; they also secure groundwater supply (Gupta, 2014, p.3).

In terms of ecosystems, eight types have been identified (Bhuju et al., 2007, p.60):

- Tropical hill sal forest in the inner valleys
- Sal forest in the inner valleys
- Hygrophytic tropical forest on the northern slopes[8]
- Tropical riverine forest
- Khair-Sissoo riverine forest
- Pseudo steppe with Gramineae
- Terai tropical sal forest
- Tropical dense forest with *Terminalia* sp.

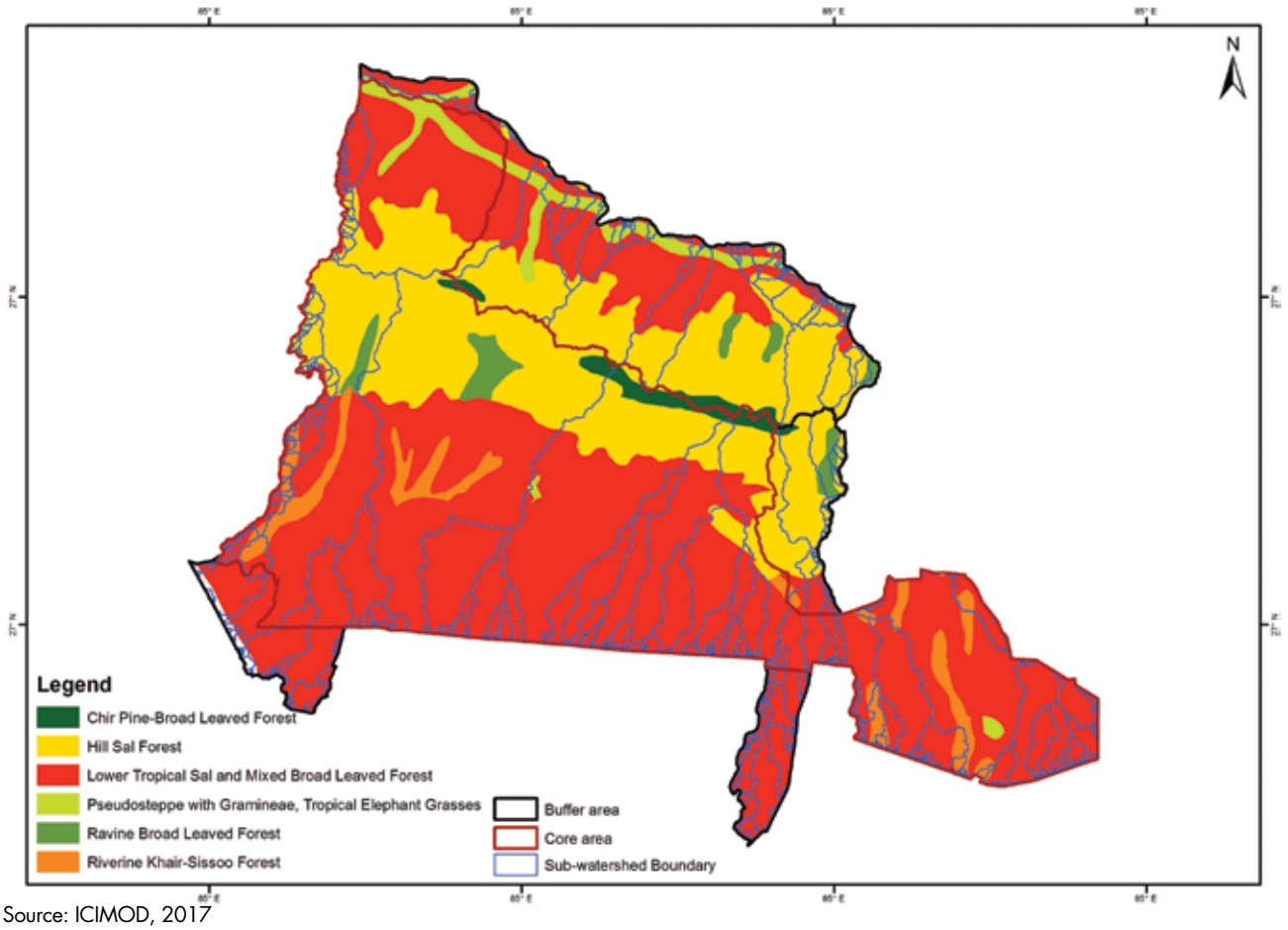
[8] During the validation workshop, some participants suggested the confirmation of this ecosystem later. The sources of information used by Bhuju et al., (2007) were from the Biodiversity Profile Project (BPP), 1995 and the Tree Improvement and Silviculture Component (TISC) maps from 2001.

As can be seen in the ecology zone map (Figure 8), the forests are mainly composed of tropical and subtropical species with sal forest constituting about 90% of the vegetation.[9] Open sal forest occurs on the dry, steep, south-facing slopes of the Siwalik (Seidensticker et al., 2010, p.312). The dominance of this type of vegetation might be explained by the fact that the sal is fire resistant and its seedlings are much less palatable to deer and other ungulates than those of other tree species (ibid.). Without human interference, the plant succession sequence in the TAL forest is from short to tall grass and from diverse successional forest to continuous mature forest (ibid.). The grass in the riverbeds is essential because it is the main source of food to the ungulates. Annually, these grasses are adapted to severe disturbance events such as monsoon, floods, and natural fires (ibid.).

Along the banks of the rivers, riverine forests are found containing species like khair (*Acacia catechu*), sissoo (*Dalbergia sissoo*), and the silk cotton tree (*Bombax ceiba*). Chir pine (*Pinus roxburghii*) grows in the Churia hills, as well as sabai grass (*Eulaliopsis binata*), which is a commercially important species (WWF-Nepal, 2014). In 1995, approximately 919 species of flora were recorded; these included 298 vascular plants, 5 pteridophytes, 1 gymnosperm, 234 dicots, and 58 monocots (Bhuju et al., 2007, p.59).

Regarding the fauna diversity, there are between 30 to 37 species of mammals, around 500 species of birds, 13 species of reptiles/amphibians, and 8 species of fish (Bhuju et al., 2007, p.59). Symbolic bird species include the crow-billed drongo (*Dicrurus annectans*), the thick-billed green pigeon (*Treron curvirostra*), the long-tailed broadbill (*Psarisomus dalhousiae*), and the red jungle fowl (*Gallus gallus*) (ibid). The emblematic mammal species of PNP are the royal Bengal tiger (*Panthera tigris*), the gaur (*Bos gaurus*), the Asian wild elephant (*Elephas maximus*), the striped hyena (*Hyaena hyaena*), and the dhole (*Cuon alpinus*) (ibid), although other carnivores such as the leopard (Panthera pardus) and the golden jackal (*Canis aureus*) can also be found, as well as other prey species such as the sambar (*Rusa unicolor*), the nilgai (*Boselaphus tragocamelus*), the spotted deer (*Axis axis*), the barking deer

Figure 8: **Ecological zones in Parsa National Park**



Source: ICIMOD, 2017

[9] For further information, see Annex 3: Main tree species in Parsa National Park

(*Muntiacus muntjak*), and the wild boar (*Sus scrofa*) (Lamichhane et al., 2017, p.1). In addition, a recent biodiversity survey conducted by NTNC, DNPWC, and ICIMOD, recorded the presence of the smallest mammal, the pygmy white-toothed shrew (*Suncus etruscus*) for the first time in the park, making it home to the smallest and largest mammals (NTNC & ICIMOD, 2017, p.14). However, the high diversity of fauna is not merely connected to low anthropogenic disturbance; availability of water sources seems to be a crucial factor in enhancing the biodiversity profile, especially of birds, butterflies, reptiles, and amphibians (NTNC & ICIMOD, 2017, p.14).

Within the core area of the park, interactions between different terrestrial and freshwater ecosystems provide conditions to ensure the survival of those species. The flora and fauna are in turn are related, for example, through predation and competition, which occurs over the course of a short temporal scale, like days; or through a breeding process within a larger temporal scale, like a season. They may also be related through successional processes between grasslands, woodlands, and forests on a long-term temporal scale. Although for some species, such as tigers, elephants, and migratory birds, the core area only represents part of their habitat.

Considering all the features explained above, Figure 9 shows the key ecological attributes which maintain the functionality and provide adaptation and resilience to the SES. They have been grouped into:

- Climate which includes seasonality, solar radiation, and temperature.
- Hydrology which includes water quantity and quality, current and precipitation.
- Geomorphology which includes soil structure, permeability, aspect, and humus.
- Connectedness and exchanges in ecological processes such as gene flow, river dynamics, forest type interrelations, natural species composition, endemic species, and production of biomass.

In addition, these key ecological attributes support the existence of a set of biodiversity objects in PNP (Figure 9), such as forest ecosystems and grasslands; freshwater ecosystems; and key species which live in these ecosystems, interacting through intraspecific and interspecific relations.

Ecosystem services and human well-being

All the biophysical and ecological characteristics mentioned above interplay with the social components, shaping a complex system in PNP. These biophysical structures and processes allow for specific ecological functions which provide services and benefits to the people, and also contribute to some aspects of their well-being as can be seen in Figure 10. Simultaneously, these people assign different values to those benefits and generate a chain of pressures altering the biophysical structures and processes of the system. This is called the "cascade model" which describes a kind of pathway for delivering ecosystem services (Potschin & Haines-Young, 2016). For instance, in PNP, the Siwalik hills provide a variety of ecosystem services such as prevention of soil erosion, recharging of groundwater for the Terai plains, and preventing natural disasters such as flash floods (GoN & MFSC, 2014, p.7).

