Chapter 1
Opportunities and Advances to Mainstream Nature-Based Solutions in Disaster Risk Management and Climate Strategy

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Abstract There has been tremendous advancement around the world in terms of conceptualisation, research, implementation and policy uptake for Nature-based Solutions (NbS) to address and reduce the severity of disaster risk and climate vulnerability. There has been growing momentum in ongoing international policy dialogues to understand, include and facilitate implementation of NbS. This book includes scientific articles and study reports drawing from research-based knowledge and experience by professionals from the diverse fields of science, policy and practice to enrich the existing knowledge base on effectively implementing NbS especially highlighting its potential in using ecosystems and ecosystem services for climate change adaptation and reduction of disaster risk. Some of the highlighted evidences in this book are from mountains, wetlands as well as urban built environments. The thematic and cross-cutting chapters that the book comprises share scientific evidence that further support and emphasise the prospective ability of NbS to create co-benefits that include environmental, economic and social benefits. NbS has the potential to help achieve and localise goals and targets proposed in international agreements related to biodiversity conservation, disaster risk reduction,

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climate change adaptation, and mitigation to name a few. Apart from an introduction of NbS and its application in disaster risk management and development of climate change strategy, the present chapter also offers a synopsis of the chapters in the book.

1.1 Introduction

Human civilisation is facing wide-ranging challenges, from pressures on ecosystems to human well-being and rapid depletion of natural capital, resulting in increased risk of disasters and compromised food, water and energy security (Faivre et al. 2017). Countries across the world are increasingly exposed to growing disaster risks due to loss of ecosystem services and emerging climate vulnerability (Peduzzi 2019). Increasing disasters such as droughts, floods, landslides and land degradation not only degrade ecosystem services but also affect human lives and economic growth of nations (Renaud et al. 2016; Botzen et al. 2019). Climate change is a pressing challenge that the global community is facing today, with its noteworthy influence on ecosystem functioning and human well-being (van der Geest et al. 2019). Well-managed, healthy and diverse ecosystems are crucial for human existence and well-being, resulting in resilient and prosperous social structures (Diaz et al. 2015). Ecosystems have a proven ability to mitigate climate vulnerability and protect communities by reducing the intensity and impact of disasters (Lo 2016). NbS, as a novel concept, was introduced by the International Union for Conservation of Nature (IUCN) to endorse the benefits that nature brings in as important solutions to meet challenges of climate vulnerabilities (Cohen-Shacham et al. 2016).

Growing awareness of NbS and its wise application can help safeguard people against the severity of climate change impacts by reducing additional surface warming, improving biodiversity and reinstating ecosystem services (Seddon et al. 2020a). NbS facilitates judicious utilisation of natural resources for human well-being with minimum impact on the surrounding environment. Since 2015, when the European Commission presented the European Union (EU) research and innovation policy agenda for NbS and developing green infrastructure of cities in Horizon 2020 (European Commission 2015) that was later followed by IUCN (Cohen-Shacham et al. 2016), incredible progress has been made in NbS research, related policies and field-based implementations. Some of these original concepts and ideas were discussed at a workshop on ‘Ecosystem Management, Nature-based Solutions and Sustainable Development Goals (SDGs)’ co-organised by the IUCN India office, New Delhi, at CSIR-National Environmental Engineering Research Institute (CSIR-NEERI), Nagpur, India, and at the South Asia Regional chapter of the Commission on Ecosystem Management of IUCN in New Delhi, on December 2014. The workshop had dedicated discussion on ecosystems management and NbS to address emerging challenges of climate vulnerability and increasing frequencies of extreme climate events and disasters.

There were four important sessions with focus on:

1. Evidence and ground-based examples of NbS implementation.
2. Scientific, Indigenous and Local Knowledge (ILK) and tools for field implementation of NbS.
3. Innovative institutional arrangements for NbS.
4. New pathways for mainstreaming NbS in policies and decision making processes: transformative approaches in resilience building.

Chapters in this book are authored by key participants of this workshop as well as from experts specially invited based on their distinct work experience. As a concept, NbS received immense global attention and recognition after 2015 in terms of its importance for achieving and localising major global agreements related to climate change (UNFCCC), biodiversity (CBD), wetlands (Ramsar), sustainable development goals (SDGs, 2015) and land degradation (UNCCD) (European Commission 2015; Cohen-Shacham et al. 2016, 2019; Nesshöver et al. 2017; Albert et al. 2017; Fernandes and Guiomar 2018). The Sendai Framework for Disaster Risk Reduction 2015–2030 emphasises on NbS as an important strategy for climate change adaptation, mitigation, disaster risk reduction and strengthening of community and ecosystem resilience (Arce Mojica et al. 2019; Ruangpan et al. 2020). These solutions were also acknowledged as part of the Paris Agreement (UNDP 2019; Seddon et al. 2020b) and Ramsar convention targets (Nagabhatla 2018). NbS has been considered useful for helping to achieve the SDGs set by the UN General Assembly in 2015 (Keesstra et al. 2018a, b; Seifollahi-Aghmiuni et al. 2019; Sørup et al. 2019).

Ecosystems and ecosystem services emanating from the application of NbS play a pivotal role in reducing disaster vulnerability and developing resilience. It offers noteworthy approaches through ecosystem and biodiversity-based interventions that are cost-effective and discourage intensive use of engineering structures (Sahani et al. 2019). NbS helps achieve sustainable development by reducing climate risks through adaption and mitigation strategies that are well recognised by experts, featuring in various recent international dialogues and agreements (Fig. 1.1).

