7 Biodiversity values of the Koshi Tappu Wildlife Reserve

Authors: Nakul Chettri[1], Sunita Chaudhary[1,2], Kabir Uddin[1], Bikash Sharma[1], Pratikshya Kandel[1], Top Bahadur Khatri[3], Maheswar Dhakal[4], Wu Ning[1], Eklabya Sharma[1]

7.1 Introduction

Biodiversity (the variability among the living organisms) and ecosystem services (the benefits people obtain from ecosystems) are declining worldwide (Vitousek et al. 1997, Hoekstra et al. 2005, Butchart et al. 2010), spurring scientists and policymakers to act together to identify effective policy solutions (Görg et al. 2010, Díaz et al. 2015). Recently, the recognition that these two forms of environmental change are inextricably linked is widely documented (Daily 1997, MEA 2005, TEEB 2010). They are also considered as products of coupled and nested social–ecological systems in which humans depend on biodiversity for the generation of goods and services that contribute to human wellbeing (MEA 2005, Daw et al. 2011, Reyers et al. 2013, Hicks et al. 2015).

The growing popularity of the ecosystem services concept can be seen primarily as a reaction to the long-term disconnect between biophysical and ecosystem integrity in societal systems, and also partly as a response to growing concern in relation to degradation of ecosystems that are the basis for providing these services (Boyd and Banzhaf 2007). This anthropocentric approach to biodiversity promotes new thinking about the contribution of the coupled system to human wellbeing (Costanza et al. 1987, Daily and Matson 2008, Scholes et al. 2013, Chaudhary et al. 2015c). In recent years, ecosystem services have also been recognized based on the ecological and social values separate to the economic values (Castro et al. 2014, Maes et al. 2016) and have been considered as an important factor for poverty alleviation where the dependency of people on ecosystems is much higher (Grêt-Regamey et al. 2012, Sandhu and Sandhu 2015, Suich et al. 2015).

Wetlands, which are well recognized for their significant role in supporting high biodiversity and providing food, water and livelihoods security to the people living around them (Rebelo et al. 2009), are subject to over-exploitation and continuous degradation (Gopal 2013, Lamsal et al. 2014). During the 20th and the beginning of the 21st century, about 87% of wetlands worldwide have already been lost compared to losses in the 18th Century (Davidson 2014). Of the remaining wetlands, more than 60% are being degraded or used unsustainably, especially from land conversion, pollution and over-harvesting (MEA 2005). This is a prominent issue in many developing countries, including Nepal, where people are highly dependent on natural resources, especially on wetlands, for their

1 International Centre for Integrated Mountain Development, Kathmandu, Nepal
2 Macquarie University, Department of Geography and Planning, Australia
3 Department of Hydrology and Meteorology, Government of Nepal, Kathmandu, Nepal
4 Ministry of Forests and Soil Conservation, Government of Nepal, Kathmandu, Nepal

subsistence livelihoods (Chettri et al. 2013, Chaudhary et al. 2015c, Lamsal et al. 2015). However, these wetland ecosystems, though some are designated and managed as protected areas, are considered as islands for biodiversity repository without linking them to the surrounding landscapes (Chettri et al. 2013, ICIMOD & MoFSC, 2014).

With these considerations, we have used a driver, pressure, state, impact and response (DPSIR) Framework following Pinto et al. (2013) to review the biodiversity and ecosystem services values and the socio-ecological linkages of the wetlands of the Koshi Tappu Wildlife Reserve (the Reserve), to understand the following key questions:

1. What is the significance of the Reserve in terms of its biodiversity value?
2. In what way does the Reserve support the local communities in terms of ecosystem services?
3. How is the surrounding Koshi Basin related to the Reserve for its sustainability?

Material and methods

To address the above research questions, we primarily relied on published literature available for the Koshi Basin with special reference to the Reserve. To answer the first question, major conservation values in terms of species of global significance and major fauna reported until 2013 were discussed along with recent analysis by Chettri et al. (2013). Likewise, the ecosystem services provided by the Reserve were included from the recent study by Chaudhary et al. (2014) and the economic values from Sharma et al. (2015). The third question regarding the state of the Basin in terms of risk to the Reserve was articulated from other basin-level studies (i.e. Neupane et al. 2013, Uddin et al. 2015, 2016).

Study area

Koshi Tappu Wildlife Reserve is one of the most important wildlife reserves of Nepal. The Reserve, a protected area established in 1976 under IUCN category IV, spreads over an area of 175 km^2 (IUCN 1990).