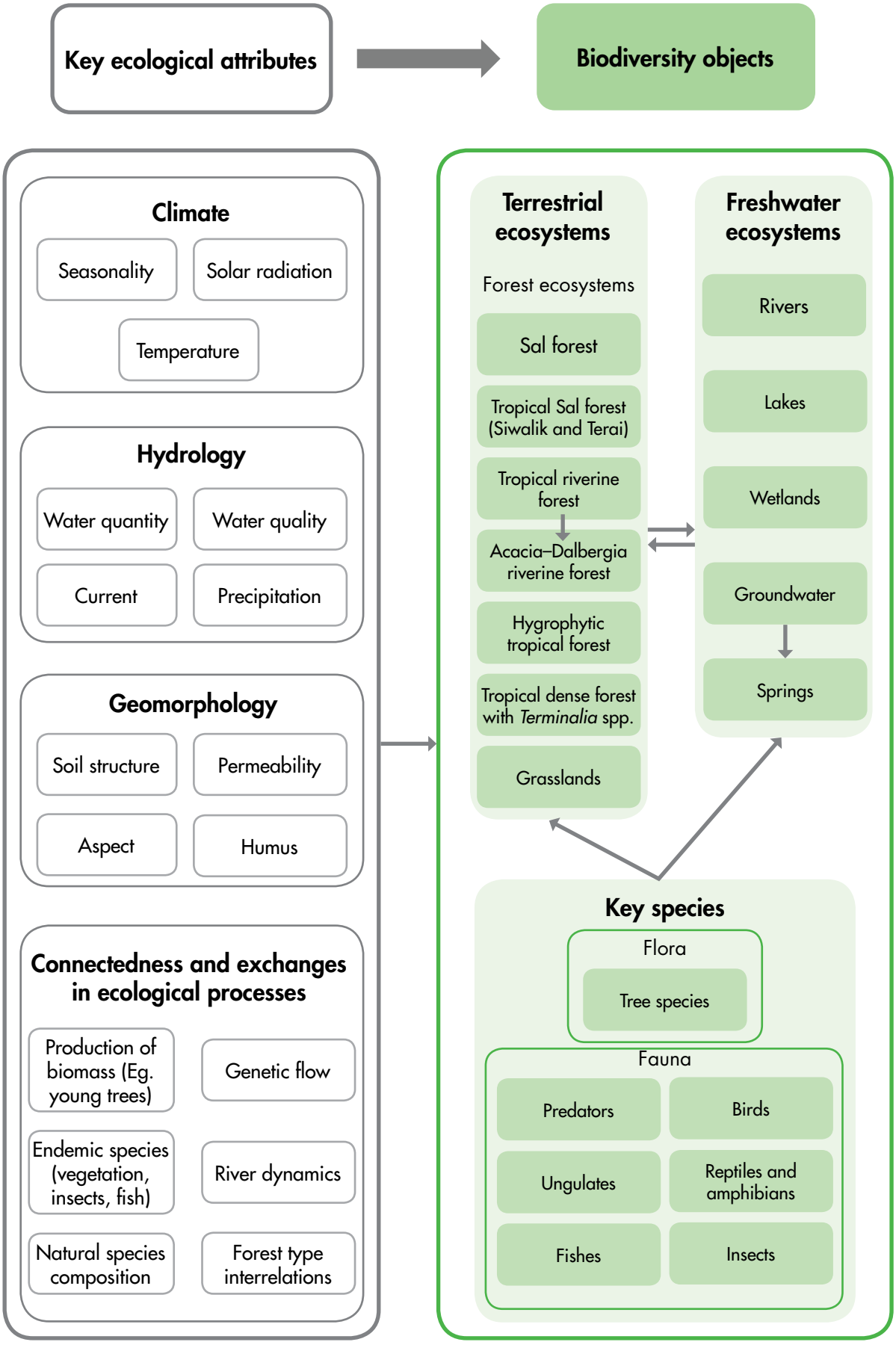
During the validation workshop in Parsa, the local people confirmed that the set of ecosystem services identified[10] provide them with some elements of well-being[11] (Figure 10), such as:

- Necessary material for a good life; e.g., access to natural resources for livelihood, opportunities for employment, etc.
- Health; e.g., environmental quality, access to local medicine, etc.
- Security; e.g., reduced risk from natural hazards.
- Good social relations; e.g., local participation and sharing of knowledge.

The local communities in the buffer zone are highly dependent on forest and hydrological ecosystem services. For instance, in the high elevations of the buffer zone of PNP, the local people depend on rivers and precipitation as well as ponds and springs for their main source of water. Meanwhile, in the low areas, groundwater is pumped to be used for drinking purposes and for agricultural activities. However, there are some tensions between them and the park regarding the use of natural resources and local participation. This and other tensions which threaten the sustainability of the park are discussed in the next subsection.

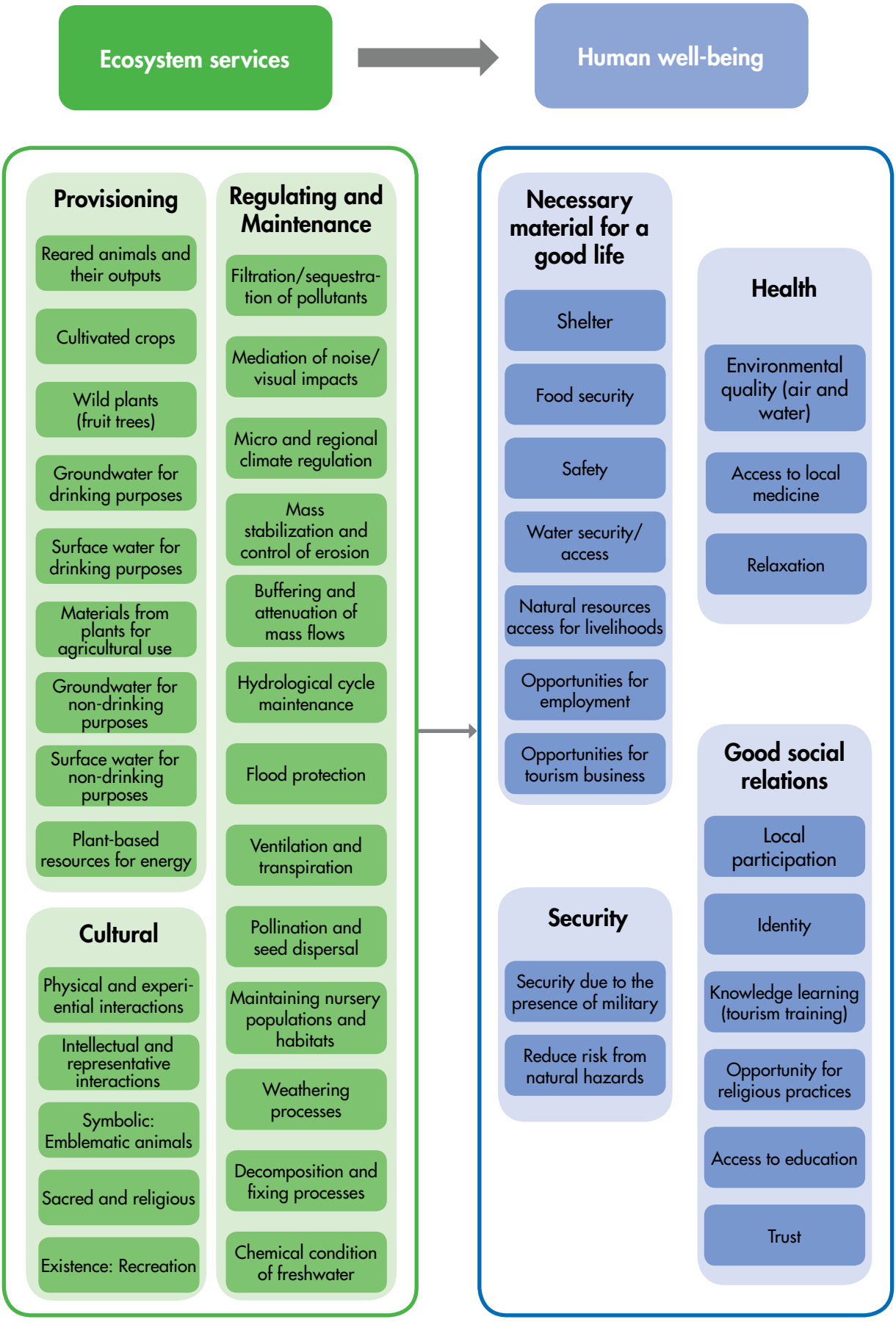
[10] A full list of the ecosystem services identified in PNP can be found in Annex 4.
[11] The classification of the human well-being elements is based on the Millennium Ecosystem Assessment.

Figure 9: **Key ecological attributes and biodiversity objects of PNP**



Source: Based on desktop study, interviews with stakeholders, and the validation workshop

Figure 10: **Ecosystem services and human well-being in PNP**



Source: Based on interviews with stakeholders and the validation workshop

In addition, PNP has a diverse range of ecosystem services whose benefits extend beyond the people in the buffer zone. Considering different space scales, these benefits can be grouped into three categories (Cumming, 2016, p.49):

- Interior benefits, such as cultural and symbolic animals (like elephants and tigers); or, sacred and religious places like the Hindu temple in the core area.
- Local benefits, such as groundwater for drinking purposes; fuelwood; and natural remedies and medicines within the buffer zone.
- Regional benefits, such as improvement in water quality and quantity; maintenance of the gene pool; and carbon storage in the surrounding landscape.

Drivers influencing the dynamics of the socioecological system

After analysing the biophysical, ecological and social aspects which influence PNP, some stresses on the park´s ecosystems were identified, as well as the threats and their contributing factors which lead to those stresses. All these complex relationships are the basis of the analysis in this subsection and are shown in the conceptual model in Annex 5.

The stresses identified and validated by the local stakeholders are: loss of area covered by dominant vegetation; reduction of waterbodies; decrease in riverine forest; decrease in groundwater availability; soil erosion; land degradation; indirect species effects (e.g., the increase in competition for food among the ungulates because of the cattle fed in the grasslands); habitat shifts (e.g., forest converted into grassland or cultivated land); species disturbance (e.g., disturbances in the life cycle stages of fishes); loss of forest habitat; species mortality; and loss of habitat connectedness. It is important to point out that the critical level and the priority of the stresses have not been evaluated in this study. However, it is essential to understand the threats which lead to those stresses as well as the different factors that are behind them.

