Helping nature help us

Transforming disaster risk reduction through ecosystem management

Fabiola Monty, Radhika Murti and Naoya Furuta

Global Ecosystem Management Programme

Convention on Biological Diversity

Japan Biodiversity Fund

CEM

Helping nature help us

Transforming disaster risk reduction through ecosystem management

Fabiola Monty, Radhika Murti and Naoya Furuta

Convention on Biological Diversity
Japan Biodiversity Fund
CEM

This publication has been produced with funding from the Japan Biodiversity Fund under the Convention on Biological Diversity.

Published by: IUCN, Gland, Switzerland

Citation: Monty, F., Murti, R. and Furuta, N. *Helping nature help us: Transforming disaster risk reduction through ecosystem management*. Gland, Switzerland: IUCN. vi + 82 pp

Contributors: Milena Berrocal, Kevin Lloyd, Bora Masumbuko, James McBreen, Milika Naqasima Sobey, Mine Pabari, Karen Podvin, Shreema Rana, Anshuman Saikia and Alberto Salas

ISBN: 978-2-8317-1821-7

DOI: http://dx.doi.org/10.2305/IUCN.CH.2016.15.en

Cover photos: Nor Yauyos Cochas Landscape Reserve in Peru © IUCN/ Doris Cordero

Back cover photos: Vietnam © Li Migura

Designed by: Chadi Abi (www.chadiabi.com)

Printed by: Akita Kappan Printing Co., Ltd.

Available from: IUCN (International Union for Conservation of Nature)
Rue Mauverney 28
1196 Gland
Switzerland
Tel +41 22 999 0000
Fax +41 22 999 0002
www.iucn.org/resources/publications

Acknowledgements: We would like to thank all the authors of the regional assessments and contributors to this publication. We are very grateful to the following people who took time and effort to comment on earlier drafts of the regional assessments: Angela Andrade, Birguy Lamizana, Peter Smith and Jeffrey McNeely. We are very grateful to Thomas Brooks and Deborah Murith for their support, advice and guidance in adhering to the IUCN publications standards. Our colleague Camille Buyck provided useful technical input with lessons from the Ecosystems Protecting Infrastructure and Communities (EPIC) project. A special thank you to Angela Andrade and Karen Sudmeier-Rieux for the peer reviews and feedback that contributed to improve this document. Thanks to Caroline Snow for proofreading the document. Any remaining errors are the sole responsibility of the authors.

Table of Contents

Executive summary

With the increasing threats that disasters present particularly in the light of climate change, there is an urgent need to prioritise proactive disaster risk reduction over reacting to disaster events. Healthy ecosystems in particular are increasingly being recognised as important tools to prevent and minimise disaster risk. However, the use of the ecosystem approach for disaster risk reduction (Eco-DRR) is still underdeveloped worldwide and in need of scaling up. With the overlap in practice and common challenges that need to be addressed, there is great scope to enhance the co-benefits between Eco-DRR and biodiversity conservation by scaling up and mobilising actions for the integration of both fields.

This publication documents the importance of biodiversity in disaster risk reduction and makes a case for the implementation of common approaches that contribute to both conservation and risk reduction. Assessments of regional experiences on Eco-DRR also highlight the opportunities and entry-points to scale-up integrated approaches.

Part 1 of this report provides a conceptual background on the importance of biodiversity in disaster risk reduction, and opportunities to mainstream Eco-DRR as a crosscutting issue into policy and practice.

Key messages from Chapter 1 – Background on disasters, disaster risk and disaster risk reduction:

- 'Natural disasters' do not exist. While natural hazards are naturally-occurring phenomena, disasters are defined by the impacts that these hazards have on a society
- Not every hazard will turn into a disaster if more investments can be made towards proactive and effective risk reduction that allow society to cope
- Human actions contribute to increase the risk of a natural hazard to result in a disaster (disaster risk)
- There remains a need for further research and translation of knowledge into actions on the use of the ecosystem approach for disaster risk reduction

Key messages from Chapter 2 – Ecosystem services and disaster risk reduction:

- Degradation of ecosystems and ecosystem services increases disaster risks
- Natural hazards affect ecosystem structure and components, ecosystem processes and functioning. However, healthy ecosystems also have the ability to recover from disturbance
- The recovery and reconstruction phase following a disaster can damage ecosystems and exacerbate existing vulnerabilities. It is thus important to integrate environmental management into post-disaster activities
- Different ecosystems and associated services can provide protection and reduce damages from hazards
- Protection and restoration of ecosystems can be more cost-effective than man-made engineered options as illustrated in this chapter
- While there are increasing efforts invested in maintaining and enhancing ecosystem services for disaster risk reduction, much action is often implemented after the occurrence of major disasters

Key messages from Chapter 3 – the role of biodiversity in disaster risk reduction:

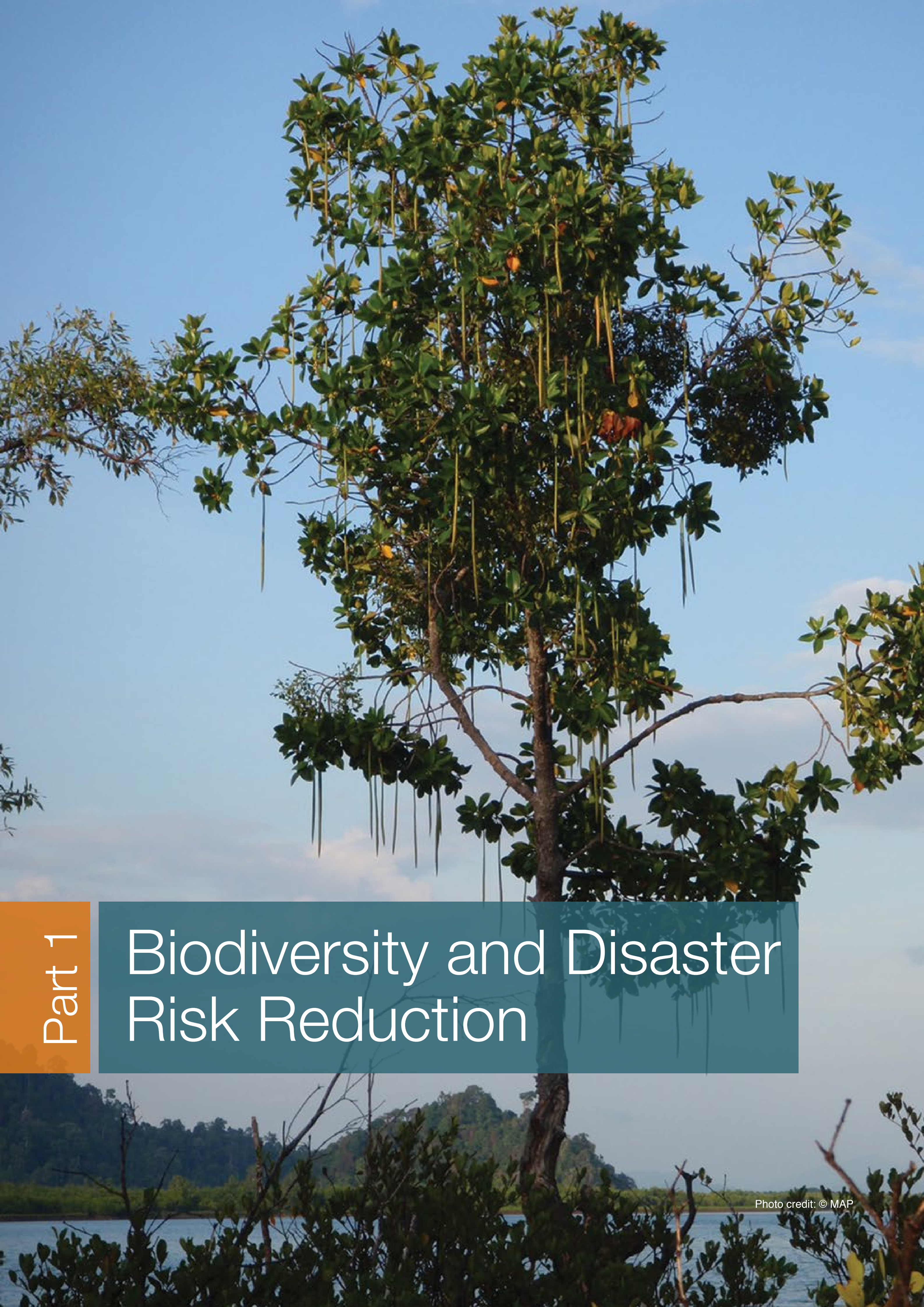
- While there is an increasing recognition of the role of different ecosystems in disaster risk reduction, the role of their constituents i.e. species and genetic diversity in reducing risk has been given less attention

- There is a lack of clear scientific and quantitative evidence on the role of species and genetic diversity in disaster risk reduction
- However there are three areas where species and genetic diversity can contribute to disaster risk reduction namely: 1) by contributing to the resilience of ecosystems to disturbances, 2) by enhancing the protective functions of ecosystems, and 3) by contributing to social resilience
- Eco-DRR provides co-benefits for conservation and through the focus on society, can also be used as an incentive
- Biodiversity conservation can also be used as a tool for Eco-DRR
- Eco-DRR and biodiversity conservation while differing in goals, share multiple commonalities in terms of measures used and challenges that affect both, thus providing a strong basis for integration

Key messages from Chapter 4 – Policy context:

- There have been several recent and positive policy developments at global and regional level with regard to the recognition of the role of ecosystems in disaster risk reduction
- These policies provide increasing opportunities to mainstream Eco-DRR and scale-up integrated actions as countries establish targets for implementation
- It is important for national and regional action plans to enable cross-sectoral coordination to achieve multiple national commitments

Part 2 of the report provides a summary of individual regional assessments on the role of biodiversity in disaster risk reduction. The summaries particularly highlight key disaster challenges in each region, experiences with Eco-DRR, and use regional examples to make a case for the adoption of Eco-DRR approaches. Each regional summary concludes with key messages and recommendations to implement integrated approaches.



Part 1

Biodiversity and Disaster Risk Reduction

Photo credit: © MAP

Chapter 1

1.0 Background

The past three decades have seen a rise in natural catastrophes worldwide, with increased incidence of climate-related disasters, mostly due to floods and storms (Figures 1 and 2). Natural hazards such as cyclones, earthquakes and tsunamis are increasingly taking a toll on human lives and causing increased property and economic losses, particularly in developing countries. The year 2015 alone has seen the occurrence of 1,060 disaster events resulting in 23,000 fatalities and up to US$ 100 billion of economic losses worldwide (NatCatService, 2016). Damages in the past two decades are significantly greater than in the earlier decades and more so in rich countries, mainly due to infrastructure loss (The World Bank, 2010). With the prediction that extreme weather events will increase over the long term due to climate change (IPCC, 2014), it is likely that the current trend will persist, undermining development and economic growth and putting more and more people and development investments at risk. People from low-income countries, communities and households, particularly face the highest risk, as they are the most vulnerable and also the last to recover from extreme events (UNSIDR, 2009a; Winsemius et al., 2015).

While the term natural hazard refers to events such as cyclones, earthquakes, tsunamis – events that occur in the physical environment and can potentially cause harm to people and property, disasters are defined as *"A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts which exceeds the ability of the affected community or society to cope using its own resources"* (UNISDR, 2009b). Therefore, not every hazard will turn into a disaster if more

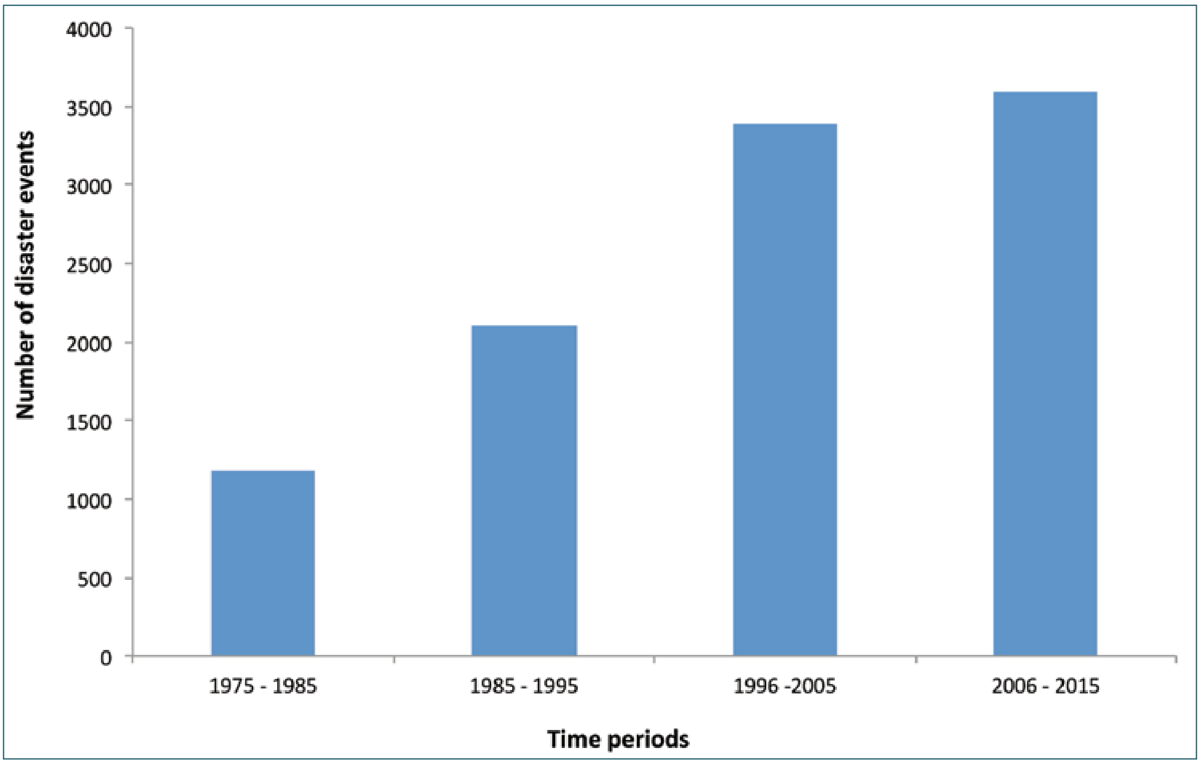


Figure 1. Trend in reported number of disaster events worldwide, 1975-2015 (Compiled from data from CRED EM-DAT-database, 2016)