In the last few years, there have been considerable efforts to understand the potential multi-functionality of NbS and to enhance its benefits for improving human well-being across the world (Keesstra et al. 2018a). NbS includes diverse concepts such as green infrastructure, ecological engineering, ecological restoration, forest landscape restoration, area-based conservation, ecosystem-based management, natural infrastructure, ecosystem-based adaptation, ecosystem-based disaster risk reduction, ecosystem-based mitigation, climate adaptation services and many similar ideas, which have emerged or are being further developed in recent years to address emerging societal and development challenges especially climate change, water security, food security, human health, disaster risk and socio-economic development (Cohen-Shacham et al. 2016). Restoration of degraded landscapes using natural practices has proved to be more sustainable and effective than engineering solutions, as it involves the natural course of matter and energy flow with solutions based on local and traditional knowledge that includes the understanding of periodic changes in ecosystems (Meli et al. 2014). NbS has emerged as a sustainable and

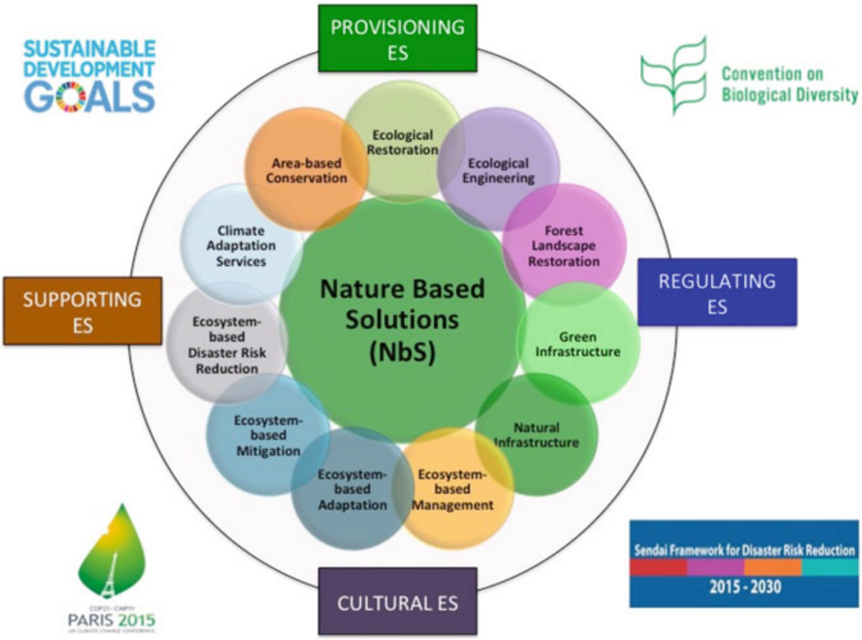

Fig. 1.1 NbS uses ecosystem services for achieving community resilience and helps realise the goals and promises of international agreements and national goals and targets [Adapted from: Keesstra et al. 2018a]

efficient approach for rehabilitating degraded ecosystems and reducing climate and disaster risks (Temmerman et al. 2013; Nel et al. 2014), as proved by established field-based experiences.

Recent years, however, have seen diverse definitions of NbS. The multiplicity of concepts and different definitions create problems of conceptual clarity making the term more subjective and unrealistic (European Commission 2015; Cohen-Shacham et al. 2016; Albert et al. 2017). There have been discussions on developing criteria that can help implement and reinforce NbS, while mainstreaming it in policy discourse to address societal challenges (Albert et al. 2017). These include benefits to local communities, the environment as well as to the economy. There is also a need to understand the concept from a trans-disciplinary approach that includes natural infrastructure in engineering structures, nature's contribution to socio-economic landscapes, as well as physical landscape functions from environmental planning perspectives (Diaz et al. 2015; Albert et al. 2017). Further, there is a need to introduce NbS and provide enough time to cautiously assess its applications on ground level and how they can be further refined.

With fast advancement of various NbS concepts, its integration and mainstreaming in policies and field-based implementation projects, it is imperative to understand and take stock of the lessons from NbS implementation from practical point of views. The main purpose of this book is to report successful NbS experiences from Asia in general and South Asia in particular, to be presented at the IUCN World Conservation Congress on 'One Nature, One Future' in France and the landmark UN biodiversity conference, 'Ecological Civilisation: Building a Shared Future for All Life on Earth' in Kunming, China. The book captures the essence of established examples of NbS from South Asia, where years of experience of local communities in tackling and addressing climate and disaster risks have either been ignored or have not received due consideration. In the forthcoming subheadings of the chapter, we will deliberate on concept of NbS by showcasing how the concept has been endorsed in scientific research and field-based implementation over the last few years. The chapter will provide an understanding of the importance of scientific advances of NbS in natural (forest, mountains) and human modified (urban green spaces) ecosystems. Opportunities, new pathways for transformative development of NbS and entry points in sectoral policies, instruments and business continuity perceptions and practices are argued in the last chapters (Gupta et al. Chap. 23 and 24).

1.2 Nature-Based Solutions (NbS)

The concept of NbS has been discussed in all chapters of this book. The scope and definition for NbS is broad, and the core highlight is on augmenting the resilience of ecosystems and communities by building back the natural stock against traditional engineered approaches (Cohen-Shacham et al. 2016). It has been well defined as engagements stimulated by or sustained by impersonating nature to support people in ecological, societal and financial tasks through sustainable ways. Evolution in the archetypes of decreasing disaster vulnerability and adapting to climate change in a framework that is continuously shifting from 'response and relief' to 'mitigation and preparedness' has appealed a lot of attention to NbS, which is a fairly new concept. It is defined as an umbrella term covering an assortment of approaches to adapt and mitigate climate impacts and reduce disaster risks (Jones et al. 2012). All the NbS definitions proposed in this book highlight the vital importance of managed, diverse ecosystems that help build human resilience and well-being by protecting and creating healthy ecosystems. NbS as a term involves a group of solutions grounded on natural practices and ecosystem services to resolve diverse societal challenges. Climate mitigation and adaptation approaches of NbS are of particular importance in addressing disaster risks and climate-related challenges (Kalsnes and Capobianco 2019) that are surging past technical abilities. It is well aligned with ideas of adaptive or natural systems agriculture (Dubey et al. 2019), natural solutions (Dudley and Stolton 2003; Lopoukhine et al. 2012; Dudley et al. 2018), ecosystem-based approaches (Renaud et al. 2016), green infrastructures (Andersson et al. 2014; Kopperoinen et al. 2014) and ecological engineering (Dhyani and Dhyani 2016; Dhyani and Thummarukuddy 2016).