In this regard, a set of drivers that influences the dynamics of the SES has been identified and grouped into specific topics that are inherently linked: a. Boundaries; b. Ecosystemic knowledge gaps; c. Unsustainable natural resource use and other human activities; d. Land-use and land-cover change; e. Governance and local perceptions towards the park; and, f. Infrastructure development, hydropower development, and extractive industry.

a) Boundaries

In terms of spatial distribution of the PA, there are some parts of the core area without a buffer zone. Additionally, the demarcation of the core area is basically through natural barriers like rivers and hills (Figure 1). The park has an official documentation of the borders; however, it seems that some people are not familiar with this information, thereby creating some demarcation conflicts.

North

On the northern side of the park, the river Rapti establishes the limit of the buffer zone; meanwhile, the Churia range establishes the limit of the core area. Even though in some parts there are also symbols to establish the limit of the core area, some of the interviewees consider that there are not enough park posts in the northern side to monitor the borders of the core area, although in 2016, two guard posts were installed (Lamichhane et al., 2017, p.7). The buffer zone in this side of the park includes forest areas, settlements, and agricultural lands mainly shaped by terraces.

South

Forest roads (fire-lines network) demarcate the boundary of the core area in the south. Despite there not being a buffer zone contiguous with the southern core area, there is a collaborative forest which plays the role of a buffer zone in ecological terms; it is used by wildlife as refuge especially to access water, considering that water is a limited factor in the whole park (Lamichhane et al., 2017, p.7).

However, there are some conflicts between the wildlife and the local settlements around that collaborative forest; the wild animals face the threat of poaching and persecution from the communities located there. This type of forest primarily yields timber and other products; hence, it seems the users of the forest are not aware of the importance of wildlife. To illustrate this, when interviewed on 5 July 2017, B.R. Lamichhane said that in a village close to that collaborative forest, a tiger was killed because it entered the centre of the village and it attacked some people; they did not know how to cope with that situation and just killed the tiger. Because the collaborative forest is managed by the Parsa district forest office affiliated with the DoFSC, the park is not allowed to conduct any conservation activity. The NTNC has done some lobbying for converting this collaborative forest into a buffer zone of PNP; however, that would mean the removal of the district forest office from this area and the transfer of the management of the collaborative forest to PNP; this conflict of interest makes the proposal to convert this area into a buffer zone more difficult to implement for the MoFE (Poudel, 2017, pers. comm., 2 July).

West

The western border is adjacent to CNP, along 35 km, connecting the forest ecosystem from PNP to CNP in a natural way (Lamichhane et al., 2017, p.2). Nevertheless, in the south-west, there is a buffer zone with settlements and agricultural lands. That area also represents an international transboundary landscape, of global importance for tiger recovery, between Nepal and India; it is less than 2 km from the border of Valmiki Tiger Reserve[12] (Lamichhane et al., 2017, p.2).

East

Part of the eastern border has a buffer zone with settlements and agricultural lands. In these areas, the demarcation between the buffer zone and the core area is not clear for some communities who, for instance, claim that the pond Kamini "Daha" is in the buffer zone, while the park considers it to be in the core area. On the other hand, the new extended area in the core zone, which is divided by the Tribhuvan Highway, does not have a buffer zone. However, like the southern border of the park, this area is also characterized by a large sal forest under the collaborative management system (WWF, 2017, p.17).

Looking at PNP beyond its administrative boundaries shows the multiple connections between PNP and its surrounding landscape, as well as the various interlinks between the several stakeholders related to PNP.

b) Ecosystemic knowledge gaps

PNP has its research focus on fauna, especially wildlife species like tigers, elephants, and rhinos. Nevertheless, there is no monitoring system[13] related to hydrological processes, vegetation distribution, climate change impacts, etc. Taking into account the recent change in status of the PA, the main purpose of the national park should be "to protect large-scale ecological processes, along with the complement of species and ecosystems characteristic of the area" (IUCN, 2017). In this regard, some knowledge gaps about the main ecological processes, the role of biodiversity in maintaining ecosystem services, and interrelations in the socioecological system, among others, were detected. For example, *Mikania micrantha* (Figure 11) is an invasive species which "blocks the light to plant by covering it and retards the growth and competes with plants for nutrients and water and sometimes produces the growth inhibitors" (Karki & Paudel, 2013); however, because *Mikania* is currently a big issue in CNP but not in PNP, there is no monitoring of how this invasive species may be reducing the carrying capacity of the habitats in PNP.

Besides, global climate change is affecting the components of the hydrological cycle. Higher temperatures increase evaporation from the humid vegetation layers, exposed soils, and water surfaces, as well as the transpiration of vegetation (IPCC, 2014). Likewise, changes in the quantity, intensity or distribution (spatial or temporal) of precipitation affect the water regulation and availability in rivers, watersheds, and lakes (ibid.). Currently, the Terai region is experiencing more extreme weather events, with more frequent and devastating floods (MFSC, 2015, p.9). According to the National Adaptation Programme of Action (NAPA) to climate change , Chitwan, Parsa, and Bara present high levels of projected flood vulnerability (GoN and MoE 2010, p.58). For instance, it is expected that heavy rainfalls will cause extensive floods and flash floods in the Rapti River (WWF- Nepal, Hariyo Ban

[12] For further information, see: http://valmikitigerreserve.com/

[13] The strongest monitoring systems are for tigers, for example, using camera traps.

Program 2016, p.53). Thus, CNP and PNP, along with community-managed forests, could be more exposed to impacts from climate change (ibid.). In fact, among the four protected areas in TAL, PNP was considered as the most vulnerable to climate change, according to a climate vulnerability assessment of TAL (ibid, p.67). Further, the local people also perceive climate change impacts; for instance, they claim that some crops can be cultivated in very short periods because of changes in the temperature and rainfall patterns. Certainly, this situation is affecting the livelihoods of the local people; and as a consequence, it can generate more pressures on the forest ecosystems.

A good starting point to close these knowledge gaps can be the Biodiversity Monitoring Protocol REDD+ implemented by NTNC and ICIMOD in early 2017. This protocol has covered both flora and fauna assessment, focusing on indicator species (NTNC & ICIMOD, 2017). Also, conservation programmes for the recovery of tigers (Panthera tigris) in PNP and CNP are moving towards a more comprehensive management structure as part of the Chitwan–Parsa–Valmiki forest complex of the Terai Arc Landscape (Lamichhane et al., 2017, p.1).

Figure 11: **Mikania micrantha, Chitwan National Park, August 2017**

c) Unsustainable natural resource use and other human activities

Illegal activities as well as practices which promote land-use change are the main unsustainable natural resource uses within the buffer zone (and sometimes even in the core area) of PNP and its surroundings, as can be seen in the conceptual model (Annex 5). Some illegal activities are: poaching, logging, extraction of wood for energy uses, overfishing and poisoning of waterholes (a common method of illegal fishing) that violate existing permissions and the usufruct rights of the local people to use timber and non-timber products in the buffer zone. On the other hand, livestock grazing in the forest and the increase in cultivated land are the main drivers of land-use change caused by the local population. Likewise, there are other activities such as groundwater extraction as well as sand and stone extraction which are mainly performed by the extractive industries. All of these unsustainable practices represent threats to the ecosystems and generate several stresses, such as soil erosion, land degradation, increased food competition, loss of forest habitat, and species mortality.

However, it is fundamental to note that there are several socio-demographic, socio-economic and sociocultural factors as well as industry-related issues that are leading to the threats mentioned above. For instance, human population growth and migration processes generate settlements and encroachments. This situation intensifies poverty and inequality which, in turn, generate urgent short-term needs, like for shelter, food, energy sources, etc.

Nevertheless, according to the majority of the interviewees, most of these activities have decreased in the last few years because of improvements in the park´s security, resettlement, and eviction of encroachments. The security has improved thanks to the community setting up 13 anti-poaching units; these were formed in 2010 by the voluntary participation of more than 200 youths from the communities around Parsa. Their duties include: controlling illegal grazing, hunting, and forest resource extraction; as well as providing information on poachers and smugglers to the PA authority. In addition, the park increased the number of forest guard posts from seven in 2013 to nine in 2016

(Lamichhane et al., 2017, p.7). Furthermore, the voluntary resettlement of two villages[14] (Rambhori Bhata and Ramauli Pratappur), consisting of 473 households, from the core area in 2009 and 2013, has helped in the recovery of the ecosystems (Lamichhane et al., 2017, pp. 2–3). However, according to a study conducted in the extended core area before the official declaration of the park's expansion (Sitikhu 2015), the main disturbances in that area were human presence, tree felling, livestock, fodder collection, and logging, as can be seen in Table 1.

Livestock grazing in the forest is directly connected to the livelihoods of the people from the buffer zone and its surroundings. The livestock can be goat, buffalo, and cow which compete for the resources with wild ungulates (Thapa & Lohani, 2007). Some interviewees mentioned that illegal logging, livestock grazing, along with fuelwood and timber extraction, are still pressures – although on a smaller scale – for the buffer zones in the north and south of the park. To counter it, the park has a capacity building programme in place to promote community forests; however, in some areas, there are only a few of them. These community forests are under the management of the BZUCs.