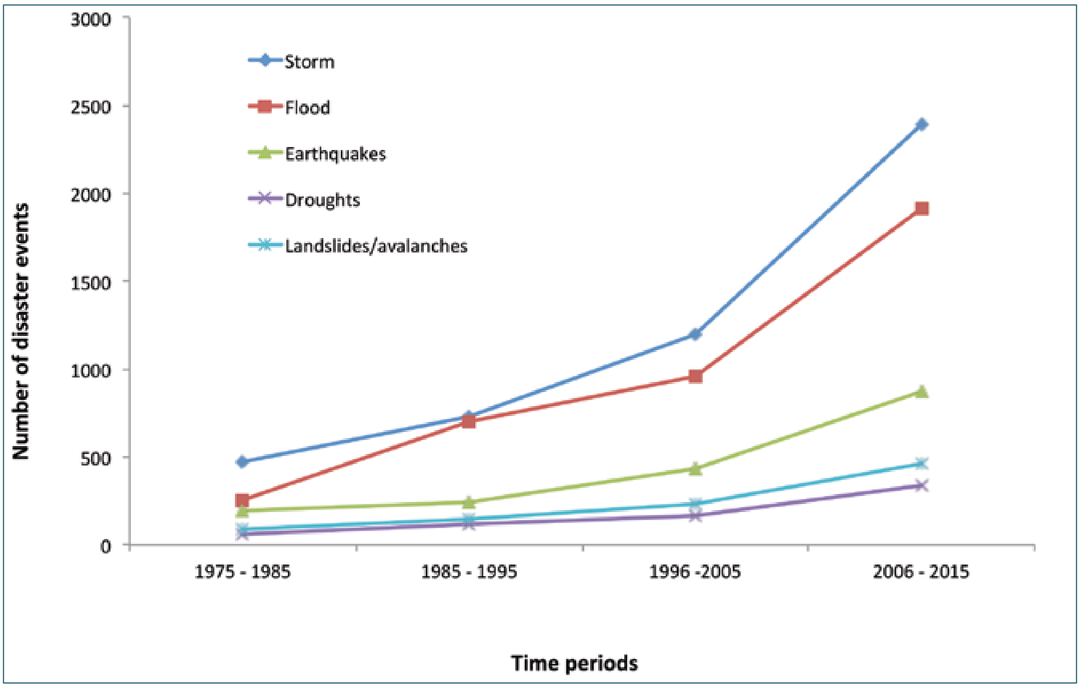
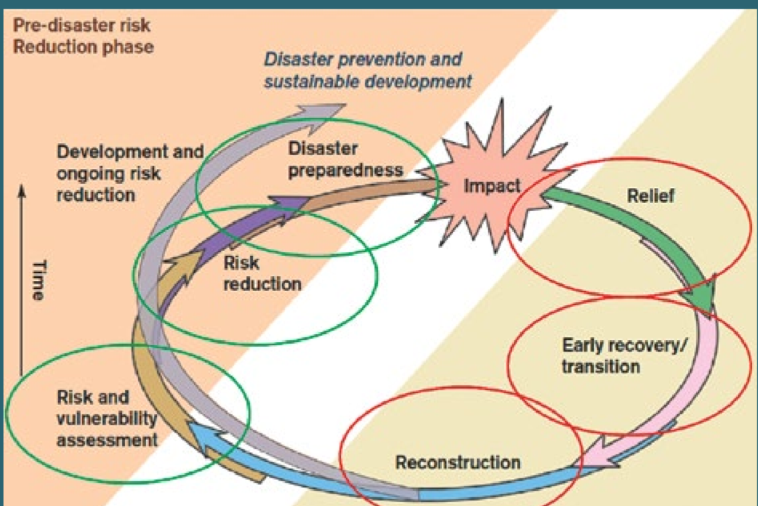


Figure 2. Trend in reported number of disaster events per natural hazard types worldwide, 1975-2015 (compiled from data from CRED EM-DAT-database, 2016)

investments can be made towards disaster risk reduction (DRR), enabling affected communities and the society to cope.

There is an urgent need to shift efforts from response to proactive action (Box 1) through managing disaster risks. According to the Global Assessment Report on Disaster Risk Reduction "Twenty-five years after UN Member States adopted the International Decade for Natural Disaster Reduction (IDNDR) and ten years after the adoption of the HFA, global disaster risk has not been reduced significantly" (UNISDR, 2015).

Box 1: The Disaster Management Spiral



The disaster management spiral highlights that if over time (y-axis) DRR is implemented effectively, it is possible to break out of the disaster cycle of impact (hazard event) to relief, early recovery/transition, reconstruction. With consecutive disasters, the losses would become less and there would be an overall spiralling upwards, out of the cycle and towards sustainable development (RICS, 2009). The red circles indicate current efforts in disaster management and the green circles highlight the need for proactive action.

The risks of a natural hazard turning into a disaster are determined by three main factors: 1) frequency and magnitude of the hazard event, 2) the degree of exposure to the hazards, and 3) the vulnerability, for example, level of poverty, quality of infrastructure, etc. (Renaud et al., 2013):

Disaster Risk = Hazard x Vulnerability x Exposure

Whereby vulnerability is defined as "the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard" and exposure is defined as "people, property, systems, or other elements present in hazard zones that are thereby subject to potential losses" (UNISDR, 2009b).

The way human actions influence rates of exposure and vulnerability to the physical events, the impacts of human interventions in the physical environment that lead to the development of new hazards, higher levels of damage or the potential to damage of prevailing hazards, as well as the way humans perceive, comprehend and assimilate risks, are a few of the factors that amplify vulnerability and exposure through social processes and choices (Cardona et al., 2012). With the predicted and observed increasing frequencies and magnitudes of disasters, there is a strong case for investing upfront in reducing disaster risks, in addition to responsive action in the aftermath of a disaster.

Disaster risk reduction is defined as *"reducing disaster risks through systematic efforts to analyze and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events"* (UNISDR, 2009b). The international humanitarian aid assistance funding has steadily increased in the past decade in response to disasters globally (Kellet and Sparks, 2012). If the current trend of increased losses in rich countries continues (The World Bank and The United Nations, 2010), it may become even more difficult to mobilise humanitarian aid assistance for the poorer and more vulnerable countries. Therefore, the global community must invest in risk reduction proactively and shift priorities to pre-disaster action, including improved understanding and ownership of risks and vulnerabilities.

> "Hundreds of thousands of trees toppled by a severe hurricane are a visible sign of environmental destruction wrought by a disaster. And flooded coastal villages and washed away beaches whose natural protective belt of mangroves has been chopped down in pursuit of economic interests are, in turn, a sign of the considerably greater risk in the wake of a natural disaster where the natural environment has been destroyed. There is an interactive link between environmental destruction and disasters that many examples can serve to describe. But so far, these insights have been given too little attention by politics and science." Extracted from the World Risk Report (2012).

It is well recognised that environmental degradation exacerbates vulnerabilities and can also increase exposure to hazards (UNISDR, 2015; Renaud et al., 2013, IPCC, 2014). While disaster risks are influenced by many factors, degradation and destruction of ecosystems can severely limit their ability to 1) serve as protective barriers against the physical impacts of a disaster event, and 2) provide goods and services for basic needs (such as food, medicine, water, shelter) as well as livelihood opportunities (such as fisheries and farming) that reduce social vulnerabilities (Sudmeier-Rieux et al., 2013). In May 2004, Haiti and the Dominican Republic were affected by intense rainfall, which generated flooding in the south-central, cross-border region of the island (Hispaniola). This was followed by hurricane/tropical storm Jeanne, which affected the island in mid-September. For both events, the damage and number of casualties were greater on the Haiti side of the island, which has a significantly smaller forested area compared to the Dominican Republic side. According to published literature, major flooding from the rain and storm could have been avoided if the forests were present on the Haitian side (Renaud et al., 2013).

Systematic reviews to collate evidence on the direct role of ecosystems and ecosystem services for disaster risk reduction have only recently begun and there remains a considerable need for further research as well as translation of knowledge into actions.

1.1 Scope of and purpose of this publication

Environment and disasters interact in multiple ways. Major disasters lead to severe environmental consequences while well-managed environments can act as a buffer against disasters and reduce risks of impacts. However, despite its importance, environmental management is still underexplored in disaster risk reduction strategies. The ecosystem approach which is defined as a "strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way" and its principles were endorsed by the fifth conference of the parties to the Convention on Biological Diversity (CBD) in Nairobi, Kenya, in May 2000. Several of the principles are relevant to the use of ecosystems for disaster risk reduction, for example principle 5 which states that "Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach" (CBD, 2004).

The ecosystem-based approach to DRR (Eco-DRR) calls for the protection of ecosystems and associated services that contribute to prevent disasters and reduce risks. However, it still remains a relatively new concept to practitioners and policy makers. Lack of knowledge on such nature-based approaches, their effectiveness and implementation process poses a serious barrier to its adoption and scaling up. Thus, there is a growing need for countries to understand what is meant by Eco-DRR and how to make this operational, so that it can become a key investment option for sustainable development.

With an increasing number of disasters leading to ever increasing human tragedy and economic costs globally, the international community is calling for the substantial reduction of disaster risk under several international agreements and frameworks. The years 2014 and 2015 have seen the adoption of major global agreements and decisions that recognise the importance of ecosystems in disaster risk reduction or provide entry points to upscale such approaches, for example:

- At the CBD COP12 in 2014, a decision XII/20 titled 'Biodiversity and Climate Change and Disaster Risk Reduction' was adopted. The decision encourages Parties to promote and implement ecosystem-based approaches to climate change and disaster risk reduction.
- In March 2015, the Sendai Framework for Disaster Risk Reduction 2015-2030 was adopted as the successor to the Hyogo Framework for Action 2005–2015. This new framework places a stronger emphasis on the importance of ecosystems, biodiversity and proposes a more rigorous monitoring framework, which strongly advocates for capacity development and knowledge transfers for risk management.
- In June 2015, the Ramsar Convention Decision XXII.13 was adopted recognising the role of wetlands in disaster risk reduction.

- In September 2015, the UN General Assembly adopted the Sustainable Development Goals (SDGs).
- In December 2015, the Paris Agreement was adopted by 195 countries.

It is thus urgent to strengthen the knowledge base on Eco-DRR to ensure that the role of ecosystems is recognised as a key practice to implement these different global commitments.

Also, there remain information gaps that need to be addressed when it comes to the implementation of Eco-DRR. Current work in the field is focused on using different ecosystems for DRR but little is known on the role that different levels of biodiversity such as species and genetic diversity can play. A better understanding of the contribution of the different components of biodiversity to DRR and synergies with biodiversity conservation is not only critical for the field but can also help countries to implement integrated approaches for achieving multiple goals beyond DRR.

Regional assessments on the role of biodiversity in disaster risk reduction

To address the current knowledge gaps on the scale and extent of the importance of biodiversity in Eco-DRR, six regional assessments have been conducted as part of IUCN's RELIEF-Kit initiative. The latter project is a three-year initiative funded by the Japan Biodiversity Fund under the Secretariat of the Convention on Biological Diversity. The project aims to address both the knowledge gaps and capacity needs for Eco-DRR by achieving the following goals:

1. To carry out assessments for biodiversity to generate knowledge on the role that biodiversity can play in disaster risk reduction through focusing on highly hazard prone countries
2. To develop capacities, facilitate networks and catalyse action to protect biodiversity for DRR
3. To inform policies for integrated approaches to DRR, biodiversity conservation and climate change adaptation (CCA)

For each region, a combination of disaster data analysis, desk-based review of scientific literature and case studies, surveys and policy analysis was used to cover the following subjects:

- Priority hazards and impacts of disasters
- Regional experiences with Eco-DRR
- The contribution of Eco-DRR to biodiversity conservation
- The role of biodiversity in DRR
- Policy preparedness and opportunities for integration of biodiversity conservation and DRR
- Economic case for Eco-DRR

The regional assessments conducted provided the basis for this report and covered the following regions and focal countries:

1. **Mesoamerica and the Caribbean**: Mexico, Belize, Guatemala, Honduras, El Salvador, Nicaragua, Costa Rica, Panama, Cuba, Jamaica, Dominican Republic, Trinidad and Tobago
2. **South America**: Argentina, Bolivia, Colombia, Ecuador, Peru, Chile
3. **West and Central Africa:** Burkina Faso, Togo, Senegal, Mali, Ghana, Nigeria, Cameroon
4. **Eastern and Southern Africa**: Kenya, South Africa, Zimbabwe, Madagascar, Mozambique, Ethiopia, Malawi, Uganda, Namibia
5. **Asia**: Bangladesh, Cambodia, China, India, Nepal, Philippines, Thailand, Viet Nam
6. **Oceania**: Fiji, Marshall Islands, Papua New Guinea, Samoa, Solomon Islands, Tuvalu, Vanuatu

Altogether, the assessments covered 51 focal countries that encompassed at least half of the countries in a specific region. To select these countries, a set of criteria was used and varied slightly according to regional experiences and contexts. One main common criterion amongst the regions was vulnerability of the countries with the most vulnerable ones being prioritised.