In the late 2000s, the World Bank first introduced the NbS approach (MacKinnon et al. 2008) for promoting ecosystem-based methodologies in their projects to address climate vulnerability and increasing disaster risks. The concept was first used by the European Commission (EC) in their Horizon 2020 research programme for its uptake and promotion in growing urban sprawls to institute Europe as the world leader in NbS, but the notion was not well defined by the EC. The EC has expressed NbS as, '…*living solutions inspired by, continuously supported by and using nature, which are designed to address various societal challenges in a resource-efficient and adaptable manner and to provide simultaneously economic, social, and environmental benefits* (European Commission 2015; Maes and Jacobs 2017)'. Ecosystem-based adaptation (EbA), urban natural infrastructure (UNI), urban green infrastructure (UGI) and ecosystem services (ESS) were regularly discussed in theoretical arguments and have been progressively included and mainstreamed in policy making (Pauleit et al. 2017).

NbS is a way to adapt to climate change and mitigate impacts of climate change, secure clean water, food, fodder and energy demands, and reduce socio-economics by driving economic growth (Balian et al. 2014; Cohen-Shacham et al. 2016). IUCN has been spearheading NbS in UN climate dialogues and negotiations, to halt and reverse the trend of biodiversity and ecosystem loss, while developing core principles and principles for successful application and upscaling of NbS (Cohen-Shacham et al. 2016, 2019). The term is not only restricted to dialogues and discussions on ecosystem services and natural capital build-up, it has been regularly used to provide information related to soft engineering practices that increase resilience from disasters and climate change (Marton-Lefevre 2012; van Wesenbeeck 2014). IUCN defines NbS as, '…*actions to protect, sustainably manage and restore natural or modified ecosystems, that address societal challenges (e.g. climate change, food and water security or natural disasters) effectively and adaptively, while simultaneously providing human well-being and biodiversity benefits* (WCC-2016-Res-069-EN) (Cohen-Shacham et al. 2016)'.

According to the IUCN, the predominant aim of NbS is to sustain the success of societal goals of development to protect well-being of society in means that redirect cultural and societal standards and enhance the resilience capacities of ecosystems, as well as their capability for regeneration along with improving provision of services. Maes and Jacobs have defined NbS as, '*Transition to use ecosystem services with reduced inputs of non-renewable natural capital and enhanced investment in renewable natural processes* (Maes and Jacobs 2017)'. Eggermont et al. have deliberated three significant characteristics of NbS: a) no or nominal external interferences in ecosystems, b) interferences in managed ecosystems that involve multi-functionality and sustainability for establishment, and c) expansion of natural ecosystems to foster green and blue setups to recover the flow of variety of ecosystem services (Eggermont et al. 2015). These methods have been materialised from a range of domains (some from scientific investigation fields, others from customary or policy frameworks) but allocate a mutual emphasis on ecosystems and ecosystem services to tackle socital challenges. NbS statement by the EC's professional group (European Commission 2015) listed 310 actions that include: safeguard and growth of forests to absorb gaseous contaminants, plantation of wind breaks for soil protection, creation and protection of urban green spaces and planning green roofs for various co-benefits viz. biodiversity conservation, improving carbon sinks and flash flood management as examples (Kabisch et al. 2017).

In our introductory chapter, to be precise, we have used the acronym, NbS, to emphasise the role of NbS to enhance the capability of communities and ecosystems to adapt to climate change and disaster risk reduction and management. Therefore, we define NbS as *the conservation, sustainable management and restoration of ecosystems as per site-specific natural and cultural contexts by engaging communities to build community and ecosystem resilience against climate adversaries and disaster risks and achieving equitable sharing of sustainable and resilient development dividends*.

It is to be noted that authors of succeeding chapters of this book have been free to detail and use the term and concept of NbS that best describes their study or work.

1.3 Global Recognition and Acceptance of NbS

Climate adaptation and resilience building play a synergistic role in developing strategies for addressing impacts of growing climate vulnerability to ecosystems and societies. Resilience building is considered to be an inherently nature-based approach for enhancing the capacity of communities and ecosystems to adjust to current risks and future uncertainties.[1]

Nature-based solutions are projected and endorsed as alternatives to grey engineering/concrete structures, viz. protection walls from rivers and seas as well as irrigation or drainage structures. While in reality there is an array of approaches that include both ‘grey-green’ interventions (hybrid solutions), the evidence base for NbS is still growing. However, it has been observed that NbS can offer low-risk and cost-effective solutions to hazards created due to climate change and are beneficial over engineered solutions. Though engineering structures provide instant and quantifiable impacts to reduce immediate threats, they are many times costlier and do not have the ability to deliver co-benefits; whereas NbS are inexpensive and, if appropriately implemented, can bring many co-benefits such as livelihood opportunities (Andersson et al. 2017) including making the engineering structures more resilient and long lasting. The Paris Climate Agreement clearly identifies the role of nature to address the adverse impacts of climate change. Calling on all parties, the Paris Agreement acknowledges the significance of safeguarding ecosystems and conservation of biodiversity. This view has been explained and endorsed at high-level policy dialogues and national commitments mainly in the form of Nationally Determined Contributions (NDCs) submitted by parties to the Paris Agreement to UNFCCC (Seddon et al. 2019, 2020b).