Before its declaration as a Reserve in 1976 by the Government of Nepal, the area was accessible to local communities for fishing, hunting, grazing, livestock, and collecting fodder, fuelwood, and other resources (CSUWN 2009). However, their access was restricted with the declaration of the Reserve, resulting in illegal harvesting of resources (Heinen 1993b). To halt illegal harvesting and meet the basic needs of people, the Reserve established a buffer zone of 173.5 km^2, encompassing 16 village development committees (VDCs) from Sunsari, Saptari, and Udayapur districts with a total population of 77,970 people from 10,693 households (Shakya et al. 2013). The overall literacy rate is less than 50% and agriculture is the dominant mode of production for just over 87% of households. Only 20% of households are food secure. Livestock density is very high with 1.5 cattle per household. The harvest and use of resources from this important floodplain play a prominent role in local people's occupations and way of life. Besides subsistence farming, livestock rearing is a major economic activity, and income from livestock contributes a substantial proportion of local household

income (Sah 1997, CSUWN 2009). A large proportion of communities still directly or indirectly depend on the Reserve for various goods and services (ICIMOD & MoFSC 2014).

Review framework

We used a driver, pressure, state, impact and response (DPSIR) Framework (Figure 7-1) to understand the coupled socio-ecological linkages in the Koshi Basin. The framework elements used to develop the linkages were taken from the published literature (e.g. Pinto et al. 2013).

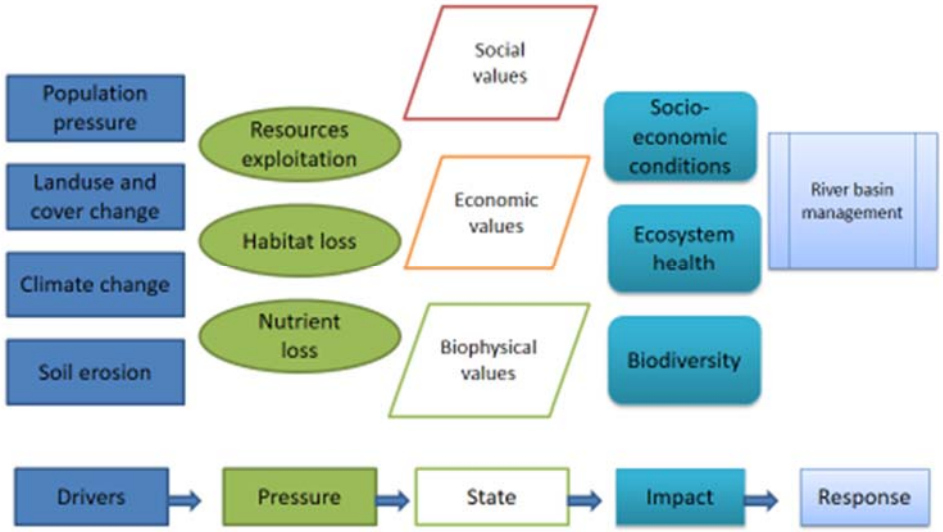

Figure 7-1 DPSIR Framework used to understand the coupled socio-ecological system in Koshi Basin. Drivers can include flow regime change, hydropower development, drought (for example)

7.2 Biodiversity and ecosystem outcomes

Biodiversity value

The Reserve was designated as a wetland of international importance by the Ramsar Convention in 1987 for its special value in maintaining the genetic and ecological diversity of the region (Sah 1997). Located in the floodplains of Sapta Koshi river, the Reserve is a freshwater, natural and permanent river system. The Reserve is rich in biodiversity with 670 species of vascular plants (Siwakoti 2006), 21 species of mammals (Chhetry and Pal 2010), 23 species of herpetofauna (Chhetry 2010), 77 species of butterflies (DNPWC 2009), 494 species of birds (BCN 2011) and is habitat for a large number of globally and nationally threatened species (CSUWN 2009). The Reserve is also designated as one of the Important Bird Areas of Nepal with habitat for a number of endangered bird species. The wetland is also home to Ganges River Dolphin (*Planatnista gangetica*), Gharial crocodile (*Gavialis gangeticus*) and Smooth coated Otter (*Lutrogale perspicillata*). These globally important species play a vital role in maintaining the ecological integrity of the area.