Several indices were used to determine and compare the vulnerabilities of the countries in the region (Table 1).

Table 1. Indices used to determine vulnerabilities of focal countries for the regional assessments (Sources: World Risk Report, 2015; Groeve et al., 2015; Kreft et al., 2016):

NAME	DESCRIPTION	Developer
WorldRiskIndex	It indicates the risk of disaster as a consequence of extreme natural events and consists of four components: exposure to natural hazards, susceptibility, coping capacities and adaptation capacities	University of Stuttgart, Germany
Inform Risk Index	It identifies countries at risk from humanitarian crises and disasters that could overwhelm national response capacity. It is made up of three dimensions: hazards and exposure, vulnerability and lack of coping capacity	Inter-Agency Standing Committee (IASC) Task Team for Preparedness and Resilience
Global Climate Risk Index	It analyses to what extent countries have been affected by the impacts of weather-related loss events (storms, floods, heat waves, etc.)	Germanwatch

Unless stated otherwise, figures on the impacts of disasters were obtained from the CRED EM-DAT online international disaster database.

Chapter 2

2.0 Ecosystem services and disaster risk reduction

Recent estimates of global ecosystem services from different biomes are evaluated at US$ 125 trillion per year with a loss of US$ 4.3–20.2 trillion per year due to land use change (Costanza et al., 2014). In efforts to address the challenges posed by disasters, special attention needs to be given to ecosystems and the services that they provide. An ecosystem is defined as a "dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit" (CBD, 1992). Through the concept of ecosystem services (Figure 3), which are the benefits that people derive from ecosystems (Millennium Ecosystem Assessment, 2005), it is largely recognised that ecosystems are important for human well-being. Besides contributing non-material benefits, the economic importance of ecosystems for society is increasingly being documented. The Economics of Ecosystems and Biodiversity (TEEB) initiative reveals that forest conservation can avoid greenhouse gas emissions worth US$ 3.7 trillion and that coral reef ecosystem services entirely support around 30 million people through the provision of food, income and livelihood (TEEB, 2010).

Rapid-onset disasters refer to those that are "triggered by natural hazards such as earthquakes, cyclones, floods, landslides, avalanches, volcanic eruptions and certain types of disease epidemics. They occur suddenly, often with very little warning" (Twigg, 2004). Slow-onset disasters refer mostly to "food shortage or famine triggered by drought or pest attacks on crops, where the crisis builds up over several weeks or months. It can also cover disasters caused by environmental degradation or pollution" (Twigg, 2004).

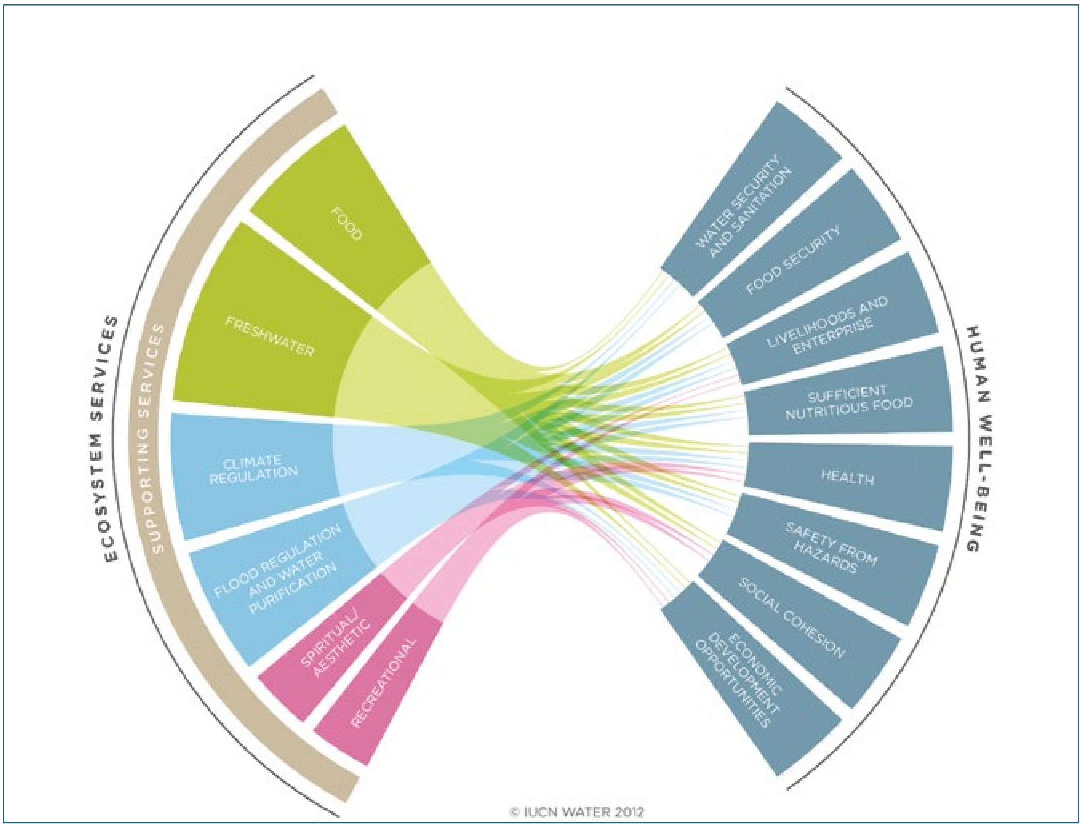


Figure 3. Ecosystem Services and Human well-being (©IUCN Water, 2012)

2.1 Degradation of ecosystem services and increased disaster risks

According to the Millennium Ecosystem Assessment (2005), humans have changed the natural environment of this planet more rapidly in the past 60 years than ever. It also highlighted that as ecosystem services declined there has been a steady gain in human well-being at a global scale. Of the four categories assessed; 1) provisioning services 2) regulating services 3) cultural services 4) supporting services, provisioning services were expanding whereas regulating and supporting services were declining. Regulating services are critical for coping with and recovering from disasters (Renaud et al., 2013) and supporting services can support in the recovery process from a disaster. While society's capacity to deal with disasters has increased, such capacity varies across the globe. The poor are often more exposed to disasters, and improving the well-being of local populations through enhancing regulating ecosystem services in highly exposed areas can reduce their vulnerabilities (Raudsepp-Hearne et al., 2010). Degradation of one service is often attributed to expansion of another type of ecosystem service. Therefore, it is critical to understand how the multiple services are inter-related and how they are affected collectively due to human and natural interventions. Without adequate knowledge and understanding, we may risk undesirable trade-offs, missed opportunities in optimising synergies and experience dramatic or unintended changes in services (Bennett et al., 2009). We may especially continue to exacerbate the vulnerabilities of people to the increasingly occurring disasters. In South East Asia, wide-scale clearing of coastal mangrove forests for aquaculture production together with ground water withdrawal has led to significant coastal erosion, damages to coastal flooding infrastructure and salt-water intrusion (Wesenbeeck et al., 2015). Once production collapses (mainly due to pollution and disease), production ponds are abandoned, leaving the coastlines significantly exposed to such damage. Countries such as Thailand, Indonesia and Philippines are now undertaking large-scale restoration efforts in order to reverse the effects of such degradation, especially considering the increasing risks of coastal hazards. These efforts can be extremely expensive and highlight that short-term profits from unsustainable production systems can be significantly outweighed by longer-term costs to local communities and the government.

According to Constanza et al. (1997), wetlands provide up to 40% of the planet's renewable ecosystem services, despite covering only 1.5% of Earth's surface. They are critical for flood control and drought management (Murti and Buyck, 2014; Renaud et al., 2013). If 80-90% of the wetland area is cleared in a landscape, there is an increase in the risk of flooding and eutrophication (Cedfeldt et al., 2000). In the upper mid-western region of the United States of America, up to 60% of the wetlands were drained for agriculture production leading to a decline in ecosystem services for flood control, water purification and biodiversity support (Zedler, 2003). Ecosystem degradation also exacerbates risks from slow onset disasters such as drought and desertification. In an analysis of 132 case studies carried out by Geist and Lambin (2004), 95% highlighted that agricultural activities or agrarian land uses are the key proximate causes of desertification.

Ecosystem management practices such as integrated water resource management and protected area management must actively be integrated into risk and vulnerability assessments, DRR planning and implementation for preparedness. Degradation of ecosystems must also be taken into account during the relief and reconstruction phases of a disaster (Murti and Buyck, 2014).

2.2 Impacts of natural hazards and disasters on ecosystem services

The relationship between disasters and ecosystems runs two ways. While ecosystem management and ecosystem degradation mitigate and exacerbate disaster risk respectively, disasters and the natural hazards that causes them also affect ecosystems and the services that they provide.

Negative impact of natural hazards on ecosystems

There is a wide range of literature on the impact that individual natural hazards have on ecosystems particularly with regard to the impacts of droughts on forest ecosystems

Table 2. Examples of negative impacts of natural hazards on ecosystems

Hazards	Ecosystem	Impacts	Reference
Drought	Forest	Tree mortality; Loss of forest biomass; Forest dieback	Allen et al., 2010; Lewis et al., 2011; Phillips et al., 2009
Drought	Freshwater	Water bodies diminish in size; Loss of fish species; Water flow affected; Decrease in water quality	Bond et al., 2008
Storms	Mangrove	Changes in structural composition, mangrove mortality, changes in relative species presence	Smith et al., 2009
Earthquakes	Forest and shrubland	Ecosystems destroyed, changes in structural composition, changes in relative species presence	Zhang et al., 2011; Ouyang et al., 2008
Landslides	Mountain	Changes in species composition and abundance	Restrepo et al., 2009
Earthquakes	Intertidal flats	Changes in species compositions and diversity, loss of sessile animal species	Urabe et al., 2013
Storms	Agricultural systems	Coffee yield loss	Philpott et al., 2008
Earthquake	Temperate montane forest	Tree mortality, tree damage, loss of tree biomass	Allen et al., 1999
Landslides	Freshwater	Change in stream flow due to debris, destruction of fish habitats, poor water quality due to sedimentation, heavy metals contamination	Geertsema et al., 2009
Earthquake	Coastal systems	Change in composition of invertebrate species, loss of sand beach habitats and associated species	Jaramillo et al., 2012
Tsunami	Island	Loss of sand dunes, increase in soil salinity, coastal pollution, destruction of corals, siltation and biodiversity loss, salinisation of coastal freshwater	Ramachandran et al., 2005; Bahuguna et al., 2008
Volcanic activity	Ocean	Ocean acidification, decrease in algae biomass, loss of calcareous organisms	Hall-Spencer et al., 2008
Floods	Rivers	Reduction in organic matter, reduction of invertebrate diversity	Robinson and Uehlinger, 2008
Storm floods	Coral reefs	Reduction in salinity, coral reef mortality, phytoplankton boom, change in coral reef species composition	Jokiel et al., 1993

(Table 2). Additionally research on the impact of climate change and its consequences also provides useful insights into how climate extremes affect or may affect ecosystems.

Two main types of impacts emerge from the literature namely 1) changes in the physical structure of the ecosystems and 2) loss or changes in the ecosystem components, for example species or groups of species. Table 2 illustrates some examples of how natural hazards affect ecosystems. Most examples of the impacts of hazards on ecosystems highlight degradation processes rather than actual ecosystem loss. Examples of the latter are mostly reported for events like earthquakes and earthquake-induced landslides. For example, large areas of destruction of forest, grassland and wetlands have been recorded following the 2008 Wenchuan earthquake in China (Ouyang et al., 2008).

Natural hazards can also affect ecosystems indirectly through secondary events such as accumulation of debris, mudslides and sedimentation that, for example, can cause mangrove mortality (Geertsema et al., 2009; Smith et al., 2009; Zhang et al., 2011).

Impact of natural hazards on ecosystem services and benefits

A look at the impact of natural hazards on ecosystems in Table 2 provides some clear indication of how ecological degradation can lead to a decline in provision of ecosystem services and benefits. For example, soil and freshwater salinisation in cases of tsunamis will not only affect provision of clean water but can also be expected to affect agriculture and ultimately food production. Hazards like droughts can also feedback into contributing to climate change by decreasing forest biomass and carbon sinks as noted for the impact of

Box 2: Why use ecosystem-based approaches if ecosystems are also affected by natural hazards?

Promoting the use of ecosystems in DRR strategies may seem contradictory considering they are also affected by disasters. One may argue that since some ecosystems are destroyed or affected by natural hazards, how will they be able to protect society? There would be one main argument for this: ecological resilience.

The healthier and more resilient an ecosystem is, the less damage it will experience from natural hazards and the easier and faster it will recover from impacts (Adger et al., 2005). Environmental degradation determines an ecosystem's resilience and the extent by which it will be impacted by disasters highlighting the importance of addressing the causes and drivers of environmental degradation to reduce risks. For example, man-made modifications of streams are documented to exacerbate the severity of the impact of drought on aquatic ecosystems (Bond et al., 2008). Similarly, human-driven changes in species composition in an ecosystem, such as the introduction of invasive species and activities like road construction, can increase susceptibility to hazards like landslides and fires (Restrepo et al., 2009).