[1] https://www.undp.org/content/dam/nepal/docs/projects/EbA/UNDP_NP_EbA%20Project%20Document.pdf

Considerable research work are available to show the potential of NbS in making the climate change strategies and actions plans to provide over 1/3 of the total cost-effective climate adaptation and mitigation needed by 2030. Such work can reduce climate warming well below 2 °C to achieve nature's mitigation potential of 10–12 gigatonnes of CO_2 per year (Environment UN 2017; Griscom et al. 2017). In total, more than 65% of the parties of the Paris Agreement have included NbS to achieve their NDCs. A total of about 103 countries have highlighted at least one or more type of NbS actions for achieving adaptation constituent of NDC, while 27 nations have highlighted NbS in achieving their climate mitigation targets (Seddon et al. 2019, 2020a, b).[2] Such an impressive global acceptance of NbS as a noteworthy adaptation tool is a welcome move. National intent to use and deliver NbS, however, will differ by diverse levels of financial conditions, state boundaries and their natural resources affecting the translation and achievement of robust targets-based on-the-ground actions (Seddon et al. 2020a). Cohen-Shacham et al. (2019) presented the core principles for successfully implementing and upscaling NbS. IUCN has developed global standard for NbS by involving all stakeholders including governments, non-governmental organisations, practitioner communities, private sector and financial institutions. For developing global standard for NbS, a public consultation was carried out in 2018–2019 to create common understanding and consensus. Draft NbS standards are composed of seven criteria broken into several indicators. The standards planned to be launched at the upcoming World Conservation Congress will accompany a verification tool that will help define to what extent a project can be considered as NbS, as per the IUCN framework (Cohen-Shacham et al. 2016, 2019). Watkin et al. proposed an agenda for evaluating benefits of NbS that will help to mainstream infrastructure choices (Watkin et al. 2019) (Fig. 1.2). This framework can be adapted to suit different national situation in South Asia region using multiple conceptualisation of values—taking into consideration of both direct and indirect benefits. This is extremely important since unlike other regions, in South Asia economic and short-term benefits are given much higher priority which disadvantages NbS.

Başoğlu et al. proposed an urban-scale life cycle assessment (LCA) as a broad valuation tool to assess the potential and success of NbS (Başoğlu et al. 2018). This approach uses urban metabolism as a predominant methodology to model the urban ecosystem. Undertaking a dynamic valuation using time series data helps to identify the hotspots of key indicators considered within a definite time frame.

In the subsequent sections, a few contemporary scientific progresses of NbS are additionally presented to describe how the process has helped restore degraded landscapes, growing urban sprawls and mountain ecosystems for adaptation to climate change and disaster risk management.

[2] https://www.NbSpolicyplatform.org/

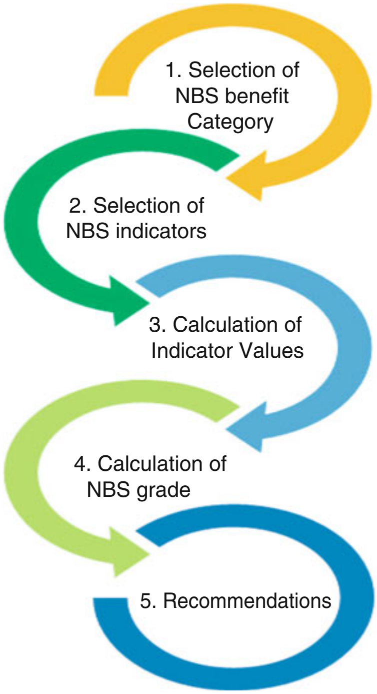

Fig. 1.2 (Watkin et al. 2019) Outline for Evaluating Benefits of Realised NbS

1.4 Progress and Developments in NbS on the Science Front

1.4.1 Restoration of Degraded Landscapes and Natural Forests for Increasing Ecosystems Resilience

The vigour and efficiency of global land capitals have been rapidly declining, with increasing demand of land resources. Land degradation neutrality (LDN) targets to preserve or improve land-based natural assets and allied ecosystem services (Chasek et al. 2017). Land degradation across the world has negatively affected more than 3.2 billion people and costed more than 10% of the annual global gross product (GGP) due to massive loss of biodiversity (Pandit et al. 2018; IRP 2019) (Fig. 1.3). Most policy documents highlight only physical degradation of land focusing on erosion due to water and landslides, and chemical degradation of land, due to point contamination such as organic and inorganic contamination, etc. Other common sources of degradation such as compaction, soil subsidence, loss of organic matter and biodiversity are usually not considered, though they affect the natural, social and economic spheres.

The Intergovernmental Panel on Climate Change (IPPC)'s special reports on 'Climate Change and Land, 2019' and Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES) report 'Land Degradation Assessment, 2018' have highlighted the seriousness of land degradation in global discussions. The

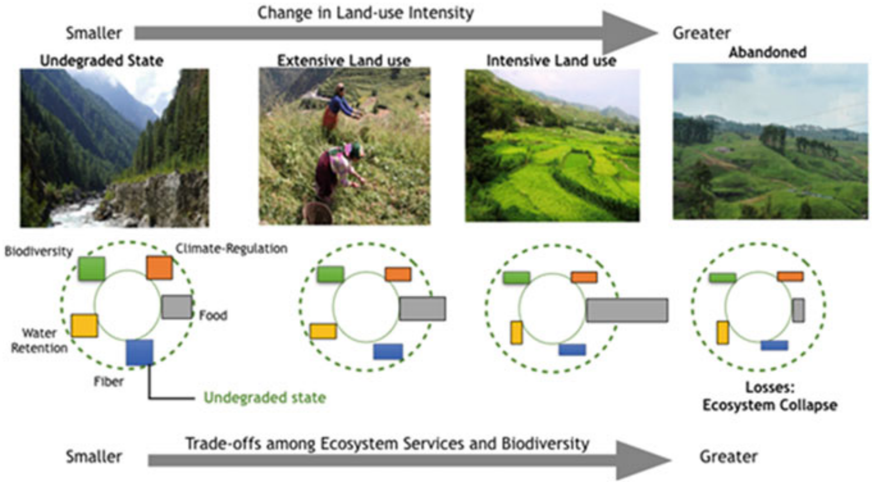

Fig. 1.3 Change of land-use intensity leading to degradation and trade-offs in ecosystem services and biodiversity (adapted from IPBES Land Degradation Assessment 2018)