Table 1: **Disturbances in the extended core area (2015)**

SN°	Disturbance recorded	Percentage of the total disturbances recorded
1	Human presence	82.35%
2	Tree felling	82.35%
3	Livestock	47.06%
4	Fodder collection	47.06%
5	Logging	41.18%
6	Firewood collection	17.65%
7	Sand extraction	17.65%
8	Litter collection	11.76%
9	Hunting spot	5.88%
10	Vehicles	5.88%
11	Poaching	5.88%
12	Encroachment	5.88%

Source of data: Sitikhu, 2015

Regarding poaching, it is a latent threat to the wildlife in the park if the enormous illicit trafficking led by international networks is considered (WWF & Dalberg, 2012). When interviewed on 2 July 2017, S. Poudel said the people involved in this kind of activity are mostly poor and they do not seem to respect religious principles like not to kill sacred animals; these hunters can be from Nepal or India.

On the other hand, subsistence agriculture within the buffer zone and the surrounding areas is also an important activity that supports the livelihoods of the people. During the study trip, fields with wheat, rice, corn, and bananas were observed. In this regard, for irrigation in the high elevations, the people depend on rivers and precipitation as well as ponds and springs for their main source of water. Meanwhile, in the low areas, the main source is pumped groundwater. However, during the interviews, the interviewees mentioned that the agricultural activities are changing; in some areas, the cultivation of new agricultural products for commercial purposes has started, and the use of small tractors, too, can be observed.

In addition to these unsustainable practices, there is a Hindu temple inside the core area of PNP which is frequented by Nepalese and Indians – approximately 3,400 people per year (Kandel, 2017, pers. comm., 2 July). The visitors use different types of vehicles to get inside the park, thereby disturbing the wildlife, especially through noise pollution. Moreover, such visitors are not obliged to pay the entrance fee because the visit is on religious grounds; thus, the park is not able to generate any additional revenue.

d) Land-use and land-cover change

Land-use and land-cover changes in the Terai-Siwalik landscape play a pivotal role in the sustainability of livelihoods in the region and in its future development; they can also help us in understanding the human responses to development activities (Ghimire & Basnet, n.d., p.4).

[14] In these villages, the local people practised subsistence agriculture, livestock grazing, and collection of fodder, fuelwood, timber, and other forest products. However, human–wildlife conflict as well as the limited access to health and education were the reasons for their relocation (Lamichhane et al., 2017, p.3).

The final report called "Land Use, Land Cover Mapping of Parsa Wildlife Reserve Using Satellite Imagery of 2002 and 2013" (WWF Nepal, 2014) (Table 2) has pointed out three main land-use and land-cover changes.

First, that the increase in cultivated land and grasslands is linked to the occurrence of fresh encroachments in the north-eastern side of the park; and, second, there has been a decrease in waterbodies and riverine forest.

Table 2: **Land-use/land-cover change in Parsa Wildlife Reserve (2002–2013)**

(Expressed in %)

Land use/ Land cover	Core zone		Buffer zone	
	2002	2013	2002	2013
Sal forest	75.26	81.97	42.5	50.89
Mixed forest	6.78	4.74	11.48	7.34
Riverine forest	9.66	5.69	7.5	4.53
Grassland	0.9	4.06	2.52	5.19
Cultivated land	0.04	0.38	25.01	26.2
Exposed surface	6.16	2.77	7.67	4.91
Waterbody	1.19	0.37	3.33	0.94

Source: WWF, 2014

Socio-demographic factors can explain the increase in cultivated areas. The share of the Terai in terms of the country's population increased from 36.4% in 1961 to 50.3% in 2011 (GoN, 2014, p.19).). In the Siwalik, the increase in population due to migration during the 1960s has been the main driver of change in land use and has led to deforestation and degradation processes (Gurung & Khanal, 1986–88, p.33). In the Tarai, many natural habitats have been converted into settlements, agriculture land, and plantations (Thapa et al., 2015, p.27). As can be seen in Table 3, in the period 1991–2011, the population in Bara and Parsa (both located in central Terai) showed an increase (except in the case of hilly Makwanpur) probably because of migration from the hills to the Terai. In the same period, the population density, too, increased considerably (even in the case of Makwanpur) in the districts within which PNP is located.

Table 3: **Percentage of population and population density in the districts where PNP is located**

Year	Total population of Nepal	Percentage of the total population (%)			Population density (Person/sq km)		
		Central Terai		Central Hill	Central Terai		Central Hill
		Parsa	Bara	Makwanpur	Parsa	Bara	Makwanpur
1991	18,491,097	2.01	2.25	1.70	275	349	130
2001	23,151,423	2.15	2.42	1.70	367	470	162
2011	26,494,504	2.27	2.60	1.59	444	578	173
Source: GoN, (2014)							

Although conflicts in terms of encroachments were critical in the past, especially before the declaration of the PA as a wildlife reserve, encroachments are still a problem. For instance, one encroaching settlement located in the buffer zone towards the south-west of the park was relocated in 2016 after a dialogue process was coordinated by the Buffer Zone Committees and the park management (Kandel, 2017, pers. comm., 2 July). Currently, the park is restoring that area through natural grassland management. Several other encroaching settlements in the buffer zone and core area have been relocated. After relocation, the challenge has been about how those relocated would maintain their livelihood because only the legally relocated settlements receive land unit as compensation. Furthermore, despite the relocation of settlements from the core area, pressures on the forest from grazing and extraction of fuelwood and timber continue in the northern part of the buffer zone (Lamichhane et al., 2017, p.7).

Landscape fragmentation is another issue associated with the forest-cover change around PNP because of the increase in population, expansion of road networks, encroachments, agricultural sprawl, etc. (Lamichhane, 2016, p.71). Based on the calculated landscape metrics of Parsa district, a study determined that the forest area in that district was fragmented during 1993–2009, with the highest number of patches being observed in 2009 (ibid., p.72). Such a situation can indeed create biodiversity loss and habitat isolation (ibid.).

Another reason for the decrease in waterbodies and riverine forest could be the hydrological changes in the Siwalik (Churia) in terms of lesser number of streams and changes in their courses, caused by changing rainfall and run-off patterns generated by the increase in climate variability.

e) Governance and local perceptions towards the Park

Nepal is a young democracy. It became a federal republic in 2008, and in 2015, the Constitution was approved, and it implemented a new federal structure. This transition process has created some political instability and generated changes in the overall government structure (Cosic, Dahal, & Kitzmuller, 2017, p.ix). This transformed situation – at the national level – along with cultural factors, have also affected the governance of the park.

Thus, some weaknesses have been detected in the stewardship as well as in the participatory mechanisms. Regarding stewardship, the updating of the management plan has taken too long. Until 2017, the last management plan was for the period 2008 to 2012; however, the plan was not in the public domain and was difficult to access. The park management argued that the plan's delay has to do with the change in status of the PA. As for participatory mechanisms, the official procedure for local participation in the management activities of the park is currently through meetings between the chief of PNP and the Buffer Zone Management Council. This council integrates all the presidents/leaders from each of the 13 BZUCs in PNP. The meetings occur three to four times a year. However, the people from Amleshwor BZUC who participated in one such local meeting expressed their disagreement with not being included in the preparatory process of the new management plan for PNP; they also said that they have had no access to the buffer zone management plan as yet.

Another important issue is the perception of the people from the buffer zone towards the park. Within the buffer zone, the livelihood of the people is mainly dependent on agriculture and cattle grazing. When interviewed on 2 July 2017, a person from Amleshwor BZUC mentioned that their relationship with the forest area has mainly got to do with cattle grazing. A study conducted in 2013 in two buffer zone VDCs in PNP, found that there are seven types of resources used by the local people: fodder, fuelwood, thatch grass, leaf litter, edible plants, timber, and other forest products, including non-timber ones (Thapa, 2016, p.44). In addition, almost 85% of the people in those areas use fuelwood as the only source of energy for cooking and heating (ibid). However, the villages that are part of the buffer zone have some restrictions in relation to forest use. For instance, Amleshwor residents (Amleshwor BZUC, 2017, pers. comm., 2 July) said that they can collect fodder and fuelwood only for three days a week, and harvest thatch grass inside the park once a year. Indeed, according to Thapa (2016, p.47), some of the local people in and around the PA have a negative attitude towards it, basically because of the restrictions on resource use from both the core and buffer zone (53%).

Other reasons for this negative attitude are: the loss of crop and livestock (16%); fear of wildlife and forced evictions (10%); human casualties (5%); and beating, arrest and prosecution by PNP authorities (16%) (Thapa, 2016, p.47). However, Thapa (ibid) also found some positive attitude towards the PA linked to factors such as: the role of the park in biodiversity conservation (43%); generating opportunities for employment (2%); tourism and business prospects (8%); provisions for natural resource use (25%); a feeling of security due to the presence of the military (20%); and sentimental attachment to the place (2%).

The loss of crops and livestock, the fear of wildlife, and incidents of human casualties are part of human–wildlife conflicts, a big issue for many PAs in Nepal (GoN & MFSC, 2014, p.27). In PNP, because of the increase in the tiger population in the last few years, more such human–wildlife conflicts could arise, especially in the settlements located close to the borders of the core area of the park (Lamichhane et al., 2017, p.7). Despite the fact that PNP does provide monetary compensation to people who have suffered damages due to the wild animals, the local communities consider the compensation as not commensurate with the property damage/loss (Thapa 2016). In addition, it takes too long to get the compensation: three to four months on an average (Poudel, 2017, pers. comm., 2 July).

f) Infrastructure development, hydropower development, and extractive industries

The expansion of road networks, building of hydropower plants and some extractive activities by the private sector are creating threats such as fragmentation of the landscape, disturbance of wildlife, and noise pollution; there's also the issue of illegal sand and gravel extraction from the riverbank in the buffer zone of PNP and its surroundings.

In terms of road network, the Tribhuvan Highway connects Kathmandu to the Terai region and India, but it passes through the core zone of PNP. This highway was completed in 1956 with Indian assistance (Shrestha 2014) and is part of the East–West Highway which was constructed along the foothill of the Churia. It enabled the extraction of forest resources and facilitated migration from the hills to the Terai (Singh 2012, p.1). In addition, the Tribhuvan Highway usually has heavy traffic because it is the main road to transport the oil that is stored in the depot of the Nepal Oil Corporation; the depot is located on that part of the highway where it crosses the core area of PNP. The park has implemented some measures like speed limits for this stretch of the highway in order to reduce adverse impacts. However, that has not prevented the death of animals – elephants, leopards, deer, and monkeys – while trying to cross the highway.