A land cover/ecosystem and habitat matrix indicated that the majority of species use a wide variety of land cover or ecosystems and in many cases they are overlapping (Chettri et al. 2013). For example, Rock Python (*Python molurus)*, Red-crowned Roof Turtle (*Batagur kachuga*), Yellow-headed Tortoise (*Indotestudo elongata*), Greater Adjutant (*Leptoptilos dubius*) and Swamp Francolin *(Francolinus gularis*) were reported from more than three land cover types or ecosystems. Many

species have narrow habitat ranges. Gharial Crocodile (*Gavialis gangeticus*) and Mugger (*Crocodylus palustris*) were restricted to swamps/marshes and river/lakes. In a matrix analysis (Table 7-1), swamps/marshes scored the highest species number with 15, followed by forest (14), river and lake (13) and grassland (12) and the least by agriculture (2). It was observed that forested ecosystems of the Reserve are one of the most important habitats used by 15 globally significant species followed by rivers/lakes and grassland. These matrix ranking values were then converted to raster maps prepared for land cover of 2010 to show their potential richness (number of species) to each of the ecosystems types defined earlier (Figure 7-2).

Table 7-1 Species Habitat Matrix of the Koshi Tappu Wildlife Reserve, Nepal.● indicates the species has been recorded as occurring in that land cover/use (Source: Chettri et al. 2013)

Species	Status*		Land cover / land use					
	IUCN	CITES	Grass land	Swamps /marshes	Forests	River /lakes	Sand/ gravels	Agri-culture
Wild Water Buffalo (*Bubalus arnee*)	EN	III	●	●		●		
Ganges River Dolphin (*Platanista gangetica*)	EN	I				●		
Black Giant Squirrel (*Ratufa bicolor*)	NT	I	●		●			
Hog Deer (*Axis porcinus*)	EN	I	●		●			
Smooth coated Otter (*Lutrogale perspicillata*)	VU	II		●	●	●		
Fishing Cat (*Prionailurus viverrinus*)	EN	II		●	●	●		
Asian Elephant (*Elephas maximus*)	EN	I	●	●	●			
Indian Bison or Gaur (*Bos gaurus)*	VU	I	●		●			
Spotted Leopard (*Panthera pardus*)	NT	I	●		●			
Gharial (*Gavialis gangeticus*)	CR	I		●		●		
Mugger *(Crocodylus palustris)*	VU	I		●		●		
Rock Python *(Python molurus)*	NT	II	●	●	●	●	●	
King Cobra (*Ophiophagus hannah*)	VU	II	●	●	●			
Red-crowned Roof Turtle *(Batagur kachuga)*	CR	II	●	●	●	●		
Yellow-headed Tortoise *(Indotestudo elongata)*	EN	II	●	●	●	●		
Indian Softshell Turtle *(Nilssonia gangetica)*	VU	I		●		●		
Greater Adjutant *(Leptoptilos dubius)*	EN			●	●	●		●
Pallas's Fish Eagle *(Haliaeetus leucoryphus)*	VU	II		●	●	●		
Bengal Florican *(Houbaropsis bengalensis)*	CR	I	●	●				
Swamp Francolin *(Francolinus gularis)*	VU	III	●	●	●	●		●

(*) Status
IUCN (International Union for Conservation of Nature). CR=Critically Endangered; EN=Endangered; NT=Near Threatened; VU=Vulnerable
CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) status. (Appendix) I = species that are threatened with extinction; II = species not necessarily threatened with extinction, but may become so if trade is not regulated; III = species listed by one member country to request other countries to assist in controlling their trade