The ability of healthy ecosystems to recover is also one key attribute that distinguishes them from man-made structures. Once damaged, the latter requires reconstruction and many resources. Different ecosystems can recover from disturbances, and furthermore the recovery rate can increase as the ecosystem is more complex and biodiverse (see chapter 3). For example Smith et al. (2009) in a study on cumulative impacts of hurricanes on mangroves in Florida, documented that several ecosystems have recovered from disturbances brought by three different hurricanes in 1960, 1992 and 2005.

droughts on amazon forests (Lewis et al., 2011). Direct examples of the impact of natural hazards like landslides and droughts on ecosystem services include mostly impacts on ecosystem processes and functioning, namely soil quality, carbon cycling, primary productivity and climate regulation (Guariguata, 1990; Huenneke et al., 2002; Hilton et al., 2011).

Disaster aftermaths

Following a disaster, damages can also occur to ecosystems when environmental management is not incorporated in the reconstruction and recovery phases. There is much focus on immediate humanitarian and relief responses after a disaster and environmental issues are at times left out of the equation, with negative consequences for the state of the environment. In the long-term, such impacts just contribute to a country's vulnerability to future hazards. Some possible environmental impacts of activities during the early recovery phases include the following (International Recovery Platform, 2009):

- Over-exploitation of water supplies
- Improper waste disposal
- Contamination of water sources
- Overexploitation of timber for construction and firewood
- Land degradation and soil erosion

The impacts of post-disaster reconstruction can also exacerbate existing environmental problems in a country, as noted by a UNEP assessment two years after the 2004 Asian tsunami. Reported impacts of the reconstruction process on the environment include, for example, pollution of ground and surface water and over-extraction of fuel wood used to prepare burnt clay bricks for the reconstruction of houses (UNEP, 2007).

Similarly in Sri Lanka, it is recorded that clean-up efforts led to the spread of invasive species like the prickly pear (*Opuntia humifusa*) (Miththapala, 2008 in Sudmeier-Rieux et al., 2013).

2.3 Enhancing ecosystem services for disaster risk reduction

According to a study by Swiss Reinsurance, every US dollar invested per hectare to protect the coral reef in Folkstone National Park in Barbados can reduce potential damages from cyclones worth US$ 20. Similarly, in Viet Nam, the planting of mangroves has reduced the risk of disasters and enhanced communities' livelihoods. Planting 9,462 hectares of forest (of which 8,961 hectares were mangroves) in 166 communes in disaster-prone northern Viet Nam, was found to reduce damage to dykes from typhoons by an estimated US$ 80,000-295,000. The benefits to communities were found to be much larger and were estimated at around US$ 15 million. In addition, mangroves provided additional income to coastal communities through increased yields (200-800%) in aquaculture and other economic activities (honey bee farming) equivalent to US$ 344,000-6.7 million. Furthermore, mangroves sequestered carbon valued at over US$ 200 million (using US$ 20/tCO2e) (IFRC, unpublished).

The role of forest protection in mitigating mountain hazards has been recognised since the 1870s in the alpine landscapes of Europe. Such forests have increasingly gained importance in the last 50 years, considering increasing populations leading to denser settlements and intensified infrastructure development. Switzerland invests up to CHF 150 million per year in forest management, as it is 5-10 times less expensive than engineered structures for reducing risks from landslides, rock falls and avalanches (Wehrli and Dorren, 2013).

Together with providing protection from the direct impacts of disasters, healthy ecosystems can also reduce the underlying vulnerabilities of communities through providing subsistence, livelihood options and safety nets (such as

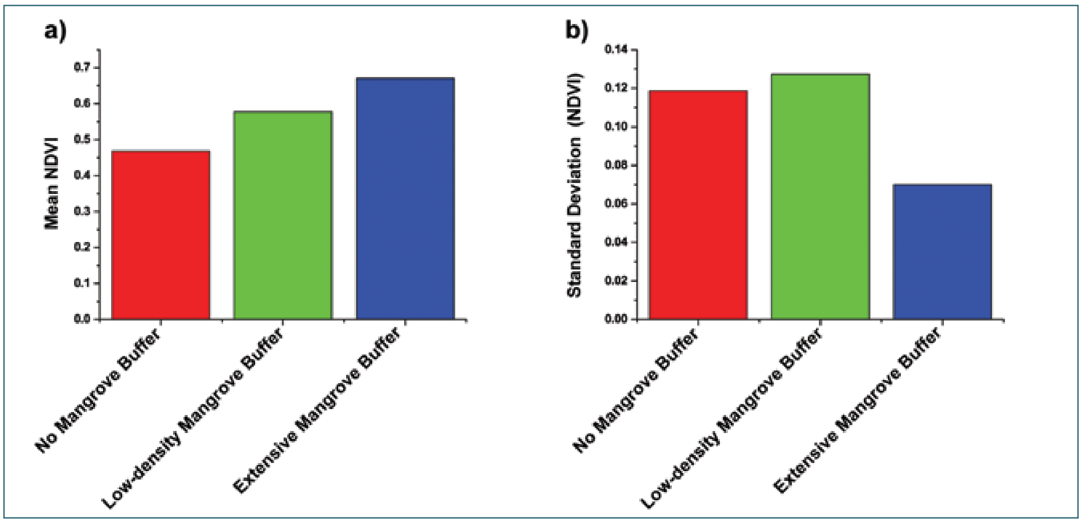


Figure 4. The recovery rates measured as (a) mean satellite measure greenness (NDVI) and (b) standard deviation in satellite measure greenness (NDVI) in rice croplands for buffer and non-buffer plots when compared to extensive buffer (Source: Duncan et al., 2015)

regulation of ecological processes and shelter) (Renaud et al., 2016). Thus healthy ecosystems can support the recovery processes during the aftermath of disasters and support poor communities to recover their livelihood options. The Cham Islands Marine Protected Area of Viet Nam is highly exposed to extreme weather events and impacts of climate change. Through the establishment of zoning plans, regulatory, monitoring and enforcement mechanisms, as well as co-management plans for the area, livelihood options and income for the communities have gradually improved, which enables them to cope with and recover from extreme events faster (Murti and Buyck, 2014). In the Bhitarkanika Conservation Area in India, studies were carried out to assess recovery rates of rice paddies that had no mangrove buffer, low-density mangrove buffer and extensive mangrove buffer. Croplands with low-density buffer recovered to similar productivity levels to those with extensive mangrove buffer compared to those with no mangrove buffer (Figure 4) (Murti and Buyck, 2014).

While efforts are increasing in enhancing ecosystem services for DRR, unfortunately, much action is often catalysed following major disasters. Following hurricane Katrina, the US congress approved US$ 500 million for the restoration of its coastal national parks and salt marshes, following evidence that the parks and marshes helped reduce the damage. However, this came at a cost of 1,836 lives and an economic loss of US$ 81 billion. Similarly, the government of Japan declared the expansion of its coastal forests, in the form of Sanriku Fukko Reconstruction Park, as it helped reduce the impacts of the tsunami caused by the Great East Japan Earthquake in 2011 (Renaud and Murti, 2013). This, again, underscores the need for proactive investments and actions to reduce risks and enhance ecosystem services for DRR to provide options that are no regret measures, considering they bring multiple benefits (such as income generation and biodiversity conservation) regardless of a disaster (Renaud et al., 2016).

Figure 5 attempts to demonstrate the linkages between the state of ecosystems and the consequential impacts on resilience and vulnerabilities

2.4 Ecosystem-based disaster risk reduction

Eco-DRR is regarded as a key nature-based solution (NbS) given the focus on a societal challenge, i.e. disaster risk. IUCN defines NbS

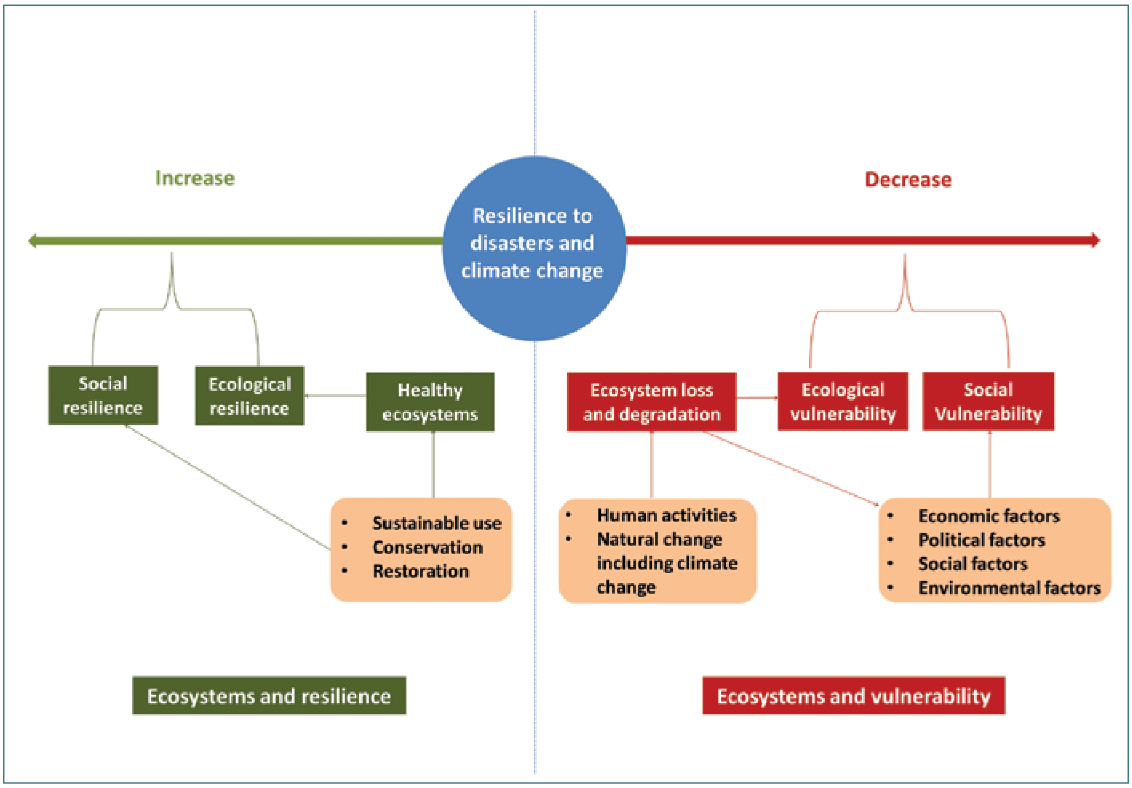


Figure 5. Theoretical model on linkages between ecosystem and disaster resilience and vulnerability (Sources: Cutter, 1996; Adger, 2000; Adger et al., 2005; Adger, 2006; Gunderson, 2009)

Figure 6. Nature-based solution as an overarching concept for ecosystem-based approaches to address societal challenges (Source: Cohen-Shacham et al., 2016)

as “actions to protect, sustainably manage and restore natural or modified ecosystems, which address societal challenges effectively and adaptively, while simultaneously providing human well-being and biodiversity benefits” (Cohen-Shacham et al., 2016) (Figure 6).

The Eco-DRR approach has evolved from practices and experiences, mainly from the past decade. It was first defined by the Partnership for Environment and Disaster Risk Reduction (PEDRR) in 2011 as the “sustainable management, conservation and restoration of ecosystems to provide services that reduce disaster risk by mitigating hazards and by increasing livelihood resilience”. It promotes the use of ecosystem management approaches in reducing risks through one or more of the following:

- sustainably using and managing natural resources to derive services;
- protecting and conserving intact ecosystems that can play a critical role in risk reduction;
- Restoring degraded ecosystems in order to reduce risks.

Such approaches are tried and tested, resulting in widely accessible lessons learnt and best practices. The approaches are relevant to a variety of ecosystem types, geographical areas and at different scales. Additionally, these ecosystem management approaches are based on participatory, local ownership, social and institutional governance mechanisms – principles that are also central to participatory risk management (Juffe-Bignoli et al., 2014). While the emphasis is on risk reduction measures, Eco-DRR principles can be applied to all phases of the disaster management cycle (Box 1). Table 3 below provides examples of ecosystem management approaches for key phases of the cycle.

Table 3. Examples of Ecosystem Management Actions for Key Disaster Management Cycle Phases. (Source: Murti and Buyck, 2014)

Disaster Management Phase	Ecosystem Considerations	Ecosystem based Approaches
Risk and Vulnerability Assessments	establish root causes of hazard exposure and whether they are related to ineffective manangement of the environment	integrated social and ecological vulnerability assessments
	consider environmental dimensions or drives of vulnerability: extent, quality and/or usage of natural resources	
	assess risk of ecosystem collapse	
	quantify the role of ecosystems for hazard mitigation	
Disaster Risk Reduction	sustainable management, conservation or restoration of:	
	forests for stabilizing slopes	slope restoration, forest landscape restoration, protection forest designation, sustainable forest use
	wetlands and floodplains to control floods	integrated water resource management

Disaster Management Phase	Ecosystem Considerations	Ecosystem based Approaches
	forest cover management for fire control	mosaic landscaping
	vegetation for drought resilience	sustainable land management
	mangroves, saltmarshes and sand dunes as buffers for coastal hazards	integrated coastal zone management
Preparedness	preparedness plans to consider the consequences of environmental degradation from relief operations on recovery processes and timelines	legislating environmental management standards during a crisis
Relief, early recovery and reconstruction	documentation of damages to/loss of ecosystem services	environmental impacts in Post Disaster Needs Assessments
	Relief plans to consider environmental footprints and impacts	Strategic Environmental Assessments
	Greener reconstruction and recovery	Green Recovery and Reconstruction Toolkits and guidelines

Implementation of Eco-DRR may be based on ecosystem management approaches, however they include additionalities to ensure that the approach is a response to a disaster risk and not merely an environmental management intervention in a highly hazard prone area.

Thus one core aspect of Eco-DRR is risk assessments including the mapping of social vulnerabilities, which provides useful information on the factors contributing to disaster risks, for example, vulnerable livelihood strategies, low income levels, degradation of natural resource (Wisner et al., 2004), which drives the implementation of effective and adequate ecosystem-based approaches to prevent and/or minimise such vulnerabilities.