rehabilitation of land is a crucial approach to improve resources, services and ecosystems (Keesstra et al. 2018b). Decision makers at all levels are facing the pressing need to protect the remaining forests and restore deforested and degraded landscapes. NbS has been observed to work at the interface of both socio-economic systems and ecosystem, and it helps and reduces the vulnerability of the socio-ecological system by developing community and building ecosystem resilience by protection, restoration and judicious management of ecosystems (Seddon et al. 2020a). A comprehensive meta-analysis on the global conservation drivers of forest restoration success, including 221 landscape study areas, disclosed that forest rehabilitation improves biodiversity by 15–84% and vegetation structure by 36–77% in comparison to degraded ecosystems (Crouzeilles et al. 2016). Decision makers and policy planners have demonstrated inspiring political will and determination to achieve ambitious global targets (Bonn Challenge and Paris COP 2015) through the restoration process, declaring 2021–2030 as the UN decade on Ecosystem Restoration (Chazdon et al. 2017; Chazdon and Guariguata 2018; Lewis et al. 2019). Considering the scale of restoration of degraded landscapes, the opportunity to re-vegetate a large part of degraded landscapes and natural forests is enormous for adapting to and mitigating climate change (Lewis et al. 2019). Few on-ground instances of successful implementation of NbS across the world are:

- Thailand, Indonesia and Philippines are employing large-scale mangrove restoration exercises to reverse the effects of such degradation, especially from increasing storm surges, cyclones and typhoons and other coastal disasters (Furuta et al. 2016), while improving blue carbon, livelihood and other benefits for the coastal communities.

- Considering the restoration of 2 billion ha of degraded ecosystems for the global economy, a systemic approach of four returns (financial capital, employment or social capital, biodiversity and ecosystem services or natural capital) resulting in human well-being or inspirational capital, in three landscaping zones (natural, mixed, along with an economic zone), for a period of 20 years to scale up landscape restoration for creating a restoration industry by corporates could also (Ferwerda 2016) be followed for involving corporates in mass-scale restorations.
- Six strategic ecological restoration projects were launched in China in the late 1970s. Total annual Carbon (C) sink from 2001 and 2010 was assessed to be 132 Tg C/year, and more than half of it (74 Tg C/year, 56%) was a result of six projects, which depicted that ecological rehabilitation missions in China has helped to meaningfully increase carbon sink across the country (Lu et al. 2018).
- In Canada the effect of ecosystem-scale rehabilitation and restoration in a peatland developing season CO_2 exchange was carried out that determined that the place was a clear sink of $\sim 20 \pm 5$ g C m^{-2} during the developing season only 2 years post restoration, and the degraded peatland ecosystem was to revert to a net carbon sink in 6–10 years of post-restoration itself (Waddington et al. 2010).
- Ecological restoration can help in moderating flood hazards, but this has hardly been the major goal of restoration. Nilsson et al. have provided evidences for ecological restoration which have been helpful in managing inland flood hazards (Nilsson et al. 2018).
- Ecological restoration has been proven to help in slope stabilisation and landslide prevention while also giving other co-benefits to communities (Xu et al. 2019). Restoration degraded slopes in Nepal to landslide stabilisation (Devkota et al. 2019) and restoration of wastelands in Central Himalayas, India (Dhyani and Dhyani 2016), helped in reducing deforestation and addressed women's drudgery.
- The Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) of the Government of India, considered one of the biggest payment of ecosystem services (or PES), uses NbS (116) and works through more than 200 direct and indirect activities including restoration that supports biodiversity conservation, restoration at landscape level and the livelihood of the rural poor.
- Proposed 103 NbS inclusive NDCs by the signatories of the Paris Agreement are managing, protecting and restoring terrestrial ecosystems, especially forests (41%), followed by management, protection and restoration of coastal ecosystems (28%), and catchment area treatment of rivers and wetlands (28%). In addition, agro-forestry was included in 23% of the relevant NDCs (47% of

NDCs by African countries) along with a few sporadic instances from mountain ecosystems (4%) and grasslands (10%).[3,4]

- A study based on people's perception suggests that models related to restoration or ecological engineering of river highlight the significance of re-wilding and re-naturising to develop capacity of riverine ecosystems for their rejuvenation (Han and Kuhlicke 2019).

All these examples highlight the cause-effect connection amid ecosystems and disaster risk management that can be confined to the area. There are various factors, which can reduce the risks of an impending disaster by incorporating NbS. However, grounded on these comprehensions and many empirical evidences not being reviewed and included, numerous technical guidelines, standards, criteria and indicators on NbS are currently being developed. Five of the total chapters in this book deliberate on the role of restoration in DRR, climate adaptation and mitigation in varying details.

1.4.2 NbS to Manage Heat Islands and Flood Risks in Urban Areas

Global urbanisation has resulted in high population densities in hazard and risk-prone areas (Andersson et al. 2017). Urban resilience and NbS approaches based on ecological ideologies are being pushed to be included in urban planning and climate change-related actions (Suárez et al. 2018). There is growing acceptance of NbS due to increasing disaster risks in urban areas (Dhyani et al. 2018) that the interaction of probable impacts of climate variability and growing uncontrolled urban expansions will bring severe stress on urban planning and water management. NbS and resilience have been endorsed as balancing approaches in urban planning to counter the problem of global warming (Suárez et al. 2018). Decreasing urban green cover and increased built up and concretisation of surface are resulting in increased city temperatures and heat islands, coupled with decreasing ground water recharge (Lahoti et al. 2019). Cities across the world are already facing issues with drainage systems, increasing flash flooding, life-threatening heat stress and droughts (Liu et al. 2014; Majidi et al. 2019). To solve challenges of growing urban sprawls especially climate vulnerability, human health and well-being, existing policy dialogues are shifting the attention from ecosystem-based solutions to NbS (Raymond et al. 2017).