Then there is the fast-track road along the Bagmati corridor, the work on which began in 2017 after a protracted design process that took almost 10 years for completion (Shrestha, 2014). This road will connect Kathmandu to the eastern Terai and is expected to decrease the travel distance by 159 km and save time by more than four hours (Shrestha, 2014). Clearly, it will also have a direct impact on the settlement pattern, potentially reducing the population in the Kathmandu Valley and increasing it in central Terai (ibid.); that would again put pressure on the forest ecosystem.

Another big construction project on the way is the Nijghad International Airport which will be located in the district of Bara and is expected to be completed by December 2025 (CAPA – Centre for Aviation 2018). However, it will not be viable in the absence of the fast-track road mentioned previously (Shrestha, 2014; GoN, 2015). According to the Centre for Aviation (CAPA, 2018), this project has been designed to relieve the expected capacity restraints at the Tribhuvan International Airport in Kathmandu and it will be capable of handling 15 million passengers annually. But the designated area where the international airport is to come up is a dense forest with wild elephants and other wildlife speices. There is also the aspect of community forestry in the area which provides livelihood to the local people.

In addition, the Department of Roads (DoR) is planning to upgrade the EWH, which would then traverse through forests, settlements, commercial areas, and farmlands (WWF, 2017, p.1). The section from Pathlaiya to Nijgadh of this road expansion project runs along the southern boundary of PNP's core zone in Bara (it was extended to this area in 2015). This is yet another area – largely consisting of sal forest – that is rich in wildlife. And the frequency of wild elephants crossing this stretch is rather high due to its connectivity to PNP (WWF, 2017, p.37).

As regards hydropower development, there are two hydropower plants being built close to PNP: Kulekhani III Hydroelectric Station (Dhakal, 2011, p.2) and Saptakoshi High Dam Project (GoN & GoI, 2016). Hydropower projects cause disturbances in the river flux and in the whole hydrology system, especially in places like Nepal with its small-scale reservoirs, which are tied to irrigation projects (WWF Nepal, Hariyo Ban Program 2014, p.17). Thus, the large hydroelectricity projects and dams planned upstream from the Terai will also have cascading impacts downstream, affecting the flow regimes of major rivers and diminishing environmental flows (MFSC, 2015, p.7). For instance, when interviewed on 6 September 2017, S.M. Nepal mentioned that the construction of dams on the India–Nepal border may contribute to enhancing the intensity and casualties of floods during the monsoon because this infrastructure obstructs the natural flow of water.

Meanwhile, oil and gas exploration is set to take place within 10 blocks designated by the government, with PNP and CNP lying in blocks 6 and 5 respectively (WWF Nepal, Hariyo Ban Program 2016, p.23; Kaphle, 2014). Such oil exploration in areas susceptible to floods could contaminate the groundwater, affect the water sources of the people, and threaten the agriculture-based economy (WWF Nepal, Hariyo Ban Program, 2016, p.23).

Finally, as for the extractive industry, close to the borders of the buffer zone on the northern side of PNP, there are companies extracting sand and gravel from the riverbank (Figure 12). This activity can affect both the aquatic environment and the soil structure, and trigger soil erosion and land degradation, especially in the Siwalik hills. In addition, there are metal factories extracting groundwater from the surrounding landscape of the park. And it seems that the impact of groundwater use is not being monitored. Besides, during the validation workshop, the local participants said that both sand and gravel as well as groundwater extraction are illegal activities that are taking place inside the buffer zone.

Figure 12: **Sand and gravel extraction in the northern side of PNP, August 2017**

Challenges and opportunities

A set of challenges, but also some potential opportunities, have been identified taking into account: a) PNP as part of an SES; b) the main drivers and structural factors; and c) the governance system of PNP.

a) PNP embedded in an SES

PNP is clearly embedded in an SES which goes beyond the administrative boundaries of the PA. The identified drivers influencing the SES as well as the governance system show how PNP is interacting simultaneously with its immediate context as well as with subsystems at the national, regional and even international levels.

The interdependence and complexity of these relationships support the idea of including cross-scale and multilevel perspectives in the management of PNP. It would allow, for example, the flow of information through exchange of ideas, perceptions and skills from stakeholders across different scales and levels (Cumming et al., 2015, p.305). Similarly, it might be strategically important for the park management to highlight the interlinkage between the beneficiaries of the ecosystem services from PNP and the stakeholders who have an impact on the biophysical structure or process which supports those ecosystem services (Palomo et al., 2014, p.188). This could contribute to enhancing conservation strategies in a broader scope and help deal with the complexity of the SES. Using the arguments proposed by Cash et al., (2006, p.4), even though dealing with these interdependencies represents a big challenge for PNP, overlooking them is creating a set of management problems such as demarcation conflicts and negative perceptions of the local people towards the park. As a consequence, these problems might weaken the resilience capacity of the system. This idea of including a cross-scale and multilevel perspective in the park management is also in line with the findings of Pravat and Humphreys (2013) who analysed the multiple dimensions of conflicts in the Terai forestry policy and practice, using a multilevel approach.

Additionally, describing the SES of PNP using a cross-scale and multilevel perspective allows, in the first place, to explore the roots which are creating stresses on the ecosystems. As can be seen in the conceptual model (Annex 5), factors related to both governance and socio-demographic dynamics are influencing both socio-economic and socio-cultural aspects. In particular, urgency in short-term needs is creating unsustainable practices in land and natural resource use within the buffer zones and around the park. Likewise, economic development policies at the national level are leading to infrastructure- and industry-related factors which, in turn, are creating a set of threats to the SES of PNP. Therefore, a systemic description helps to visualize the interconnections between a wide range of factors which usually occur outside a PA's administrative boundary (DeFries, Karanth, & Pareeth 2010, p.1).

b) Drivers and structural factors

Drivers altering the hydrological system

It is important to note that water is a limited factor in PNP, especially for the wildlife; therefore, water management is a challenge for the park, particularly during the dry season. Furthermore, water access is also a concern for the local people who perceive a decrease in groundwater availability.

Sand and gravel extraction; the increase in use of groundwater by the local communities and mining companies; and climate change impacts – these are altering the key ecological attributes related to the hydrological system. Thus, it is important that the park management takes into account the complexity of the hydrological system on which the PA depends. A better understanding of the hydrological system would contribute to improving the effectiveness of the conservation measures adopted by the park and to prevent the adoption of inadequate measures. For instance, due to the water scarcity in the park, wetland management and watering holes have been put in place by the park management in order to increase the water availability for wildlife. However, if the understanding of the whole system has not been included in the design of the measure, it will support only one part of the system in isolation and the other part could be moved farther from its optimum capacity, creating a suboptimization of the system (Waltner-Toews et al., 2008, p.18).

Drivers promoting loss of connectedness

Despite the importance of maintaining the connectedness within PNP and with its surroundings, it is threatened by the expansion of road networks and the proposed establishment of an international airport in the district of Bara. Although several of these infrastructure projects may seem to be important for the economic development of Nepal, it will be necessary to find innovative solutions that can simultaneously provide the basis for human well-being and also maintain the landscape structure. Probably, this would mean some structural transformations in the governance mechanism of the country.

It is expected that the combined effects of infrastructure and hydropower development, the extractive industry, and the uncertain challenges of climate change will exacerbate the fragmentation of the landscape. Because of a high level of vulnerability, PNP and the eastern parts of CNP could be isolated, with a lack of access to climate refuge for the wildlife (WWF Nepal, Hariyo Ban Program, 2016, p.65).

If provisions for appropriate mitigation measures against the threats of road expansion are not made, it will have a big impact on the diverse ecosystems and fauna, reducing and fragmenting habitats (WWF, 2017, p.62). This fragmentation would reduce the movement of long-ranging animals such as elephant, tiger, and leopard which have the capacity to move nutrients within the ecosystem and spread seeds. The loss of connectedness can interrupt this efficient distribution of nutrients and the flow of genetic information within the ecosystems of the SES of PNP. Therefore, it will be crucial to apply an adaptive risk management mechanism based on the monitoring of the vegetation distribution on a landscape level. It would allow for anticipating vegetation shifts and help in understanding the long-term changes in the forest ecosystem.

Structural factors influencing the dynamics of the SES

The conceptual model (Annex 5) depicts how the SES of PNP is shaped and outlined by different processes mainly attributable to human activities. Taking into account the location, connectivity, and context of PNP, the park´s relevance is not only ecological, but also socio-economic. However, the study has found that particular problems caused by structural factors are affecting the sustainability of the SES.

Some of the structural factors which are driving the ecosystem modification in the surrounding landscape of PNP have to do with poverty and social inequalities caused by rapid, unplanned urbanization, political instability, and weakness of public institutions. These factors make the adoption of sustainable practices by poor people in the buffer zone and the surrounding landscape of PNP more difficult. In addition, these people have to face other difficulties associated with climate change, such as susceptibility to floods and landslides as well as a lack of adequate shelter, food, and water (Eriksson et al., 2009, p.12). This situation creates a feedback loop in the system – more poverty leads to more pressure on the ecosystems, and their degradation creates more poverty among the population which is highly dependent on the forest. Therefore, from a socioecological system's perspective, it is necessary that the park management take the interactions of people and nature into account in its conservation strategies and manage those interactions, or create the appropriate conditions for them to occur (Cumming & Allen, 2017, p.1709).