For example in Senegal, IUCN's global initiative on Eco-DRR, the "Ecosystems Protecting Infrastructure and Communities" (EPIC) project in the Saloum Delta, started with participatory vulnerability and capacity assessments (VCA) that were carried out in six surrounding villages. These assessments identified key socio-economic activities in the area, for example, agriculture, livestock and fisheries that can be easily influenced by extreme weather events. Results from the VCA also pointed out that land salinisation was a major socio-economic challenge affecting crop production and livelihoods and that unsustainable management of natural resources was also a key factor contributing to vulnerability.

Together with conducting social vulnerability and capacity assessments as part of baseline information, Eco-DRR convenes a wider range of stakeholders from the national to local levels, such as rural development planning divisions, disaster management authorities and local councils rather than working merely with conservation and environment management oriented authorities. These stakeholders often do not interact naturally and therefore Eco-DRR provides a platform for new and innovative partnerships across sectors (Figure 7).

Furthermore, Eco-DRR may be a combination of various ecosystem management approaches such as conservation (for example protected area or habitat management and ecosystem

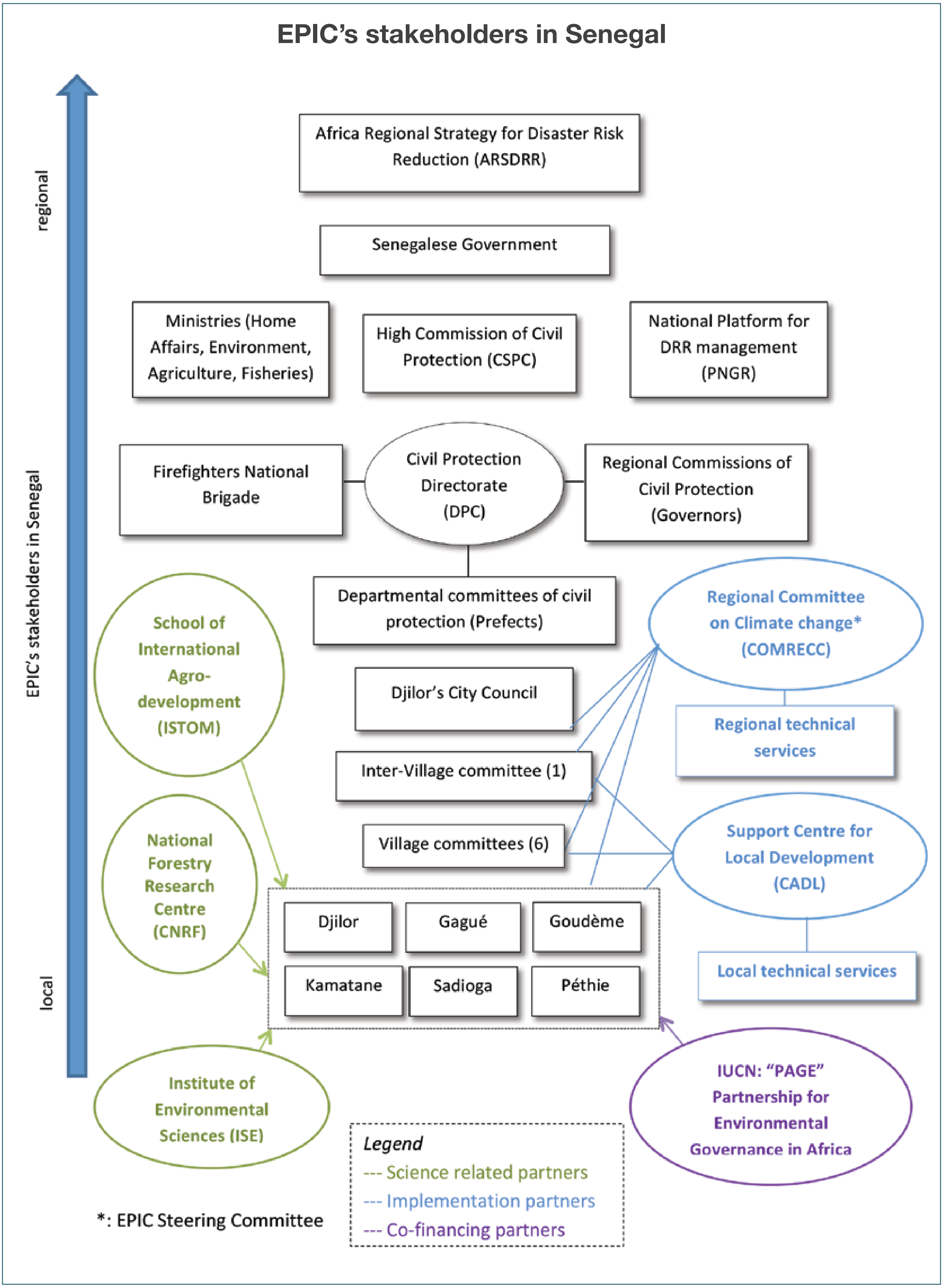


Figure 7. Example of multi-stakeholder platform from IUCN's EPIC project in Senegal.

restoration) rather than a single conservation objective oriented intervention. In doing so, the starting point of Eco-DRR is holistic solutions to the societal challenge at hand – reducing disaster risks for communities at the particular site while maintaining or restoring the ecosystem resilience in the area.

For example, EPIC is also implemented in three districts in Nepal where studies were carried out on soil erosion and landslide rates from road construction. The studies documented how these factors impacted upon the amount of sediment originating from rural roads in the Phewa Lake watershed that eventually impact its rivers and lake. A combination of bioengineering and slope restoration was used to reduce the risks of landslides and erosion. The species of vegetation used provided local communities with a livelihood source (grasses for making brooms and fodder for livestock). A cost-benefit analysis was conducted in order to compare conventionally constructed rural roads with bio-engineered roads, demonstrating considerable cost savings for bio-engineered roads. Finally, three weather stations were established at each site, including one at a school, providing the opportunity for students to monitor weather trends (IUCN and UNIL, 2016).

Additionally, Eco-DRR can consist of a combination of ecosystem management approaches and engineering hard infrastructure as also seen in the Nepal case study above. Eco-DRR seeks complementarities between green and grey infrastructure in order to ensure effective risk reduction. During Hurricane Katrina a combination of levees and trees within the national parks on the coast of New Orleans provided more effective protection while the levees with no trees behind them failed (Murti and Buyck, 2014). Since the 14th century Japan has been using a combination of green and grey infrastructure to protect its coastlines from natural hazards. Grey infrastructure such as seawalls is combined with coastal green belts, highways and zoning (to regulate residential areas) to establish multiple layers of defence (Furuta and Seino, 2016). The combination of such green and grey infrastructure is increasingly gaining importance for hazard mitigation in both developing and developed countries (Table 4).

Table 4. Summaries of the strengths and weaknesses of built, natural and combined solutions (Source: Sutton-Grier et al., 2015)

Infrastucture type	Strengths	Weaknesses
Built (seawalls, levees, bulkheads, etc.)	• Significant Expertise already exist on how to design and build such approaches	• Does not adapt with changing conditions such as sea-level rise
	• Decades of experience with implementing this approach	• Weakens with time and has a built-in lifetime
	• Excellent understanding of how these approaches function and what level of protection will be provided by different types of structures built to specific engineering standards	• Can cause coastal habitat loss and have negative impacts on the ecosystem services provided by nearby coastal ecosystems
	• Ready to withstand a storm event as soon as they are constructed	• Can lull communities into thinking they are not safe from all disasters leading to increased loss of life or property
		• May sustain more damage during small storm events than natural approaches

Infrastucture type	Strengths	Weaknesses
		• Only provides storm protection benefits when a storm is approaching; no co-benefits accrue in good weather
Natural (salt marsh, mangrove, beach, dune, oyster and coral reefs, etc.)	• Provides many co-benefits in addition to coastal protection including fishery habitat, water quality improvements, carbon sequestration and storage, and recreational use, and can provide these benefits to coastal communities all the time, not just during storm events	• Need to develop best practices for how to restore ecosystems
	• In the case of ecosystem restoration, the ecosystem grows stronger with time as it gets established	• Provides variable levels of coastal protection (non-linearity of the provisioning of coastal protection benefits) depending on the ecosystem, geography and also on the type and severity of storm; need more research to better understand how to estimate or predict the coastal protection provided
	• Has the potential to self-recover after a storm or forcing event	• In the case of restored ecosystems, it can take a long time for ecosystems to get established for the natural systems to provide the necessary level of coastal protection
	• Can keep pace with sea-level rise	• Likely requires a substantial amount of space to implement natural approaches (such as ecosystem restoration or protection of existing ecosystems) which may not be possible
	• Can be cheaper to construct	• · Permitting for natural projects can be a more difficult process than for built projects
	• Can survive smaller storms with less damage than built infrastructure, and can self-repair	• Growing but still limited expertise in the coastal planning and development community on which approaches to use where and when
Hybrid (combination of built and natural)	• Capitalizes on best characteristics of built and natural	• Little data on how well these systems perform to date
	• Allows for innovation in designing coastal protection systems	• Does not provide all the same benefits that natural systems provide
	• Provides some co-benefits besides coastal protection	• Need more research to design the best hybrid systems
	• Can provide a greater level of confidence than natural approaches alone	• Growing but still limited expertise in the coastal planning and development community on which approaches to use where and when
		• Hybrid systems, due to the built part of them, can still have some negative impacts on species diversity
		• Few data on the cost to benefit ratio for projects
		• Permitting for hybrid projects can be a more difficult process than for built projects

2.5 Supporting ecosystem-based adaptation for longer term resilience

Eco-DRR can be an effective approach to support climate change or more precisely ecosystem-based adaptation strategies. Ecosystem-based adaptation (EbA) is defined as the “sustainable management, conservation and restoration of ecosystems, as part of an overall adaptation strategy that takes into account the multiple social, economic and cultural co-benefits for local communities” (CBD, 2010). EbA aims to maintain and increase the resilience and reduce the vulnerabilities of ecosystems and people in the face of the adverse effects of climate change. Ecosystem-based adaptation is most appropriately integrated into broader adaptation and development strategies (CBD, 2009:41).

It is generally agreed that there is an overlap between EbA and Eco-DRR initiatives. While both approaches are based on preservation, sustainable use and restoration of ecosystem services, EbA strategies target longer term climate projections and impacts whereas it can be said that Eco-DRR measures are based on addressing physical impacts as well as underlying vulnerabilities from natural hazards. Table 5 summarises the differences and points of convergence between Eco-DRR and EbA, as articulated by Doswald and Estrella (2015).

Table 5. Differences and Points of Convergence between EbA and Eco-DRR (Doswald and Estrella, 2015)

DIFFERENCES		POINTS OF CONVERGENCE
Eco-DRR	EBA	
Usually adopts UNISDR termino- logy in defining disaster risk (as a function of hazard, exposure and vulnerability)	Usually adopts UNFCCC termino- logy in defining vulnerability (as a function of sensitivity, exposure and adaptive capacity)	Greater convergence towards adopting com- mon terminologies
Deals with climate-related hazards, but also non-climate hazards such as tsunamis, earth- quakes, avalanches and rockfall	Deals with climate-related ha- zards, but also deals with climate change impacts, including sea level rise, glacial lake outbursts, and broad changes to tempera- ture and rainfall patterns	Most Eco-DRR and EBA projects deal with water- and climate-related hazards; Eco-DRR increas ingly factoring in climate change impacts
aims to “reduce disaster risk”, “increase protection and resilience against hazards”	aims to “reduce vulnerability”, “increase resilience to climate change”, “undertake appropriate adaptation”	Key differences in stated aims are purely seman- tics in how terminology is being used. Both Eco- DRR and EBA emphasize the multiple benefits of ecosystem services, including for sustainable livelihoods.
Conducts disaster risk asses- sments (DRA), usually starting with a focus on hazards, exposure and vulnerabilities as core ele- ments to understanding disaster risk, but also assessing linkages to environmental conditions and natural resource management	Conducts vulnerability assessments (VA), usually starting with an ecosystem focus (e.g. impact of climate change on biodiversity loss and ecosystem integrity), and developing future change scenarios.	Both seek to incorporate ecosystems and environmental factors within their assessment frameworks; with growing appreciation in Eco- DRR to incorporate future climate trends. But given difficulties in determining future climate change projections, especially at a field/local level, both Eco-DRR and EBA projects tend to rely on examining past and current risks, a key characteristic of DRR practice.

DIFFERENCES		POINTS OF CONVERGENCE
Eco-DRR	EBA	
implementation approach - Less focus on biodiversity conservation and protection as a primary aim; focus is on optimizing ecosystem services for increasing resilience of people or reducing exposure and vulnerability to hazard impacts	implementation approach - Greater emphasis (but not always) on the health status of ecosystems and their services, and on biodiversity conservation; focus on maintaining and increasing resilience of biodiversity and ecosystem services to enable people adapt to climate change impacts.	Both apply sustainable ecosystem management principles and utilize a common set of tools and approaches, such as: integrated water resource management (IWRM), integrated coastal zone management (ICZM), protected area management, drylands management, among others.
Typically incorporates other key aspects of disaster risk management, such as establishing early warning systems and undertaking disaster preparedness	Emphasis is on strengthening "adaptive management" due to uncertainty of climate change impacts;	Both incorporate disaster preparedness / mitigation measures, including early warning systems
Less attention given to M&E, apart from standard project reporting requirements	Active discussions on developing M&E frameworks and guidelines for EBA / CCA projects	Both face challenges of attribution in evaluating effectiveness and impacts through an ecosystem-based approach. Little attention overall given to developing indicators for EBA and Eco-DRR projects.
actors involved - Typically Involve environmental agencies/ ministries, conservation NGOs but also humanitarian and disaster management actors at local and national levels, as well as climate change focal points	actors involved - Typically involve environmental agencies/ ministries, conservation NGOs, climate change national focal points; usually does not engage with humanitarian or disaster management actors	Both increasingly recognize the importance of bringing together different communities and sectors, including from disaster management, climate change, environment and other key sectors (e.g. water, agriculture).
policy advocacy can target a broad range of policies, including climate change adaptation strategies, environmental policies, and other sectoral policies (e.g. water, agriculture)	policy advocacy generally focuses on the national adaptation strategy as well as other development policy sectors affected by climate change (e.g. water); rarely works on DRR-related policies	Both typically engage with the environmental ministries/agencies and the conservation community, but still with a tendency to operate in separate policy tracks, depending on whether the project is more oriented towards DRR or CCA.