The prospective of introducing NbS (green infrastructure, natural infrastructure, urban green spaces, urban forests, ecological engineering, urban agriculture,

[3]https://wedocs.unep.org/bitstream/handle/20.500.11822/29988/Compendium_NBS.pdf?sequence=1&isAllowed=y

[4]https://www.conservation.org/docs/default-source/publication-pdfs/guide-to-including-nature-in-ndcs.pdf?sfvrsn=99aecda2_2

Eco-DRR, EbA, etc., to name a few) into urban planning is being acknowledged by academicians, scientists, urban planners as well as policy makers as approaches that can deliver cost-effective and sustainable results for climate adaptation, mitigation and DRR (Armson et al. 2013; Dhyani and Thummarukuddy 2016; Raymond et al. 2017; Dhyani et al. 2018, 2019). Some research findings have showed benefits of NbS implementation in urban areas that include improving air quality (Calfapietra et al. 2015), urban biodiversity (Connop et al. 2016; Tan and Jim 2017; de Oliveira and Mell 2019), heat islands (Makido et al. 2019), urban floods reduction (Majidi et al. 2019), and addressing other cross-cutting challenges like urban sustainability (Perez and Perini 2018), public health and well-being (Bennett et al. 2015).

Some of the significant examples of NbS approach to manage urban heat islands and storm water management are:

- Research findings by Liu et al. on the use of community-scale simulation models endorsing the importance of green infrastructure (GI) in reducing the impact of urban flooding by reducing the volume and peak flow of urban flooding. The study shows that the capacity of single GI to reduce urban flooding is not sufficient to address larger rainstorms, and integrated GIs have better impact for augmenting the benefits. The study notes that grey infrastructure (trenches and catch basins, channels and concrete drains) commonly used for managing urban floods does not offer the co-benefits that come with NbS (Watkin et al. 2019).
- Reynolds et al. assessed CO_2 sink potential, sequestration and emission offsets by trees in urban public green spaces in the Medellin Metropolitan Area, Colombia, and projected it as a potential of viable NbS for the Neotropics (Reynolds et al. 2017). They mentioned that if available space for plantations is considered, carbon offsets may be much more inexpensive, bringing many co-benefits including socio-economic upliftment. Nowak et al. and Zheng et al. have supported the role of trees in carbon sequestration of urban and community areas in the United States (Nowak et al. 2013; Zheng et al. 2013).
- Yao et al. demonstrate how urban and peri-urban green areas, tree and shrub cover have noteworthy and encouraging impact on tree and shrub carbon, while tree and shrub density have even greater impact (Yao et al. 2017). This approach can be used to quantitatively recognise the less discovered fundamental necessities between drivers and ecosystem services.
- Surveys show that lined parks along city waterways improved thermal well-being and helped in developing community resilience in Cyprus (Giannakis et al. 2016).
- The Chinese Government is working on the Sponge City model in Beijing for managing flood risks in urban areas. The programme was launched in 2015 and it is based on NbS principles, to address urban flash flood issues by natural infiltration, retention and detention, and natural cleaning (Li et al. 2017; Zhang et al. 2018; Qiao et al. 2019).
- A study carried out by Govindarajulu (2014) on urban green space design for climate adaptation in Indian urban sprawls supports the NbS approach to address climate variability and vulnerability challenges for developing Asian countries (Govindarajulu 2014). Padigala, Imam and Banerjee have also provided

inferences on how depleting green spaces in urban sprawls in India will jeopardise ecosystem benefits for India's urban citizens (Padigala 2012; Imam and Banerjee 2016).
- The exploration of the flood in Benevento, Italy, in 2015 offered an overview on NbS approaches that helped to accomplish three specific aims, i.e. reducing impermeable plains, preventing further sealing of soil and recuperating the ecosystem (Galderisi and Treccozzi 2017).

A framework mechanism based on more than 1700 research papers within and across ten prominent societal challenges globally for evaluating the costs and co-benefits of NbS was developed (Raymond et al. 2017). Recent research on benchmarking NbS and smart city assessment schemes with reference to liveability against the SDG indicator framework is important to mention as well. A study revealed that strategic approach in selection of an NbS assessment scheme that carefully supports one or more sub-goals of urban SDG 11 can actually exploit functional proficiency by developing synergies amid assessment schemes (Wendling et al. 2018).

Though promoting NbS in urban areas will be an important concern, there is growing consideration on this issue in international administrative dialogues and agreements due to lack of availability of sufficient financial support for its implementation. Public expenses on NbS will be important to understand and address owing to limited municipal self-sufficiency (Droste et al. 2017). Mainstreaming NbS will need larger partnerships amongst diverse policy areas, sectors and stakeholders. It will require multi-stakeholder partnerships, leadership from private sector and required citizen involvement, to support and enhance benefits from NbS applications in urban areas (van Ham and Klimmek 2017).

1.4.3 Slope Stabilisation and Reducing Landslide Risks

Mountain regions across the world suffer from governmental and economic negligence and less prioritised attention because of their remoteness and marginalities. However, they are immensely vulnerable to climatic and demographic alterations[5] (Gioli et al. 2019; Krishnan et al. 2019). Hindu Kush Himalayan Mountains are no exceptions. Progressive warming at higher altitudes has been reported to be up to three times higher than the global average. Climate and other global changes are creating tremendous uncertainties in the mountain ecosystems. In the Hindu Kush Himalayan (HKH) region, rapid warming is evident in scientific observations of increased snow, glacial melt and the frequency of extreme events not limited to devastating floods and droughts. These have further exacerbated the more local problems of poverty and hunger.

[5]https://NbS2017.eu/wp-content/uploads/2017/12/NBS2017_AbstractBook_211217.pdf

Landslides result in human casualties and loss of property across the world. With expansion of human activities in mountainous areas and changing global environment, the frequency of landslides has increased (Lin et al. 2017). Global warming has destabilised mountain slopes and has enhanced landslide risks. Global increase of landslides has been mainly been referred to uncontrolled degradation of ecosystems and deforestation, leading to extensive land-use changes including urbanisation (Dhyani and Dhyani 2016). Moreover, permafrost melts and water percolation deeper into mountains crags, extreme rain and snowstorms trigger hazardous landslides, mudslides and rock falls.[6] Studies on estimation of loss due to landslides in mountain areas have received immense attention. Papathoma-Köhle et al. (2015) developed an integrated approach for the assessment and documentation of exposure and damage. It was observed that most of the existing research evidences on NbS carried out in China, USA or Europe primarily focus on slope stability and use of vegetation, along with several similar terms used for NbS (Arce Mojica et al. 2019). Protection of forests that target minimising shallow landslide hazard and related slope stabilisation is one of the several instances of using the potential role of vegetation to reduce disaster risk by building community resilience (de Jesús et al. 2019).