On the other hand, there is no arguing that infrastructure development is crucial for the economic development of Nepal; several new large and linear infrastructural developments are being planned, such as highways, railways, airports, transmission lines, large-scale irrigation projects, and sand and gravel mining; however, all of these are likely to have serious ecological and socio-economic implications (WWF Nepal, Hariyo Ban Program, 2014, p.1). So, the aspect of development should be considered from an ecosystem-based perspective – "a sustainable society maintains itself in the context of the larger ecological system of which it is part; therefore, a sustainable society must maintain ecological integrity" (Kay & Regier, 2000, p.148). Indeed, external pressures from the political and socio-economic context of Nepal also influence the SES of PNP.

c) Governance system in PNP

The need for strengthening adaptive capacity

Some of the most significant issues found in this study are those related to the governance of PNP. Despite the ecological and social benefits that BZUCs can receive from the park, some of these user communities have a negative attitude towards PNP, mainly because of the restrictions on resource use. While restricting local access to natural resources – which play a crucial role in the people's livelihoods, health, and culture – might favour biodiversity conservation in the short term; in the long term, such strategies may fail if the park authorities do not take into consideration the importance of simultaneously promoting active local engagement and implementing conservation measures (Andrade & Rhodes, 2012, p.7). In addition, Moller et al., (2004, p.2) argue that instead of advocating prohibition, conservation efforts may be best directed towards ensuring the sustainable use of natural resources; as unsustainable use may persist if the local people have no other options to support their livelihoods. In this way, considering the local context, both farming terraces and agroforestry practices could be evaluated and improved – if necessary – as possible ecosystem-based adaptation measures.

Likewise, considering that some inhabitants in the buffer zones are domestic migrants, their experience with the natural processes in the new landscape are insufficient. For instance, if they have migrated from the hills to the Terai, they may continue with unsustainable practices such as cutting down of forest for establishing cultivated areas. Therefore, it is important to know the background of the people living in the buffer zones and the surrounding landscape in order to help them to develop an adaptive capacity to deal with a new context which is also permanently evolving. In this regard, the park management could enter into some agreements with the BZCUs to reactivate the capacity building programmes in order to promote community forest management. The latter has delivered good results along the TAL by restoring forested habitat corridors (Thapa et al., 2015, p.7).

Besides, the change in the classification of PNP from a wildlife reserve to a national park was based on the demand from the local people to promote tourism. However, it will be necessary, based on the experience of CNP and other PAs in Nepal, to take into account the expectations of the local people regarding the new revenue and its distribution, as well as the new threats that tourism activities would bring along. For instance, the increasing consumption of firewood and the increase in non-biodegradable waste. It will require a participative process of planning and negotiations among the stakeholders to build a pathway towards sustainable tourism which should also be nested in a national or regional sustainable tourism approach.

The need to adopt a participatory approach

Adaptive governance provides the framework for the implementation of adaptive management (Dietz, Ostrom, & Stern, 2003; Folke et al., 2005; Worboys et al., 2015) which enhances the capacity to deal with the complexity and inherent uncertainties of socioecological systems (Kay et al., 1999, p.737; SCBD, 2004, p.9); and it requires a participatory approach. In fact, many studies conducted in PAs show the relevance of including different groups of stakeholders in the management process (Andrade & Rhodes, 2012, p.2). However, PNP seems to have a weak participative mechanism to include diverse stakeholders, especially those from the BZUCs. When interviewed on 2 July 2017, S. Poudel from NTNC said that the main challenge for the park management is to improve the communication between the local people and the park, discussing ideas from both parties and getting solutions faster. For his part, when interviewed on 3 July 2017, A. Ram from PNP pointed out that working with the local people is one of the main issues that need to be addressed, in terms of community development and awareness about conservation. There's also the expectation that the situation can be improved with a better distribution of benefits, e.g., through job opportunities and the increase in revenues from tourism in PNP.

Even though the park management and other actors consider that it is necessary to build a better relationship with the local communities, this does not necessarily mean that they understand that local participation is a critical issue for the long-term sustainability of PNP. As a consequence, it will be necessary that PNP improves the participatory and dialogue mechanisms to create the bases for a collaborative process; for instance, building relationships based on voluntary compliance rather than draconian enforcements to avoid illegal activities inside the PAs (Andrade & Rhodes, 2012, p.5). In this regard, the positive achievements of the anti-poaching units through the support of the

community possibly show the willingness of the local communities to participate in the protection of the biodiversity of PNP.

The need to include local ecological knowledge

There is some evidence supporting the idea that if the knowledge and opinions of the local communities are included in the PA decision-making processes, these local communities develop a better commitment towards long-term conservation strategies (Andrade & Rhodes, 2012, p.2). Therefore, PNP should consider options like local participatory research; this could also fill the systemic knowledge gaps. For instance, during the validation workshop, the local people mentioned that they would like to be part of the research processes in PNP. In fact, local ecological knowledge is an important component of adaptive management of ecosystems. This kind of knowledge generated by the local users through local observations and experiments is more contextualized and it may complement the more general knowledge developed by professional science (Gadgil et al., 2002, p.189). In addition, participatory research can be a way of co-management between the park and the local people.

The need to promote a (co)learning attitude

In order to carry out all of this and to introduce an adaptive management structure in PNP, it will also be necessary to extend the capacity building programmes to the PA personnel in order to improve their capacities in natural resource management, conservation planning, and social skills in conflict resolution and diplomacy (Andrade & Rhodes, 2012, p.5). Likewise, it would help to promote systematic learning through experimentation and from errors (Kay & Regier, 2000, p.147; Ibisch & Hobson, 2014, p.30). In that regard, Worboys et al., (2015, p.196) propose that a learning attitude can be promoted through: i) participatory analysis and planning – e.g., through exercises using visioning, scenarios or trend analysis; ii) co-production and wide sharing of knowledge – e.g., dialogue and exchanges among academic scientists and people with experience-based and traditional forms of knowledge; and iii) developing agreements along the way – e.g., communicating among diverse forms of knowledge, values, and world views.

Conclusions and recommendations

After analysing the biophysical, ecological and social aspects and considering different scales and types of perspectives as well as external and internal dynamics, it is clear that PNP is embedded in an SES which is an open, complex system with permeable boundaries beyond PNP´s borders. In ecological terms, a set of ecosystems is connected by spatial and temporal flows of material, energy, and organisms; in social terms, a set of stakeholders with different motivations and interests is influencing decisions which affect PNP directly or indirectly. The interdependence and complexity of the relationships identified within the SES and with the surroundings suggest that cross-scale and multilevel perspectives need to be included in PNP´s management approach.

The study has also shown that the main ecological dynamics affected are those related to the hydrological system and the connectedness of the landscape. Human activities such as sand and gravel extraction, the use of groundwater by local communities and mining companies, the expansion of road networks, the proposed establishment of an international airport and the future infrastructure and hydropower development, in combination with climate change effects, are altering the key ecological attributes of the SES.

Similarly, external pressures from the political and socio-economic context of Nepal are also influencing the SES of PNP. For instance, structural factors, such as poverty, create feedback loops in the SES – more poverty leads to more pressure on the ecosystems, and their degradation creates more poverty among the local population, which is highly dependent on the forest.

This study has gone some way towards enhancing our understanding of how PNP – as also other PAs – is outlined and driven by the dynamic processes of both the social and ecological systems as well as the interactions between them. In this regard, PNP has the opportunity to consider this research as an entry point to implement an adaptive management mechanism to promote sustainable tourism and to even propose a biosphere reserve along with other PAs and collaborative forests in the surroundings. In this regard, the following recommendations are proposed:

- **Adaptive governance**: It will be necessary for the park management to develop an adaptive governance system using the participatory approach and give due weightage to local ecological knowledge. It should be based on principles such as stakeholder engagement, transparency around decision-making, co-learning process, and building trust and strong social networks (Cumming & Allen, 2017, p.1715). Therefore, the study recommends the completion of the other two phases of the MARISCO method and the introduction of MARISCO permanently into the planning process of the park in order to prioritize the elements in the conceptual model, identify what needs to be monitored, and assess currently existing strategies which tackle the contributing factors, threats or stresses, which had been previously identified.

- **Transformational strategies**: It is necessary to transform development pathways towards a more sustainable model in Nepal. For instance, under Man and the Biosphere (MAB) Programme, it could be possible to establish the first transboundary biosphere reserve site in Nepal, within the forest complex of Parsa–Chitwan–Valmiki. Biosphere reserves allow the integration of social and ecological goals to ensure the sustainable use of natural resources. They use interdisciplinary approaches to understand and manage changes in social and ecological systems, and in their interactions, including conflict prevention and the conservation of biodiversity (UNESCO, 2017, p.12).

- **Evaluation and monitoring**: These activities are part of the adaptive management cycle. In particular, it would be important to monitor changes in the hydrological system such as: i) the river flow regimes in the Siwalik; ii) the groundwater storage; and iii) the rainfall and run-off patterns. Likewise, the monitoring of vegetation distribution and forest dynamics to understand the long-term changes in the forest ecosystem and to prevent or manage the expansion of invasive species.

- **Institutional synergies**: In order to enhance our understanding of the SES and to develop collaborative programmes with shared goals, it would be relevant to establish institutional arrangements with other stakeholders which are working in the surrounding area of the park or on strategic topics. Besides, to improve institutional cooperation among collaborative forests, Chitwan National Park, and Valmiki Tiger Reserve, as well as among landscape projects such as the Terai Arc Landscape programme and the Rastrapati Chure-Madhesh Programme.