Based on this comparison, Eco-DRR can be essentially considered as EbA when addressing vulnerability to climate-related hazards such as droughts and floods. Similarly, Eco-DRR would diverge from EbA when addressing other hazard types such as earthquakes.

Several initiatives are also described interchangeably as either Eco-DRR or EbA and it is recognised that hybrid projects exists (Doswald and Estrella, 2015). In a global review on experiences with ecosystem-based approaches to climate change adaptation and disaster risk reduction, Lo (2016) classified case studies as EbA, Eco-DRR or both as some EbA projects contain Eco-DRR measures and vice versa (Figure 8).

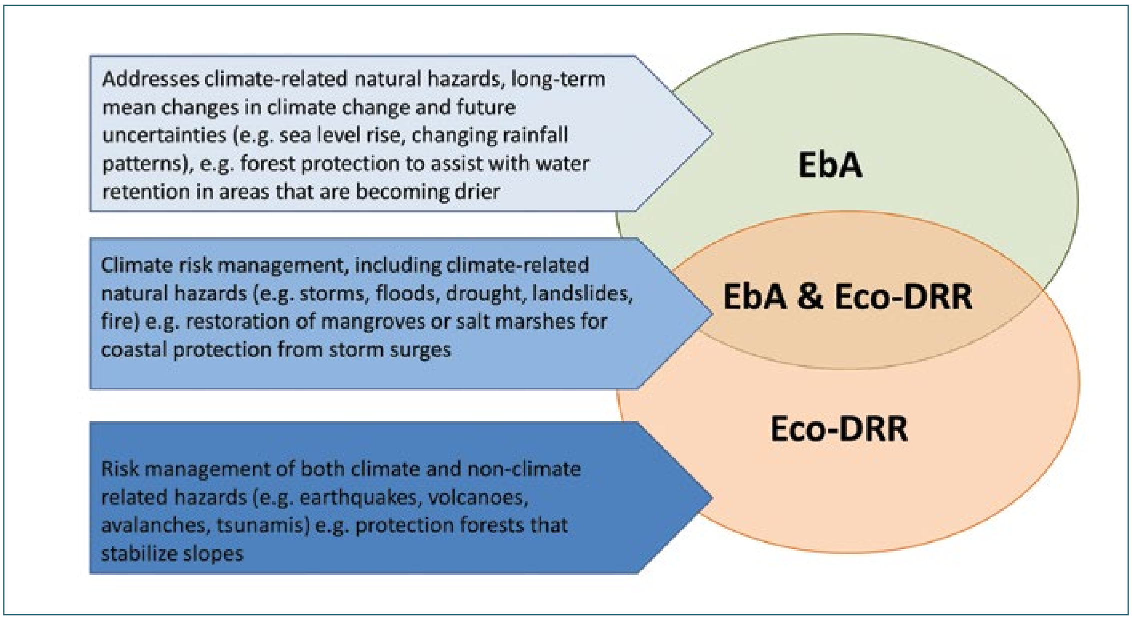


Figure 8. Overlap between EbA and Eco-DRR (Source: Lo, 2016)

Renaud et al. (2016) also provide a definition for projects that cover both Eco-DRR and climate change adaptation as “the sustainable management, conservation, and restoration of ecosystems to reduce risk and adapt to the consequences of climate change with the aim of achieving sustainable and resilient development”.

Ecosystem-based approaches for both disaster risk reduction and climate change adaptation have a great potential to support biodiversity conservation and vice-versa given that it is dependent on the maintenance of healthy ecosystems and the services that they provide. However, a greater understanding on the linkages between these fields, i.e. biodiversity conservation and Eco-DRR, is needed for integration.

Chapter 3

3.1 The role of biodiversity in disaster risk reduction

The Convention on Biological Diversity defines biological diversity or biodiversity as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems".

Using this definition, it is possible to say that the role of biodiversity in disaster risk reduction is actually well documented but only with regard to ecosystems and the associated ecosystem services that they provide. These key ecosystem services for DRR include mostly regulating and supporting services, for example, natural hazard mitigation, erosion control, water regulation and soil formation (Munang et al., 2013). Development in the field of Eco-DRR involves an increasing recognition of how different ecosystems can contribute to DRR (Table 6). However, the case for the importance of the constituents of ecosystems, i.e. species diversity and genetic diversity, to reducing risk is rarely made.

In terms of information gaps, the role of species and genetic diversity is indeed rarely documented and recognised. The literature review process for the regional assessments revealed a general lack of scientific literature and quantitative evidence on the role of species and genetic diversity. There are three possible reasons for this:

1. Species and genetic diversity simply do not contribute to DRR or their role is minimal
2. The documentation on the subject may not be explicitly documented or identified as DRR. For example, one could show evidence for the importance of marine species diversity for livelihood resilience but it would take a minimum level of familiarity with the concepts of DRR to identify the links
3. This is a relatively new field which is only now gaining attention

It is outside the scope of this publication to confirm which of the above reasons is true or to state that there is absolute certainty that "diversity within and between species is key for disaster risk reduction". However, it is very likely that the last two reasons are valid.

In spite of the lack of clear scientific evidence on the subject, there is enough information both from research and from project experiences to identify the key broad potential role of species and genetic diversity to DRR (Figure 9).

Table 6. Summary of the role of different ecosystem types in risk reduction (Sources: Estrella and Saalisma, 2013; Renaud et al., 2016)

Ecosystem	Role in risk reduction
Coastal ecosystems (mangroves, saltmarshes, coral reefs, barrier islands, sand dunes)	Protect coastline from cyclones, storm surges, tsunamis, etc.
Riverine ecosystems (marshes, lakes, floodplains, peatlands)	Mitigate floods
Forests	Reduce risk of soil erosion and landslides; mitigate droughts and floods

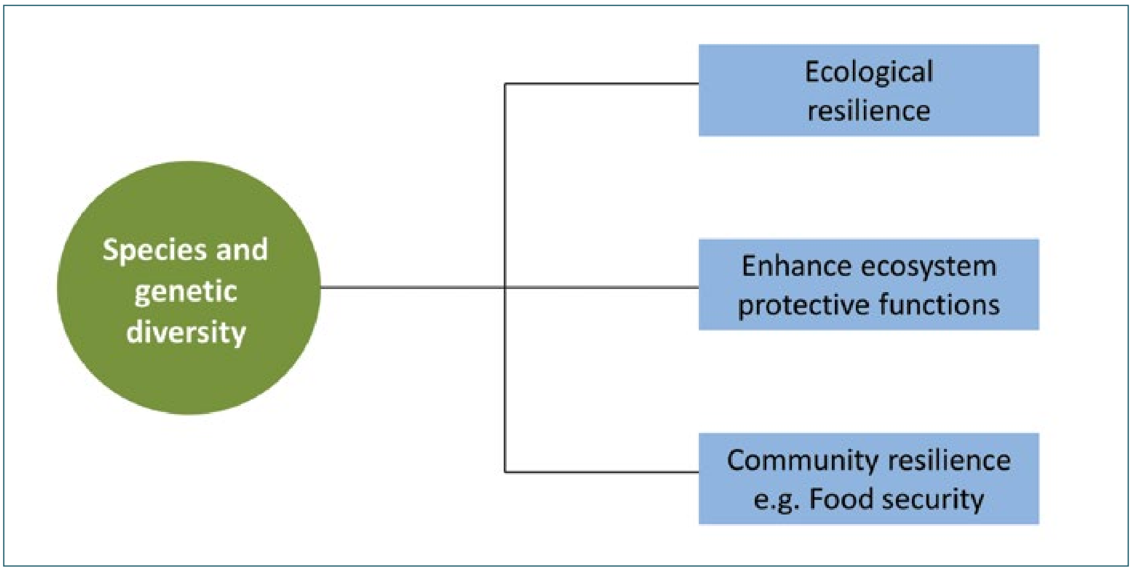


Figure 9. Potential role of species and genetic diversity in disaster risk reduction

3.1.1 Importance of species diversity for ecological resilience

Ecological resilience is considered as an indicator of disaster resilience (Cutter et al., 2008) and has an important role to play in risk reduction (Adger et al., 2005). There has been an increasing documentation as well as debate on the importance of diversity for ecological resilience, resistance and functioning. And there are now multiple studies including experiments that reveal that biotic diversity can help ecosystems recover from disturbances and environmental change more quickly (Folke et al., 2004). For example, species diversity contributes to the complexity of ecosystems and can influence ecosystem functioning and services (Folke et al., 2004; Balvanera et al., 2006). Table 7 summarises some of these examples. Diversity is reported to not only contribute to resilience but also to ecosystem resistance, which is the amount of perturbation that a system can withstand without changing state (Downing et al., 2012). For example, Isbell et al. (2015) demonstrated using field experiments that diverse grassland plant communities were more resistant to climate extremes, namely drought.

With regard to the ability of species diversity to contribute to resilience, Oliver et al. (2015) mentioned the 'insurance effect' of higher diversity, which is relevant at both species and genetic level. For example, several species perform similar functions in ecosystems, a situation known as functional redundancy, but sensitivity to disturbances may also vary among these species, meaning that some species may still persist following environmental change and would ensure the functions of other species that have been lost (Oliver et al., 2015). A similar effect can occur within species with, for example, different genotypes being more resistant to change, thus the importance of genetic diversity (Sgro et al., 2011).

3.1.2 Importance of species diversity in enhancing the protective function of ecosystems

While ecosystems can act as buffers or provide physical protection from hazards, it is also important to understand how its constitution indirectly contributes to or enhances these services. Higher species diversity in an ecosystem is equivalent to more diversity in both physical and biological traits. The latter has the potential to contribute to ecological resilience as mentioned earlier while diversity in physical or structural traits has the potential to increase the protective function of ecosystems. As mentioned earlier, mangroves are recognised as being important in protecting shorelines, for example, against storms and winds (Das and Crépin, 2013). In Mexico, mangroves are

Table 7. Examples of how species diversity can contribute to ecosystem resilience

Biodiversity type	Effect on ecosystem	Source
Beta-diversity of fish communities (species turnover)	More stable to fluctuations	Mellin et al., 2014
Diversity of seaweed species	Increased recovery rate following clearing	Aquilino and Stachowicz, 2012
Diversity of wetland plant communities	Recovery of wetland plants following clearing of above ground biomass were higher in diverse communities	Carvalho et al., 2013
Marine species diversity	Maintain provision of ecosystem services e.g. primary productivity, water quality	Worm et al., 2006
Grassland plant diversity	Higher diversity maintain ecosystem services and also greater resistance to environmental stress, including disease and pests	Isbell et al., 2015; Tilman et al., 2012; Tilman and El Haddi, 1992)
'Response diversity': variation of responses to environmental change among species of a particular community	Maintain ecosystem functioning	Mori et al., 2013

estimated to reduce storm surges by 50% (Blankespoor et al., 2016).

While the type of goods and services provided by mangroves varies according to the type of the mangrove forests, the protective role of mangrove forests can also vary depending on their species diversity components. For example, a study by Tanaka et al. (2006) in Sri Lanka and Thailand indicates that the identity of species and their structural characteristics can contribute to increasing the protective function of the vegetation against tsunamis (Figure 10), for example:

- Variation in horizontal and vertical structure can reduce the speed of tsunami currents
- Complex aerial root structure of some mangrove species provides protection from tsunami damage
- Some tree species provide soft landing for people carried by currents
- Bigger trees will catch more man-made debris
- Some tree species are also effective at providing escape routes for people by having low branches

The authors also noted that some mangrove species such as *Rhizophora apiculata* types that have complex aerial root structures provided more protection from tsunami damage.

Species diversity ensures there is a variation of traits within ecosystems, which can be defined as "a distinct, quantitative property of organisms, usually measured at the individual level and used comparatively across species" (Stokes et al., 2009). These provide a pool of desired characteristics that can be used in risk reduction strategies. For example, plant root systems can play an important role in the ability of riverine and forest ecosystems to mitigate the risks of floods, erosion and landslides, particularly when these ecosystems are being restored for their regulating ecosystem services. Plant species vary in their ability to stabilise soil and control surface-water flow depending on their set of traits that can make some species more desirable for restoration activities. Root structural diversity is important in soil bioengineering where it is used to stabilise slopes or as part of watershed management efforts (Ghestem et al., 2014). Stokes et al.