Some significant examples of NbS that help slope stabilisation and reduction of landslide risks in a warming planet are:

- Eco-engineering as a hybrid NbS approach has been applied in combination with civil engineering and plantation of deep-rooted plants for slope stability and drainage support in Panchase region in Nepal (Devkota et al. 2019). This approach can help in long-term sustainability of rural roads using community-based and inter-disciplinary research. Eco-safe rural road assessment framework developed is a well-organised procedure for design, construction and maintenance of eco-safe rural roads (Devkota et al. 2019).
- Klima 2050 [Centre for Research-based Innovation (SFI) supported by the Research Council of Norway for risk reduction through climate adaptation] provided novel NbS for landslide protection, including essential and significant approaches to ensure protection from flood and storm water (Kalsnes and Capobianco 2019).
- The Fodder Bank Model used fast growing high biomass yielding fodder trees, shrubs and grasses in upper Kedarnath valley in Uttarakhand, India, to reduce rural women's drudgery and the region's deforestation by aiding slope stabilisation, reducing land and mudslides during the 2013 Himalayan Tsunami (Dhyani et al. 2011; Dhyani and Dhyani 2016; Dhyani and Thummarukuddy 2016).
- Landslide risk is becoming progressively regular in Sri Lanka, where there is a growing awareness of opting for NbS or hybrid approaches for landslide risk management against pure engineering solutions (Bank 2019).

[6] https://insideclimatenews.org/news/26092018/climate-change-mountains-landslide-hazard-thawing-permafrost-rockfall-extreme-weather-glaciers-global-warming

- In Nepal a compilation of 28 ecosystem and community-based adaptation work at scale established that by altering vital characteristics of a system in response to climate change and its effects, NbS benefited larger population in a better way by means of multiple skills and good local governance. Scaled-up ecosystem-based adaptation influences policy, capital structure, awareness, practice and capacity using evidence and knowledge. These NbS typologies indicate the following co-benefits: (a) social and professional networking, (b) knowledge, information and best practice sharing, (c) local innovation in community mobilization and tapping local government finances and (d) improved governance of climate change adaptation resources. NbS therefore can address multi-dimensional vulnerability towards a resilient state. Peer learning, learning through practice and inclusive knowledge management can transform capacity development and technology transfer (Spotlight, Nepal; June 12, 2019).[7]
- Debele et al. presented a comprehensive classification of outline, key features and essentials required for designing NbS for alleviating the adverse effects of hydrometeorological hazards (HMHs) including landslides in Europe (Debele et al. 2019).
- The First International Conference on 'Landslides Risk Reduction and Resilience, 2019' in New Delhi, India, highlighted the importance of NbS in stabilising slopes and reducing landslides.[8]
- The Natural Forest Protection Programme (NFPP) to naturalise and stabilise slopes by promoting the alteration of agriculture fields to forest as well as orchards under the Sloping Land Conversion Program (SLCP) remain important soil bioengineering NbS to restore degraded slopes in China and have been very efficient examples from Asia (Stokes et al. 2010).
- Sloping Watershed Environmental Engineering Technology (SWEET) is an excellent example of NbS, where natural resources are managed by using simple and appropriate technological interventions to reduce landslide hazards in Indian Himalayan Region (IHR) (Maikhuri et al. 2011).
- Arce Mojica et al. evaluated more than 13,000 research papers (over 2000–2018) and finally evaluated 275 for NbS. The assessment reflected that though NbS is being promoted in many policies, there is still not enough research-based evidences of the subject. However, the efforts have increased over the past decade and will require more trans-disciplinary studies to reduce shallow landslide reduction using NbS (Arce Mojica et al. 2019).
- The proceedings of the first International Eco-Engineering Conference of September 13–17, 2004, brought research advances on ecological and ground bioengineering experiences by using plants to help landslide risks and slope stabilisation (Stokes et al. 2010). Studies reflected different characteristics of the multidisciplinary aspects of NbS. It included mechanisms and modelling of root structure and characters (Wu 2007) to develop the decision support in slope

[7] https://www.spotlightnepal.com/author/new-spotlight-online/

[8] https://nidm.gov.in/PDF/pubs/Final_Abstract_book.pdf

stabilisations. Experiences from Italy (Bischetti et al. 2007), biotechnical characters of Mediterranean region (Mattia et al. 2007), Southern England (Norris 2007), role of protection forests and trees in slope stabilisation in Iran (Bibalani et al. 2007), slope stabilisation in Iwate prefecture in Japan (Nakamura et al. 2007) and indigenous riparian plant root system of New Zealand (Marden et al. 2007) are few important mentions of the role of plants and vegetation in significantly reducing disaster risk and slope stabilisation. Dupuy et al. (2007) carried out a numerical analysis to understand the role of soil and root architecture in the stability of trees. 'SLIP4EX' used by Greenwood (Greenwood 2007) and image stress analysis procedure by Hamza et al. (2007) are a few important scientific advances using cutting-edge technological tools, which are presented in the book (Stokes et al. 2010).
- Example of agro-forestry helping locals of Burundi in improving slope stabilisation, landslide reduction and local livelihood transformation using NbS under an important project funded by Birdlife International, MacArthur Foundation and The Nature Conservancy remains an important instance of NbS from the ground.[9]

With a detailed review of available work and research, NbS seems to be more descriptive (Cohen-Shacham et al. 2016; Faivre et al. 2017; Keesstra et al. 2018b; Arce Mojica et al. 2019) with different terms such as restoration, ecological and ground engineering, natural and green infrastructure and agro-forests. The varied instances from different parts of the world with community inputs only point to the increasing prominence of NbS.