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Annex

Annex 1: List of interviewees

S.N.	Organization/ Institution	Name	Position	Email	Phone number	Date of the interview	Location
1	Department of National Parks and Wildlife Conservation (DNPWC)	Gopal Prakash Bhattarai (*)	Deputy Director General (Joint Secretary)	snpwhs@gmail.com, gopal@dnpwc.gov.np	+977-9851004501, +977-9802039244 Office: +977-1-4227926	22 June	Babar Mahal, Kathmandu
2	Parsa National Park (PNP)	Birendra Kandel	Assistant Conservation Officer			2 July	Parsa
3	Parsa National Park (PNP)	Ashok Ram	Assistant Conservation Officer	ashokrink11@gmail.com	+977-9852054105	3 July	Parsa
4	National Trust for Nature Conservation (NTNC)	Shashank Poudel	Conservation Officer	pshashank@gmail.com		2 July	Parsa
5	National Trust for Nature Conservation (NTNC)	Pramod Raj Regmi	Natural Resource Conservation Assistant	regmiprr11@gmail.com	+977-9846113398	3 July	Parsa
6	National Trust for Nature Conservation (NTNC)	Aashish Gurung	Conservation Officer			4 July	Chitwan
7	National Trust for Nature Conservation (NTNC)	Chiranjibi Prasad Pokharel	Programme Manager			4 July	Chitwan
8	National Trust for Nature Conservation (NTNC)	Santosh Bhattarai	Conservation Officer	bhattarai.ntnc@gmail.com		5 July	Chitwan
9	National Trust for Nature Conservation (NTNC)	Babu Ram Lamichhane	Research Officer (Wildlife)	baburaml@gmail.com		5 July	Chitwan
10	Zoological Society of London (ZSL)	Dipendra Adlikari	Field Biologist	Dipenadk2005@gmail.com		2 July	Parsa
11	Zoological Society of London (ZSL)	Prakash Sigdel	Monitoring and Surveillance Officer	sigdelprakash07@gmail.com	+977-9841115642	3 July	Parsa

S.N.	Organization/ Institution	Name	Position	Email	Phone number	Date of the interview	Location
12	WWF-Nepal	Shiv Raj Bhatta	Deputy Director of Terai Arc Landscape Program-WWF Nepal	shiv.bhatta@wwfnepal.org	+97714434820 +977- 9801011505	22 June and 10 August	Baluwatar, Kathmandu
13	WWF-Nepal	Santosh Mani Nepal	Senior Director – Policy and Outreach	santosh.nepal@wwfnepal.org	+97714434820 Ext. 008	6 September	Baluwatar, Kathmandu
14	Rastrapati Chure-Madhesh Programme (RCMP)	Top Bahadur Shrestha	Under-secretary, MoFSC	shresthatop25@yahoo.com	+977-9841644473	10 August	Satdobato, Kathmandu
15	Buffer Zone User Committee (BZUC)	Amleshwor Group (**)				2 July	Parsa
16	Federation of Community Forestry Users Nepal (FECOFUN)	Ganesh Bahadur Karki (***)	Chairperson	karkign@gmail.com fecofun@wlink.com.np	+977-9851119561	22 August	Bhaktapur, Kathmandu
17	Federation of Community Forestry Users Nepal (FECOFUN)	Thakur Bhandari (***)	Committee Member	karkign@gmail.com fecofun@wlink.com.np	+977-9841516209	22 August	Bhaktapur, Kathmandu

(*) Short interview

(**) The interview was conducted in Nepali; therefore, the recording was translated into English by Trishna Bhandari. During the meeting, 10 people participated, all men.

(***) There was a person from FECOFUN (Shila Pokhrel) who helped with the interpretation of English–Nepali–English during the interview.

Annex 2: List of stakeholders

Institution/ Organization	Contact person	Email and other contact details	Office location	Type	Project/Programme/Study Linked to PNP
Ministry of Forests and Soil Conservation (MFSC)	(WWF-Chitwan)			Public institution	Terai Arc Landscape Nepal (in implementation phase of the strategic and action plan 2015–2025)
	Top Bahadur Shrestha Undersecretary, MoFSC	shresthatop25@yahoo.com	Satdobato, Kathmandu, Nepal		The Rastrapati Chure-Madhesh Programme http://rccp.gov.np/
			Babar Mahal, Kathmandu, Nepal		The REDD Implementation Center http://mofsc-redd.gov.np/
Department of Forests (DoF)		http://www.dof.gov.np/	Babar Mahal, Kathmandu, Nepal	Public institution	National Forest Management Programme
Department of National Parks and Wildlife Conservation (DNPWC)	Gopal Prakash Bhattarai, Deputy Director General (Joint Secretary)	snpwhs@gmail.com gopal@dnpwc.gov.np Skype ID: gopal.prakash.bhattarai +977-9851004501,+977-9802039244 Office: +977-1-4227926	Babar Mahal, Kathmandu, Nepal	Public institution	Protected Area Management Programme (PAMP) Protected Area: Parsa Wildlife Reserve http://dnpwc.gov.np/protected_areas/details/parsawildlifereserve Buffer Zone Development Programme (BZDP)
Tribhuvan University			Kathmandu, Nepal	Public university	Thematic research. E.g.: Central Department of Zoology
National Trust for Nature Conservation (NTNC)	Shashank Poudel, Conservation officer	pshashank@gmail.com	Parsa, Nepal Chitwan, Nepal Khumaltar, Lalitpur, Nepal	Semi-governmental conservation agency	Parsa Conservation Project (PCP): http://www.ntnc.org.np/project/parsa-conservation-project

Institution/ Organization	Contact person	Email and other contact details	Office location	Type	Project/Programme/Study Linked to PNP
International Centre for Integrated Mountain Development (ICIMOD)	Nabin Bhattarai, Special Services Agreement	Nabin.Bhattarai@icimod.org	Khumaltar, Lalitpur, Nepal	Regional research organization	REDD+: Biodiversity Monitoring Protocol http://www.icimod.org/?q=26994
	Niroj Timalsina	niroj.timalsina@icimod.org			Remote sensing analysis for REDD+
	Vishwas Sudhir Chitale, Remote Sensing Analyst – Ecosystems Geospatial Solutions	Vishwas.Chitale@icimod.org			Vulnerability of forest to climate change
	Nawraj Pradhan, Associate Coordinator, Kailash Sacred Landscape Conservation and Development Initiative	nawraj.pradhan@icimod.org			Springs
World Wildlife Fund (WWF)-Nepal	Shiv Raj Bhatta, Director – Field Programs	shiv.bhatta@wwfnepal.org Tel: +977 1 4434820 Fax: +977 1 4438458 Mobile 9801011505	Baluwatar, Kathmandu, Nepal	International NGO	Terai Arc Landscape (TAL) programme http://www.wwfnepal.org/about_wwf/where_we_work/tal/
					Transcending Boundaries for Tiger Recovery: The Chitwan–Parsa–Valmiki Complex in Nepal and India https://www.iucn.org/news/species/201707/chitwan-parsa-valmiki-complex-corridors-future-tigers
	Santosh Mani Nepal Senior Director – Policy and Outreach	santosh.nepal@wwfnepal.org Tel: +97714434820 Ext 008 Mobile: 9801015436			Hariyo Ban Program – WWF Nepal http://www.wwfnepal.org/hariyobanprogram/
International Union for Conservation of Nature (IUCN) - Nepal	Prahlad Thapa	prahlad.thapa@iucn.org Tel: +977 (1) 552 8781	Kupondole, Lalitpur, P.O. Box 3923, Kathmandu, Nepal	International NGO	www.iucn.org/nepal Transcending Boundaries for Tiger Recovery: The Chitwan-Parsa-Valmiki Complex in Nepal and India https://www.iucn.org/news/species/201707/chitwan-parsa-valmiki-complex-corridors-future-tigers
Zoological Society of London (ZSL)	Dipendra Adlikari, Field biologist Prakash Sigdel, Monitoring and Surveillance Officer	Dipenadk2005@gmail.com	Parsa, Nepal Bishal Nagar Marg, Kathmandu	International NGO	Securing the Future of Nepal's Tigers https://www.zsl.org/conservation/regions/asia/securing-the-future-of-nepals-tigers-0

Institution/ Organization	Contact person	Email and other contact details	Office location	Type	Project/Programme/Study Linked to PNP
Netherlands Development Organization (SNV)	Laxmi Dutt Bhatta (ICIMOD), Ecosystem Management Specialist – Ecosystem Services	laxmi.bhatta@icimod.org	Jawalakhel, Lalitpur	International Cooperation	BISEP-ST (Biodiversity Sector Program for Siwaliks and Terai) (2001–2006) WTLC (Western Terai Landscape Conservation Project) (until 2010)
German Corporation for International Cooperation (GIZ)	Kai M. Windhorst, Chief Technical Advisor (CTA)	Kai.Windhorst@giz.de Skype ID: kai.m.windhorst Cel: +977 – 985-1237188	Khumaltar, Lalitpur, Kathmandu	International Cooperation	Project: Developing and using experience in implementing REDD+ in the Himalayas https://www.giz.de/en/worldwide/26913.html
United Nations Development Programme (UNDP)				International Cooperation	Participatory Conservation Program – PCP (2002–2006)
Federation of Community Forestry Users Nepal (FECOFUN)	Ganesh Bahadur Karki, Chairperson Sunita Shrestha, Administrator	karkign@gmail.com Cell Phone: 9851119561 fecofun@wlink.com.np Tel: 01-6616408/6616421	Bhaktapur, Kathmandu	Federation/ Network	http://fecofun.org.np
Buffer Zone User Committee (BZUC)			Amleshwor, Parsa	Local organization	
Himalayan Nature (HN)		https://himalayannature.org/index.php/about-us/		International NGO	Field centre in Chitwan
Natural Resource Conflict Transformation Center-Nepal (NRCTC-N)		http://nrctc.org.np/about-us/		NGO	Conflict transformation approach
Development Project Service Center (DEPROSC) Nepal		http://www.deprosc.org.np/Home.aspx		NGO	Proyecto en Bara and Makahuanpur: http://www.deprosc.org.np/Programs/Ongoing_Projects/Microfinance_for_Women_Empowerment_(MWE).aspx
Tourism operators in Parsa National Park				Private sector	
Factories in the Buffer Zone				Private sector	Extraction of sand and gravel Extraction of groundwater