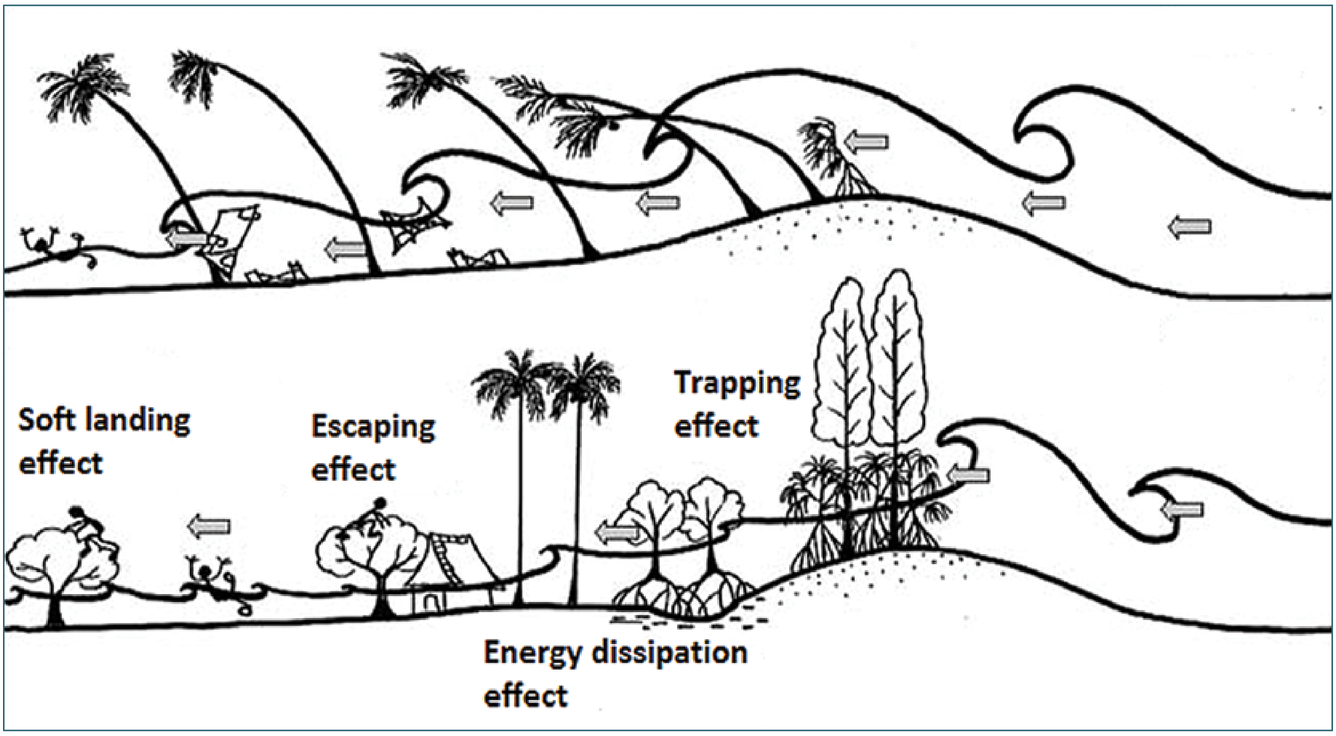


Figure 10. The functions of coastal vegetation structure during tsunami inundation (Source: Tanaka et al., 2006)

(2009) identified some of the desirable root traits for plants to increase slope stability including: root thickness, deep roots, roots with multiple orientations, etc. For example in Nepal, bio-engineering is being used to stabilise road slopes and create what are called 'Eco-safe roads'. By combining the use of plants that are suitable for slope stabilisation as well as being resistant to adverse climatic events such as droughts, landslides are not only being mitigated but there is greater chance for this benefit to be maintained under changing climatic conditions (Sudmeier-Rieux et al., 2014).

Examples of other desirable species traits for risk reduction include drought- and fire-resistance (Oldfield and Olwell, 2015). For example, depending on the level of moisture, some species contain more fuel and are more prone to fires (Livingston et al., 2016). Targeting a combination of desired plant traits can also increase the protective ability of ecosystems over time.

Coral reef diversity in species traits can also play a role in risk reduction measures such as reef restoration.

The choice of species used is one key factor that can determine the success of such restoration works. For example, reef rehabilitation through translocation of coral fragments is more successful with specific coral species that, for example, reproduce by fragmentation or are able to withstand breakage as noted in the Philippines (Cruz et al., 2014; Gomez et al., 2011).

3.1.3 Importance of genetic diversity for food security and livelihoods

Food security is an important component of community resilience and the lack of it is increasingly becoming a major challenge worldwide particularly in the context of climate change and increased frequency and length of drought periods (Godfray et al., 2010). One potential threat to food security worldwide is the homogeneity of crop species, which makes them vulnerable to climate extremes (Khoury et al., 2014; FAO, 2015). Farming is not only directly linked to food production and food availability but it is an important source of livelihood thus income for many communities around the globe, thus the importance of

Box 3: Protecting crop genetic diversity in Mali and Burkina Faso

Bora Masumbuko

Sorghum is the main cereal in Burkina Faso and the second main cereal in Mali. Sorghum and millet are the staple food in rural areas and are important for food security in these areas. This landrace is, however, facing genetic erosion for the following reasons: great inter-annual variability of rains, the reduction in the duration of the rains, the impoverishment of the soil, pressure of certain pests, competition with other crops, in particular corn, and the requirements of the market. Due to this genetic erosion, a project has been conceived in order to develop a wide range of new varieties that are more efficient and adapted to local climate conditions and to the needs of farmers. While the use of crop wild relatives is not well developed in West and Central Africa, it also has the potential to protect Sorghum and Millet farming systems. For example by protecting the wild relatives of modern cultivated species like millet or sorghum in protected areas, the productivity of the species and their availability to be used for DRR purposes can be increased.

protecting crop genetic resources (Burke et al., 2009; FAO, 2015).

Maintenance of genetic diversity in food crops provides important long-term adaptivity as it reduces the potential impacts of different stressors such as drought, as some varieties or genotypes can be more resistant to changing climatic conditions (FAO, 2015).

In efforts to establish resilient crop systems, crop wild relatives (CWR) are also important genetic resources (Dempewolf et al., 2014). CWR are defined as "a wild plant taxon that has an indirect use derived from its relatively close genetic relationship to a crop" (Maxted et al., 2006). Basically, CWR are wild species that are related to crops and can contribute traits for crop improvement including drought resistance (Vincent et al., 2013).

3.2 Synergising biodiversity conservation and Eco-DRR

Conservation can be defined as any action or intervention implemented to manage, protect, enhance or restore biodiversity or ecosystem services (Conservation Evidence, 2016). IUCN has a classification scheme illustrating the variety of possible actions for conservation, which are grouped under six main categories: 1) Land/water protection, 2) Land/water management, 3) Species management, 4) Education & awareness, 5) Law and policy, and 6) Livelihood, economic & other incentives.

Through the protection of ecosystems, its constituents and ecosystem services, biodiversity conservation has an important role to play in Eco-DRR and vice-versa. The two fields of practice mainly differ in their targets or goals with conservation aiming to conserve biological entities such as species, ecosystems and communities while Eco-DRR aims to protect society from disasters. Beside this difference, both share several commonalities in terms of measures implemented as well as the problems and stressors that they are trying to address (Figure 11), thus providing a strong basis for synergies and integration.

3.2.1 Eco-DRR contributing to biodiversity conservation

Co-benefits for conservation

Through the implementation of environmental management approaches (Figure 11), Eco-DRR

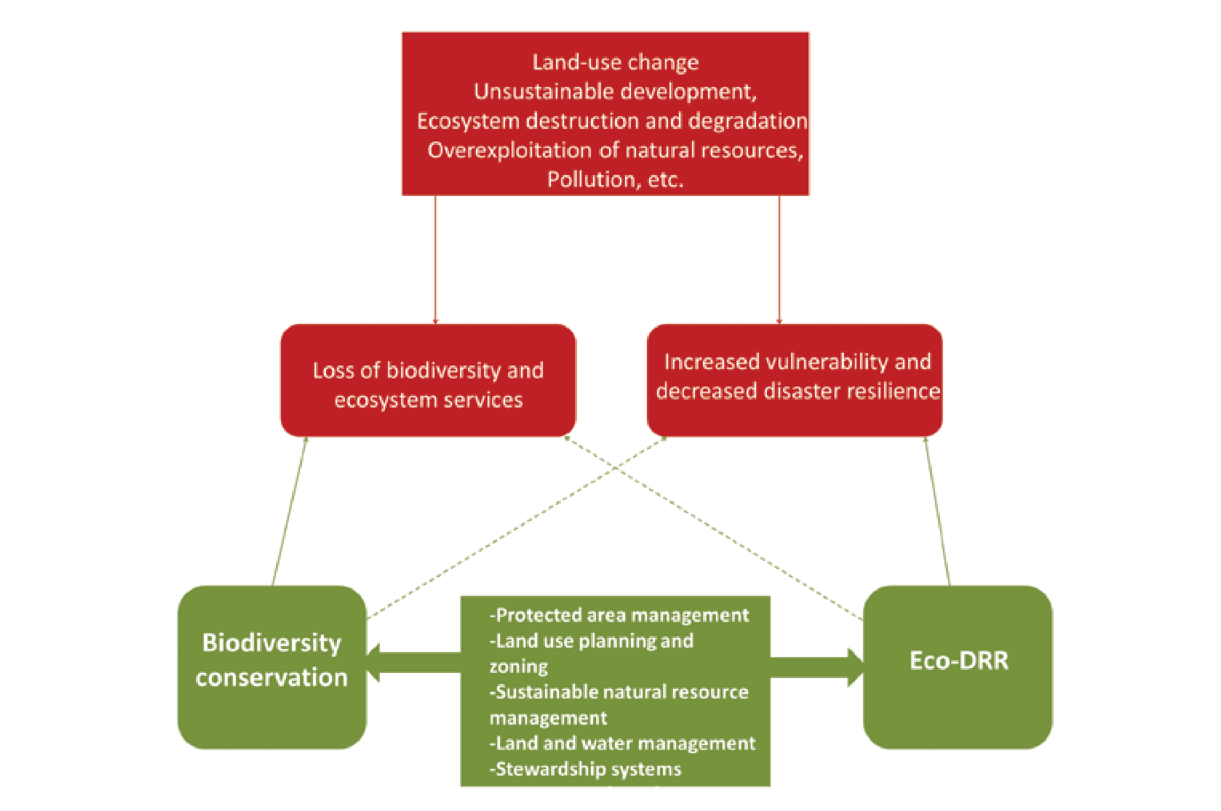


Figure 11. Commonalities between biodiversity conservation and Eco-DRR in terms of practices and challenges that affect both

can also result in conservation/biodiversity benefits. For example, the IUCN Mangrove Ecosystems for Climate Change Adaptation & Livelihoods (MESCAL) Project is being implemented in several islands of the Oceania region to build resilience of the communities using adaptive co-management of mangroves. As part of the project, inventories of the fauna and flora were conducted in the demonstration sites resulting in the discovery of previously unrecorded flora species. The surveys also revealed that an existing community conservation area in eastern Vanuatu is an important biodiversity site, which resulted in the legal registration of the site under the national Environmental Protection and Conservation Act (EPC Act).

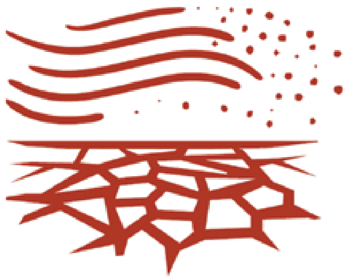
DRR benefits as an incentive for conservation

The primary arguments and justification for the establishment of new management or protected areas is the conservation value of a particular site with the species composition and threats driving the process of site prioritisation, for example, Rodrigues et al., (2004). However, the provision of key ecosystem services such as risk mitigation can add value to such conservation decisions and provide non-monetary incentives to manage and protect ecosystems primarily for DRR benefits, which ultimately cascade down to conservation of new areas. One key example of this, which is further covered in chapter 3, is the expansion of Japan's coastal forests, in the form of Sanriku Fukko Reconstruction Park to reduce coastal risks (Renaud and Murti, 2013).

3.2.2 Biodiversity conservation as a tool for DRR

DRR co-benefits of conservation

Conservation can provide co-benefits for DRR for example by maintaining healthy resilient ecosystems (Bengtsson et al., 2003) and protecting the potential risk reduction value of species and genetic diversity as discussed earlier. The role of protected areas in DRR is particularly well-documented by IUCN (Dudley



Drought, desertification and dust storms: protected areas can stabilize soils and reduce dust storms and desertification in arid areas by reducing grazing and trampling pressures. They can also help regeneration by maintaining drought resistant plants

Wildfire: protected areas can help to maintain management systems that control fire patterns and exposure in savannahs, temperate and boreal forests and scrub. In tropical forests, fires are more frequent in secondary forests so preserving primary forest can help reduce fire incidence and spread

Figure 12. Examples of the role of protected areas in mitigating risks from drought and wildfire (Source: Dudley et al., 2015)

et al., 2015; Murti and Buyck; 2014; IUCN, 2013) highlighting their role in maintaining goods and services, enhancing local resilience and mitigating climatic hazards by protecting intact ecosystems and reducing pressure on the land. Figure 12 illustrates how protected areas can be a tool to mitigate risks from droughts and wildfire.

There are documented examples on the impact of introduced invasive species in exacerbating risks from natural hazards. For example, invasive species that have shallow roots, as they become dominant in an area exacerbate soil erosion and risks of landslides (Restrepo et al., 2009).

Similarly, invasive plants can affect fire regimes by increasing the fuel content in an ecosystem (Brooks et al., 2004). For example, a study conducted on California grasslands revealed lower moisture content in non-native annuals making them more prone to fires (Livingston et al., 2016).