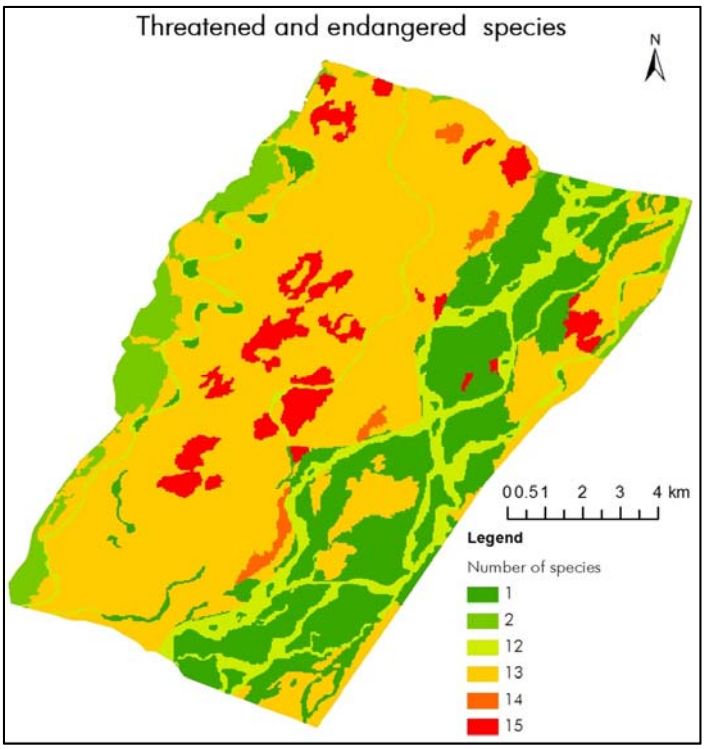

Figure 7-2 Map showing distribution and habitat use pattern by 20 threatened species in the Reserve (Source: Chettri et al. 2013)

Social value

There is high dependency of local people on the ecosystems of the Reserve and it has important social values. Of the forest products, firewood is the top dependent product of the reserve where 91% of the local populations are dependent. The dependency for thatch (dry wild grass) is the second highest (82%) followed by timber (54%), then grasses (51%). (Figure 7-3). Likewise, people are also dependent on wetland ecosystems such as rivers/streams and swamps/marshes for a variety of goods and services such as fish (38%), driftwood (31%), pater (*Typha angustifolia L.*) (30%) and snails (23%). The dependency chart (Figure 7-3) clearly shows how much the local people are dependent on the products of the Reserve. Not only contributing to their subsistence livelihoods, the collection of these products also contributes to the local economy thus reducing poverty in the area, also reported by Rayamajhi (2009).

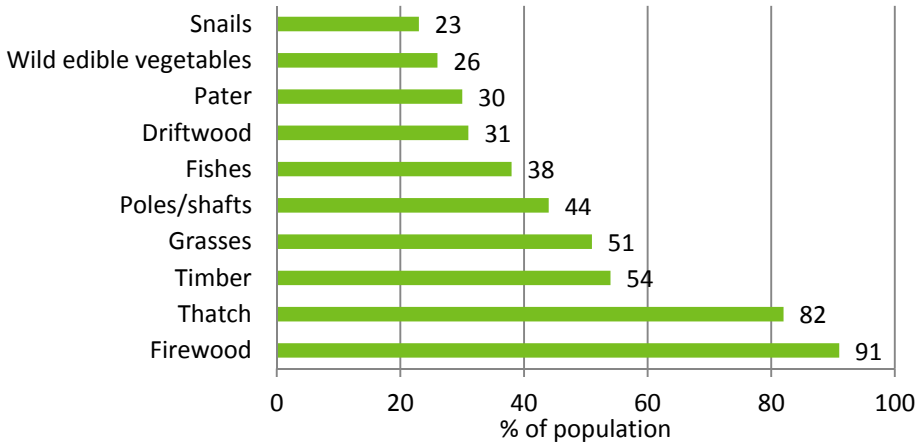

Figure 7-3 Dependency on products from the Reserve (Source: Chaudhary et al. 2014)

The listed ecosystem goods and services, which were categorized into social and cultural services, revealed that swamps/marshes, forest, river/lakes and agriculture are sources for a range of ecosystem goods and services on which the local people are highly dependent. River/lakes and swamps/marshes are the most productive ecosystems for provisioning services with 24% scores each followed by forest (21%), grassland (13%) and agriculture land (11%) (Figure 7-4). It is also interesting to note that the river/lakes covering 10% of the total area of the Reserve, and swamps/marshes with 12% of the total land area, have high capacity to provide social services to the

people (Figure 7-4). Similarly, forest land with about 8% coverage has an equally high capacity in comparison to other land uses with a greater area in the Reserve. This means that the land use with less coverage has intense pressure from the people due to higher dependency as well as due to high production capacity. Similarly, the dependencies of local people on cultural services of the Reserve have also been analysed and similar results were found (Figure 7-4). The forested areas, swamps/marshes and grassland are the most valuable for these services for the local people. However, it was observed that the cultural and supporting scores are lower than the other two services mainly due to fewer variables used to score these services.