The NbS examples and advances based on review of examples from different natural ecosystems, viz. mountains, forests and coasts, reflect the growing interest and momentum for NbS among scientists, practitioners, governments as well as international organisations and policy makers. However, there is a need for more relevant cutting-edge science and engineering tools, along with ILK-based knowledge systems for mitigating and reducing risks and resilience building. Further developments, field-based experiences and recommendations as a way forward for NbS are provided in different chapters of the book.

1.5 Structure of the Book

This book includes 23 chapters that are further distributed into four core sections, which include this introductory chapter and conclusion chapter by Gupta et al. (Chap. 23) that present the way forward, and further deliberates on the emerging challenges of the core themes cited in the beginning of the chapter.

[9]https://www.birdlife.org/africa/news/transforming-livelihoods-through-nature-based-solutions-burundi

Part I of this book entitled, ‘Decision-Making Tools for Mainstreaming NbS’, is a collection of seven chapters. Tambe et al. (Chap. 2) present an overview of the revival of natural springs in the Indian Himalayan Region (IHR) and discuss the NbS framework for springshed revival in the context of depleting water resources in the Himalayas. Experiences and lessons from the successful initiative of community participation for spring rejuvenation using NbS in Sikkim are the major focus of the chapter. Wagley and Karki (Chap. 3) make the case on Integrated and Participatory Watershed Management (IWM) to address protected landscape management challenges in Nepal, by providing an overview of best practices and field-based experiences. Baral and Rahman (Chap. 4) provide an overview of the food, energy and environment trilemma in Indonesia, offering an outline of NbS considerations that can help achieve a balance in this warming world. The chapter by Kumar and Saluja (Chap. 5) presents how wetlands can be used as buffers to address water-mediated risks. This chapter brings instances of water-mediated risks from India and explores opportunities for using wetlands as efficient buffers. Chapter 6 by Barlett outlines the importance of using community perspectives in understanding the ecosystem services for land-use planning before NbS applications. Participatory ecosystem system services assessment in data deficient areas and for remote and fragile ecosystems is a growing tool that can help the mainstreaming of NbS. Kumar and Ghosh (Chap. 7) bring insights from fast-growing megacities in Asia and their water management woes. The chapter outlines the importance of integrating NbS for improving water management for developing resilient cities of the future. Finally, in Chap. 8, Bhattarjee throws light on Forest Landscape Restoration (FLR) experiences as a prominent NbS approach for achieving the Bonn challenge pledge. The chapter focuses on efforts and examples of FLR from India and its wider benefits for ecosystems and communities.

Part II of the book, titled ‘Evidence and Examples of NbS Implementation’, comprises five chapters. The opening chapter by Ramesh and Ghosh (Chap. 9) presents a case from an important protected area along the Indo-Burma border. The chapter highlights the NbS approach, especially FLR, which has helped in restoration of armed conflict landscapes for DRR. Chapter 10 by Kinley and Norbu showcase the co-benefits of NbS (restoration and protection of wetland and riparian ecosystems) in Bhutan that have helped conserve the habitat of threatened black-necked cranes and white-bellied herons. Srivastava et al. (Chap. 11) provide additional incentives for reducing risk of high-altitude wetlands due to climate change by using Remote Sensing (RS) and Geo-Information System (GIS) tools in mapping and monitoring. In Chap. 12, Bhatt et al. provide a framework of restoration of waste and degraded community lands in IHR. This chapter involves an array of successful scientific and people-centric approaches that have helped restore large landscapes in the Himalayas. The last chapter of Part II (i.e. Chap. 13) by Tewari et al. outlines the co-benefits of NbS enabled land restoration by using appropriately transferred technologies in strengthening capacities of the indigenous community of Van Rajis in India.

Part III, titled ‘Advanced Institutional Provisions and Policies for NbS’, is composed of five chapters, with the opening chapter by Dalwani and Gopal (Chap. 14) highlighting and reviewing the need of freshwater ecosystems and how

NbS can help rejuvenate lakes and wetlands across India. Lahoti et al. (Chap. 15) talk about the situation of growing urban sprawls and increasing risks associated with hazards. The chapter outlines the role of green infrastructure, especially urban forests and urban green spaces, for addressing the risks and building urban resilience. Chapter 16 by Dubey et al. addresses the importance of NbS for ensuring food and nutritional security for a growing population. Kumar and Singh (Chap. 17) bring instances from agro-forestry practices and their importance in reducing deforestation, degradation and safeguarding rain-fed areas. Finally, Chap. 18 by Adhikari et al. provides an overview of the importance of various trees, shrubs and herbs in slope stabilisation and reducing landslide risks in the Eastern Himalayas, which have been sensitive to extreme climate events, especially floods and landslides. The chapter integrates the role of plants as an efficient soil binder to address the erosion problem.

Part IV, titled 'Insights to Research Innovations in NbS', is composed of five chapters. Dhyani et al. (Chap. 19) review the importance of including habitat suitability modelling tools, along with NbS as an effective combination to realise the targets of the Bonn challenge in South Asia. In Chap. 20, Das and Sarkar bring forth the importance of ecosystem services of wetlands with special focus on the carbon sink potential of the Barak river basin in North East India. Chapter 21 by Saikia et al. highlights the importance of forests and how depletion of forest ecosystem services will increase the risks that can be addressed by NbS. In the last two chapters (Chaps. 22 and 23), Gupta et al. provide a detailed overview of NbS as entry points in sectoral policies, economic instruments and business partnership, along with how new pathways are required for localising and achieving SDGs as a transformative approach in resilient building.

Through this book volume, the authors anticipate good response from wide ranging readership stimulating constructive critiques, insightful and forward looking professional discussions on the pros and cons of NbS as well as identification of new research issues, effective implementation and enhanced mainstreaming of NbS to improve the understanding and applicability of different types of NbS in addressing intractable sustainable development challenges. Finally, wider application of NbS for disaster risk reduction and climate change adaptation would help countries meet their NDC targets.

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