Annex 3: Main tree species in Parsa National Park

SN	Species name	Common name(1)	Familae(2)	Red List Category and Criteria(3)	Geographic Range(4)	Sources
1	Shorea robusta	Sal (English) Agrakh, sakhua, sal, sakwa (Nepali)	Dipterocarpaceae	Lower Risk/least concern	Native: Bangladesh, Bhutan, China, India, Nepal, Pakistan	(1) Orwa, C., A., Mutua, Kindt, R., Jamnadass, R. & S., Anthony. (2009). Agroforestree Database: A Tree Reference and Selection Guide. Version 4.0 http://www.worldagroforestry.org/treedb2/speciesprofile.php?Spid=1525 (2,3,4) Ashton, p.(1998). Shorea robusta. The IUCN Red List of Threatened Species 1998: e.T32097A9675160. http://dx.doi.org/10.2305/IUCN.UK.1998.RLTS.T32097A9675160.en. Downloaded on 16 June 2017
2	Acacia catechu	Betel-nut palm, black cutch, catechu tree, cutch tree, heartwood (English) Khair, khaira (Nepali)	Fabaceae	This taxon has not yet been assessed for the IUCN Red List	Native: India, Myanmar, Nepal, Pakistan, Thailand	(1,4) Orwa, C., A., Mutua, Kindt, R., Jamnadass, R. & S., Anthony. (2009). Agroforestree Database: A Tree Reference and Selection Guide Version 4.0 http://www.worldagroforestry.org/treedb2/speciesprofile.php?Spid=21
3	Dalbergia sissoo	Bombay blackwood, sissoo, Indian rosewood, sisso (English) Sissau, sisham (Nepali)	Fabaceae	This taxon has not yet been assessed for the IUCN Red List	Native: Afghanistan, Bangladesh, Bhutan, India, Malaysia, Pakistan	(1,4) Orwa, C., A., Mutua, Kindt, R., Jamnadass, R. & S., Anthony. (2009) Agroforestree Database: A Tree Reference and Selection Guide Version 4.0 http://www.worldagroforestry.org/treedb2/speciesprofile.php?Spid=645
4	Pinus roxburghii	Chir pine, long-leaved Indian pine (English) Khote salla, aule salla, rani salla (Nepali)	Pinaceae	Least concern	Native: Bhutan, China (Tibet, or Xizang), India (Assam, Himachal Pradesh, Jammu-Kashmir, Sikkim, Uttar Pradesh), Nepal, Pakistan	(1, 2, 3, 4) Farjon, A. (2013). Pinus roxburghii. The IUCN Red List of Threatened Species 2013: e.T42412A2978347. http://dx.doi.org/10.2305/IUCN.UK.2013-1.RLTS.T42412A2978347.en
5	Terminalia alata	Laurel, Indian laurel (English)	Combretaceae	This taxon has not yet been assessed for the IUCN Red List	Native: India, Myanmar, Nepal, Thailand	(1, 2, 4) Orwa, C., A., Mutua, Kindt. R., Jamnadass, R., S., Anthony. (2009) Agroforestree Database: A Tree Reference and Selection Guide Version 4.0 http://www.worldagroforestry.org/sites/treedbs/treedatabases.asp
6	Bombax ceiba	Silk cotton tree (English) Simal, semal (Nepali)	Bombacaceae	This taxon has not yet been assessed for the IUCN Red List	Nepal and India	(1, 2, 4) An Introduction about Bombax Ceiba Linn. https://www.academia.edu/1745048/Bombax_ceiba

Annex 4: Ecosystem services in Parsa National Park[1]

Section	Division	Group	Class
Provisioning	Nutrition	Biomass	Cultivated crops
			Reared animals and their outputs
			Wild plants and their outputs – e.g., fruit trees
		Water	Surface water for drinking (*)
			Groundwater for drinking
	Materials	Biomass	Fibres and other materials from plants and animals for direct use – e.g., edible plants, natural remedies, and medicines
			Materials from plants for agricultural use or building – e.g., leaves and thatch grass
			Genetic materials from all biota – e.g., wild elephants use for breeding domesticated ones
		Water	Surface water for non-drinking purposes (*)
			Groundwater for non-drinking purposes
	Energy	Biomass-based energy sources	Plant-based resources for energy – e.g., fuelwood
Regulation and Maintenance	Mediation of waste, toxics and other nuisances	Mediation by ecosystems	Filtration/sequestration/storage/accumulation by ecosystems
			Mediation of noise/visual impacts
	Mediation of flows	Mass flows	Mass stabilization and control of erosion rates
			Buffering and attenuation of mass flows
		Liquid flows	Hydrological cycle and water flow maintenance – e.g., recharging from Siwalik to Terai
			Flood protection
		Gaseous/air flows	Ventilation and transpiration
	Maintenance of physical, chemical, biological conditions	Life cycle maintenance, habitat and gene pool protection	Pollination and seed dispersal
			Maintaining nursery populations and habitats
		Soil formation and composition	Weathering processes – e.g., nutrient storage or soil structure
			Decomposition and fixing processes
		Water conditions	Chemical condition of freshwaters
			Micro and regional climate regulation

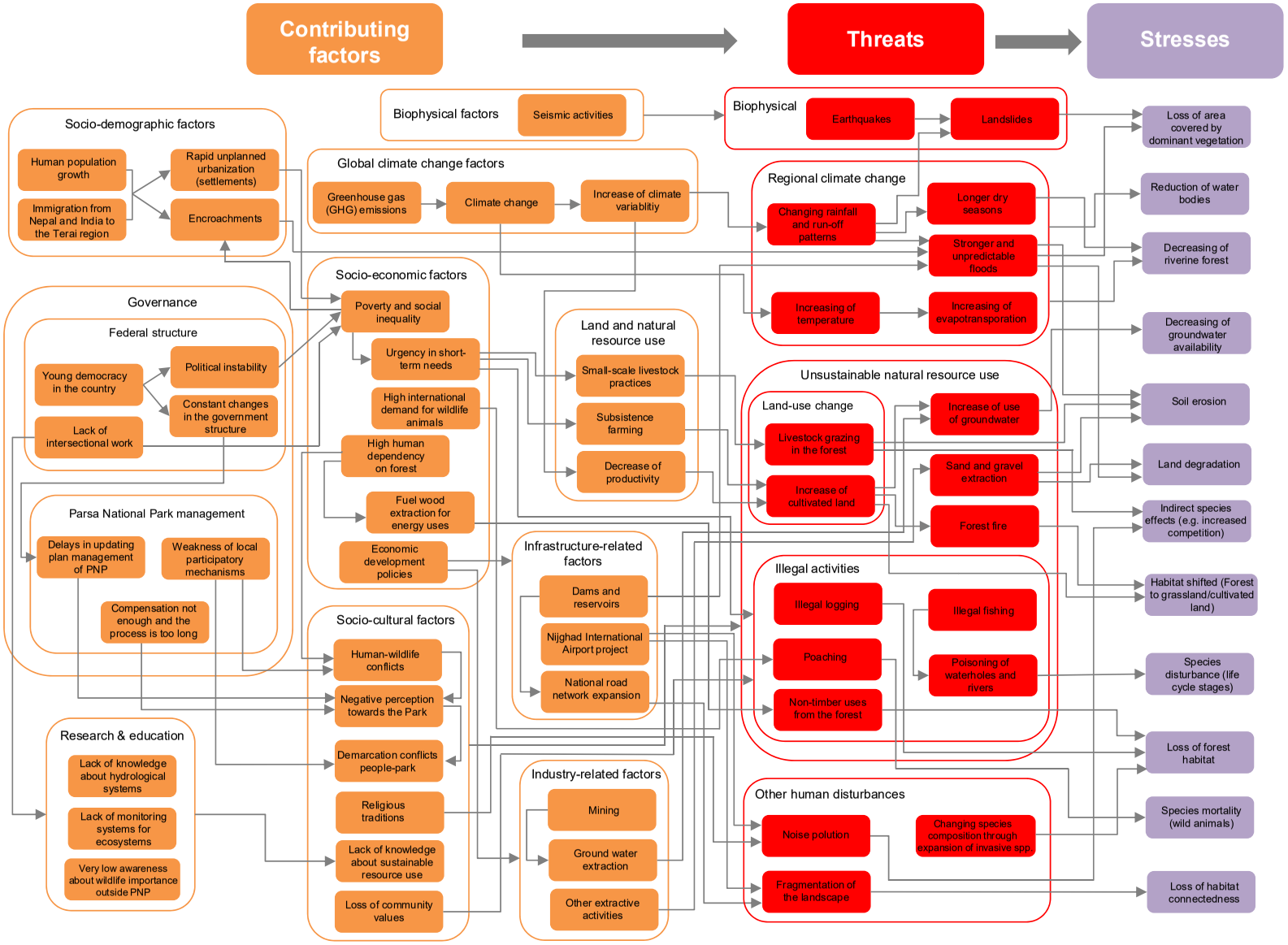
1 Elaborated according to the Common International Classification of Ecosystem Services (CICES). Further information in: https://cices.eu/

Section	Division	Group	Class
Cultural	Physical and intellectual interactions with biota, ecosystems, and land/seascapes (environmental settings)	Physical and experiential interactions	Experiential use of plants, animals and landscapes in different environmental settings – e.g., birdwatching
			Physical use of landscapes in different environmental settings – e.g., walking, hiking
		Intellectual and representative interactions	Scientific
			Educational
			Heritage, cultural
			Entertainment
			Aesthetic
	Spiritual, symbolic and other interactions with biota, ecosystems, and land/ seascapes (environmental settings)	Spiritual and/or emblematic	Symbolic – e.g., emblematic animals such as elephants and tigers
			Sacred and religious places – e.g., the Hindu temple in the core zone
		Other cultural outputs	Recreation for visitors or local people

(*) Some BZ areas do not have surface water resources and in other areas it is partially scarce.

Annex 5: Conceptual model

Conceptual model: Socioecological system of Parsa National Park – June 2018



Source: Elaboration based on desktop study, interview and validation workshop with stakeholders

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ISBN 978 92 9115 621 4