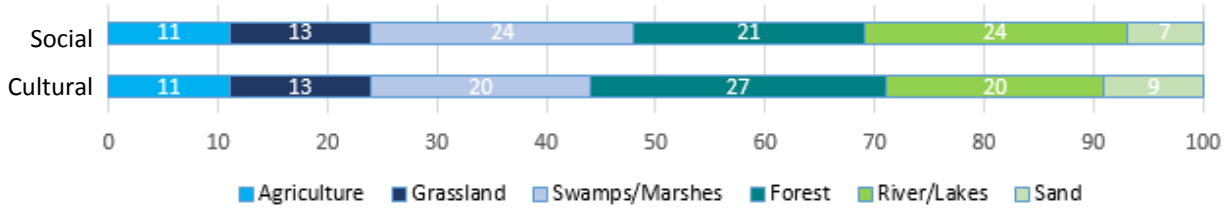

Figure 7-4 The subsistence values supporting socio-economic development: Social and dependency for cultural practices; and Cultural services being provided by each ecosystem of the Reserve (Source: Chaudhary et al. 2014)

Economic values

The overall economic benefit generated from the major types of provisioning, regulating, and cultural services assessed was estimated to be approximately USD 16 million per year (Table 7-2; NRP 1.38 billion) (see Sharma et al. 2015), equivalent to around USD 959 per household per year (based on a total of 16,710 households residing in the buffer zone) or about USD 916 per ha (based on a total the Reserve area of 17,500 ha). This translates to a net present value (NPV) of around USD 444 million, estimated from the future benefit over a period of 60 years at an assumed discount rate of 3% and constant flow of current benefit (i.e., no degradation and depletion of current benefit).

Table 7-2 Aggregate economic value of wetland ecosystem services provided by the Koshi Tappu Wildlife Reserve (Source: Sharma et al. 2015)

Ecosystem services	Total value (USD/yr)	Average value/ha/yr (USD)	Value /ha/yr (USD)	% share of total ecosystem services assessed
Provisioning services	$13,675,225	$818.4	$781.4	85.3%
Regulating services	$1,152,003	$68.9	$65.8	7.2%
Flood control/prevention	*$952,075*	*$57.0*	*$54.4*	*5.9%*
Carbon sequestration	*$199,928*	*$12.0*	*$11.4*	*1.2%*
Cultural services -ecotourism	$1,201,216	$71.9	$68.6	7.5%
Total economic value	**16,028,444**	**$959.2**	**$915.9**	**100.0%**

This estimation demonstrates the long-term economic value of the Reserve (Stuip et al. 2002). Clearly, the economic benefit generated from provisioning services ranks first in terms of contribution to estimated total economic value (85%), followed by recreational services from tourism (7.5%), and regulating services from flood control and carbon sequestration (7.2%). The benefits of different services accrue to different stakeholders. For example, the benefits of provisioning services accrue entirely to the local people, while the benefit of the regulating services

such as carbon sequestration goes to the global communities. Even though many of the ecosystem services do not enter directly into household income, the finding that a large part of the estimated total value of the wetland ecosystem services accrues locally is a clear manifestation of the vital importance of these wetland ecosystem services for the livelihoods of the local people. Ensuring a sustainable flow of these ecosystem services is therefore critical for supporting the local livelihoods and protecting the global significance of the Reserve as a Ramsar site.

7.3 Challenges and opportunities

In the Koshi Tappu Wildlife Reserve, the sources of socio-cultural services are mostly coming from rivers, swamps and forest ecosystems. This is obvious as forest and wetland ecosystems are the most productive ecosystems in terms of providing services (Biswas et al. 2010, Gopal 2013, Lamsal et al. 2015). This is very much relevant in the Reserve as dependency of local people on forest and wetland ecosystems is substantial as other alternatives for energy and livelihood options are limited (ICIMOD & MoFSC 2014, Sharma et al. 2015). It is also evident that wetland ecosystems in any human dominant landscapes have higher dependency of local people (e.g. Ambastha et al. 2007, Lamsal et al. 2014).

The Reserve has witnessed significant changes in its ecosystems over the last three decades. The changes are manifested by human pressure (Chettri et al. 2013), climate change (Agarwal et al. 2014, Bharati et al. 2016, Rajbhandari et al. 2016b); land use and land cover change (Chettri et al. 2013, ICIMOD & MoFSC 2014, Uddin et al. 2016) with loss of habitat for many aquatic and terrestrial species (Chettri et al. 2013). Interestingly soil loss from different land cover classes (Uddin et al. 2016) and higher vulnerability (Neupane et al. 2013) are bringing numerous challenges to the Reserve and the Basin. Some of the major challenges are on water availability, ecosystem vulnerability and poor adaptive capacity of the people living in the buffer zone of the Reserve and the basin (Bharati et al. 2016). Thus, the natural and human activities are bringing various management challenges in the Reserve as also reported by others in the region (Chettri et al. 2013, Lamsal et al. 2014). It is evident that the forest ecosystem is strongly linked to wetland ecosystems and plays an important role as an interface (Kollár et al. 2011). It was observed that some of the critical ecosystems such as forest have significantly changed during the past three decades. The land use and land cover changes, through anthropogenic or natural processes, bring visible changes in ecosystem functions of a given ecosystem, leading to a decrease in its capacity to provide services (Crossman et al. 2013, Baral et al. 2014). The dynamic nature of mosaic ecosystems is important, i.e. its change through time – however, if any of the ecosystems are lost beyond their threshold level, then that will have an irreplaceable impact on the society dependent on such ecosystems (Gopal 2013, Davidson 2014).

Unfortunately, due to human use and their changing capacities to provide services there is a common challenge faced by wetland ecosystem to thrive (Zhoali and Wu 2005, Deka et al. 2011, Romshoo and Rashid 2014). Apart from the Reserve, even the Koshi Basin has been witnessing changes in its ecosystems (Uddin et al. 2016). Such spatio-temporal change and the use of geospatial tools have been instrumental in understanding the dynamic nature of ecosystems (e.g. Rebelo et al. 2009, Chettri et al. 2013). Though the Government of Nepal has been proactively working with the local communities for participatory conservation and management of the Reserve (CSUWN 2009, MoFSC 2011), the dynamic nature of ecosystems needs special attention for management interventions as the fate of the Reserve is directly linked to the ecosystem health of the Basin. Therefore, understanding the monetary and non-monetary values, including people's dependency

on the ecosystem services and the dynamics of the ecosystems itself, could be highly beneficial for implementing adaptive management measures. This may further improve the flow of ecosystem services and management of the reserve.

7.4 Summary

Biodiversity and ecosystem services are declining worldwide. Wetlands, which are well recognized for their significant role in supporting high biodiversity and providing food, water and livelihood security to the people living around them, are subject to various drivers of change with continuous degradation. With increasing evidence of climate change and other drivers of change in the Koshi Basin, the Koshi Tappu Wildlife Reserve seems to be highly vulnerable.

The Reserve is an important repository of biodiversity and ecosystem services, especially for the local communities. The present review revealed that the Reserve is an integral part and strongly influenced by the Koshi Basin and any subtle change in the Basin results in direct impacts on the Reserve. Being aware of this vulnerability and the changes reported, we recommend to the planners and managers to take urgent and necessary measures for conservation of the Reserve by providing a better understanding of the catchment for sustained environmental flow provision, which will otherwise have detrimental consequence to remaining biodiversity of the Reserve.

As it seems that habitat degradation within the Reserve is also caused by river course change related to high sediment loads and occasional flash floods, a river basin management approach is recommended as a prerequisite to various management and planning activities to aid holistic understanding. It has assumed greater importance in view of the shrinkage and degradation of ecosystems and associated biodiversity values and human sustenance

Acknowledgements

We express our gratitude to Dr David Molden, the Director General of ICIMOD, for his inspiration and providing the required facilities. We are also thankful to the Ministry of Forests and Soil Conservation, Government of Nepal, and Conservation and Sustainable Use of Wetlands of Nepal (CSUWN) for their support and cooperation. Financial support received from MacArthur Foundation, and German Society for International Cooperation (GIZ) including its core donors: the Governments of Afghanistan, Australia, Austria, Bangladesh, Bhutan, China, India, Myanmar, Nepal, Norway, Pakistan, Switzerland, and the United Kingdom is highly appreciated. The views and interpretations in this publication are those of the authors and they are not necessarily attributable to their organizations.

We appreciate the constructive comments of the reviewers – Prof Ram P Chaudhary (Research Centre for Applied Science and Technology (RECAST), Tribhuvan University, Kathmandu); and Dr Heather McGinness (CSIRO Land and Water, Canberra, Australia) which helped us to enhance the quality of the chapter.

Except where otherwise indicated, photographs in this chapter have been provided by the authors.