3.3 Integrating biodiversity conservation and DRR to enhance co-benefits

Bringing lessons and knowledge from both the DRR and conservation perspectives, provides opportunities to rethink the implementation of a project to enhance co-benefits for achieving both biological and social goals of risk reduction and conservation. Considering the potential role of biodiversity in DRR, some examples for integrated actions that can be considered:

- **Conserving genetic diversity of native species in situ:** CWR also include native plant species of conservation value (Kell et al., 2012; Vincent et al., 2013) and thus provide opportunities to synergise biodiversity conservation, disaster risk reduction and climate adaptation. There are currently more and more inventories of CWR, and priority species or taxa for ex-situ and/or in-situ conservation are being identified and documented (Vincent et al., 2013; Castañeda-Álvarez et al., 2015).

- **Suitable species for restoration activities:** when studying suitability of different species for restoration and bioengineering activities, special consideration can be given to identify those species from a pool of native and endemic species in a country or region.

There are also important tools that can be used to implement projects with combined biodiversity-DRR targets through spatial planning, with GIS being one of the most promising tools particularly as more datasets are made available. Gap analysis can be a useful tool for conservation planning as well as to inform policy. Dudley et al. (2015) provided a brief step-by-step approach on how a gap analysis can be used to identify potential protected areas for both conservation and DRR by combining data on protected area occurrence with other datasets (i.e. critical sites for Eco-DRR). Further resources need to be invested in developing such maps, not only with regard to the establishment of protected areas but also to identify priority areas for different management efforts. This is particularly relevant and potential catalysts for action with the increasing opportunities for integrated approaches at the policy level.

Chapter 4

4.1 Global policy coherence and synergies

The Yokohama Strategy for a Safer World: Guidelines for Natural Disaster Prevention, Preparedness and Mitigation and its Plan of Action (Yokohama Strategy) was the first global framework for DRR, established in 1994. It was offered as guidance for member states to implement voluntarily. Following the devastation from the Western Indian Ocean Tsunami of 2004, the world came together to establish a tighter global blueprint, The Hyogo Framework for Action (HFA) 2005-2015, to promote risk reduction and define mechanisms for international cooperation in times of such events. While HFA remained as a non-binding framework, its relevance and importance were demonstrated through member states' commitments for implementation. The Sendai Framework for Disaster Risk Reduction (SFDRR) has been established as the new global framework, 2015-2030. It is informed by lessons from the last 10 years, including a stronger implementation and monitoring plan.

The Yokohama Strategy and the HFA recognised the need to address environmental degradation as a key aspect of disaster risk reduction. The HFA elaborated on the sustainable use and management of ecosystems through improved land-use planning and risk sensitive development. It also advocated for the mainstreaming of DRR into environmental management approaches within Priority for Action 4 – "(b) Implement integrated environmental and natural resource management approaches that incorporate disaster risk reduction, including structural and non-structural measures, such as integrated flood management and appropriate management of fragile ecosystems" (UNISDR, 2005). While this was a critical recognition of how degraded ecosystems can exacerbate social and ecological vulnerabilities, it fell short of advocating for investment in the effective management of ecosystems to reduce social vulnerabilities. The International Union for Conservation of Nature (IUCN) and various partners of the Partnership for Environment and Disaster Risk Reduction (PEDRR, 2016) strongly influenced the new global agreement for disaster management, The Sendai Framework for Disaster Risk Reduction 2015-2030 (SFDRR) (UNISDR, 2016) to recognise and promote the role of ecosystem management in disaster risk reduction, especially considering the lessons learnt from major disasters in the past decade (Murti and Buyck, 2014, Renaud et al., 2013). Consequently, for the first time, the SFDRR recognises the role of ecosystems and environment as a cross-cutting issue to be addressed for DRR:

Ecosystems will now need to be taken into account in undertaking risk assessments (Priority 1), risk governance (Priority 2) and investing in resilience (Priority 3). Environmental impacts assessments are also cited as important tools to achieve risk-sensitive public and private investments. The Sendai framework further acknowledges the need to tackle environmental drivers of disaster risk, including ecosystem degradation and climate change, as well as the environmental impacts of disasters. Integrating DRR in global/regional and national policies related to environment/natural resource management.

Following these positive developments, other global conventions and frameworks also recognised and adopted the role of healthy ecosystems as solutions for disaster risk reduction (Table 8).

The United Nations Environment Programme (UNEP) and IUCN supported the government of the Philippines to table a decision on the role of wetlands for DRR at the 12th meeting of the Conference of Parties in 2015. The decision was adopted as resolution XII.13, highlighting the need to better document and recognise the damages done to wetlands during and after disasters, as well as investing in wetlands for DRR. Similarly, with technical support from IUCN, the government of Japan proposed Decision XII/20 during the 12th Conference of Parties to the United Nations Convention on Biological Diversity in 2014. The Decision was adopted by all parties and advocates for the integration of disaster risk management and climate change into the national biodiversity conservation mechanisms as well as recognising the role of biodiversity and ecosystem services in DRR and CCA.

The Sustainable Development Goals are inclusive of ecosystem management, reducing ecosystem degradation as well as addressing disaster risk reduction for sustainable development. The goals also push for addressing climate change related hazards and the negative impacts of climate change on ecosystems such as ocean acidification, with targets in at least six goals (Table 8). As countries plan their SDG interventions, the role of ecosystems as a solution, and especially eco-DRR, can be prioritised, in order to support the multiple goals and targets. The UNFCCC 21st Conference of the Parties – Paris Agreement on Climate Change further re-enforced the urgent need to preserve ecosystem integrity in order to enhance social and ecological resilience to climate related hazards.

The pilot applications, advocacy and awareness raising on Eco-DRR has led to these positive developments from such key global policy frameworks in the past year. These developments provide a well aligned opportunity to dramatically scale up Eco-DRR, globally. As countries develop their disaster management plans, update their National Biodiversity Strategies and Action Plan, ratify and develop plans for the Paris Agreement as well as establish their national goals and targets for SDGs, ecosystem management can provide the option of achieving multiple national commitments through the same investment. The multiple-benefits aspect of ecosystem management becomes even more pertinent in this context, through addressing issues such as climate regulation, hazard mitigation, livelihood support, poverty alleviation and water security derived from a well maintained ecosystem. Furthermore, as highlighted in this publication, ecosystems can appreciate over time, whereas engineered infrastructure may depreciate, while serving less functions.

As the global blueprint for DRR, the Sendai monitor provides a strong basis to incorporate the recognition of effective ecosystem management as demonstrable risk reduction investments for national governments. Previously the focus on risk management has been on factors such as conducting risk assessments to better understand vulnerability and exposure as well as data sharing. Additionally, the indicators to measure risk reduction are based on mortality rates and economic losses. These aspects re-enforce the reactive and at best preparedness mind-set rather than encourage proactive risk reduction actions. Eco-DRR could provide a way for national governments to put forward tangible and demonstrable actions towards active risk reduction and, importantly, with an option that brings about multiple social, economic and ecological benefits (MEA, 2005).

Similar to the challenges of setting DRR targets, biodiversity has been difficult to define due to its multi-levelled, multi-scaled and complex nature. Until the MEA 2005 assessment, it was challenging to articulate ecosystem services and incorporate actions to preserve them into planning. However, with the articulation of concepts such as natural capital (Natural Capital Project, 2016), natural infrastructure (WRI, 2013) and nature-based solutions (Cohen-Shacham et al., 2016) actionable investments are increasingly becoming possible for Eco-

Table 8. Summaries of recent policy developments with regard to Eco-DRR (Renaud et al., 2016)

Policy agreement	Summary description	Number of signatory parties (Member States)	Key provisions on Ecosystem-based DRR/CCA in the Agreement	National-level instruments/mechanisms for implementing the Agreement and scope for promoting Eco-DRR/CCA through these instruments
Sendai Framework on Disaster Risk Reduction – SFDRR (2015-2030)[1]	The SFDRR is the global framework on Disaster Risk Reduction, with seven targets and four Priorities for Action. It seeks to prevent new and reduce existing disaster risk through the mainstreaming of disaster risk reduction across all development sectors, programmes and policies. While the SFDRR is a voluntary, non-binding agreement, it calls for an all-of-society engagement, with governments having the primary role of reducing disaster risk.	187 Member States adopted the SFDRR at the 3rd World Conference on DRR in March 2015. The SFDRR was subsequently endorsed at the UN General Assembly's 69th Session in June 2015	The SFDRR recognises ecosystem degradation as a driver of risk as well as the environmental impacts of disasters. A new milestone is that the sustainable management of ecosystems is recognised as a key measure for building resilience to disasters. The role of ecosystems will need to be taken into account in disaster risk assessments (Priority Action 1), strengthening risk governance (Priority Action 2) and investments in disaster resilience (Priority Action 3). The SFDRR also calls for greater collaboration between institutions and stakeholders from other sectors, including from the biodiversity and environment sectors. It calls for ecosystem-based approaches to be implemented in transboundary cooperation for shared resources, such as within river basins and shared coastlines.	Countries will develop their national and local DRR strategies and plans. A focus on strengthening environmental resilience and ecosystem-based approaches could be featured in national and local DRR strategies, with targets and indicators developed as appropriate. Eco-DRR/CCA should also be mainstreamed across sectoral development plans and strategies (e.g. environment, water, agriculture, rural and urban land-use planning, etc.) (see also Sustainable Development Goals, below).

1 http://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf

Policy agreement	Summary description	Number of signatory parties (Member States)	Key provisions on Ecosystem-based DRR/CCA in the Agreement	National-level instruments/mechanisms for implementing the Agreement and scope for promoting Eco-DRR/CCA through these instruments
Sustainable Development Goals – SDGs (2015-2030), also the 2030 Sustainable Development Agenda[2]	With a total of 17 goals and 169 targets, the SDGs focus on three main areas: (i) eradication of poverty; (ii) protecting the planet from degradation, while ensuring that economic, social and technological progress occurs in harmony with nature; and (iii) promoting universal peace and just and inclusive societies. While the SDGs are not legally binding, governments are expected to take ownership and establish national frameworks for the achievement of the 17 Goals.	193 UN Member States have endorsed the SDGs, at the UN General Assembly's 70th Session in September 2015.	A major pillar of the SDGs is protecting the planet from degradation, including through sustainable consumption and production, sustainably managing its natural resources and taking urgent action on climate change. Sustainable ecosystem management is explicitly addressed under targets of Goals 2, 6, 11, 14 and 15, and with reference to curbing environmental degradation under Goal 8. DRR (and resilience) is explicitly mentioned under targets of Goals 1, 2, 4, 9, 11, 13 and 15, with reference to strengthening resilience under Goal 14. Climate change (including climate extremes) is explicitly mentioned under targets of Goals 1, 2, 11, 13, with reference to ocean acidification under Goal 14 and climate-related hazards under Goal 15. Maximum inter-linkages between ecosystems, DRR and climate change actions can therefore be supported under **Goal 2** (End hunger, achieve food security and improved nutrition and promote sustainable agriculture), **Goal 6** (Ensure availability and sustainable management of water and sanitation for all); **Goal 11** (Make cities and human settlements inclusive, safe, resilient and sustainable), **Goal 14** (Conserve and sustainably use the oceans, seas and marine resources for sustainable development) and **Goal 15** (Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss).	193 countries will develop their respective National Sustainable Development Strategies or National SDG Frameworks, and countries are tasked to develop corresponding indicators for each of the targets listed under the SDGs. To maximise integration between ecosystems, DRR and climate change, efforts can focus initially on Goals 2, 6, 11, 13, 14 and 15 where there are already strong linkages, as expressed through their respective targets: Goal 2 – Target 2.4 Goal 6 – Targets 6.5, 6.6. Goal 11 – Targets 11.4, 11.a Goal 13 – Targets 13.1, 13.2, 13.3, 13.b Goal 14 – Target 14.2 Goal 15 – Targets 15.1, 15.3

2 https://sustainabledevelopment.un.org/sdgs

Policy agreement	Summary description	Number of signatory parties (Member States)	Key provisions on Ecosystem-based DRR/CCA in the Agreement	National-level instruments/mechanisms for implementing the Agreement and scope for promoting Eco-DRR/CCA through these instruments
UNFCCC 21st Conference of the Parties – Paris Agreement on Climate Change[3]	The Paris Agreement seeks to significantly scale-up climate actions and deal more comprehensively with climate change impacts to safeguard development and eliminate poverty. Countries committed to hold the global average temperature to well below 2°C above pre-industrial levels (and to pursue efforts to limit the increase to 1.5°C). It specifically aims to “significantly reduce the risks and impacts of climate change and foster climate resilience”. Countries have also agreed to a global goal for adaptation that considers enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change.	195 countries adopted the Paris Agreement, which is legally binding.	The Paris Agreement recognises protecting the integrity of ecosystems and biodiversity for both climate change mitigation and adaptation actions. It specifically lays out principles of adaptation that takes ecosystems into consideration. It also calls for integrating adaptation into relevant environmental policies and actions, where appropriate, as well as for building resilience of ecosystems through sustainable management of natural resources. It further recognises the importance of reducing the loss and damage associated with climate change impacts, including extreme events and slow onset events, and the role of sustainable development in reducing risk of loss and damage. Within the Warsaw International Mechanism for Loss and Damage associated with Climate Change, it calls for early warning systems, preparedness, comprehensive risk assessments and management as well as a range of insurance solutions.	National adaptation planning (NAP) enables all developing and least developed country (LDC) Parties to assess their vulnerabilities, to mainstream climate change risks and to address adaptation. In decision 1/CP.20, the COP also invited all Parties to consider communicating their efforts in adaptation planning or consider including an adaptation component in their intended nationally determined contributions (INDCs). Efforts should focus on ensuring that NAPs and INDCs incorporate the key adaptation principles set out in the Paris Agreement, which include taking into account building ecosystem resilience in adaptation and protecting the integrity of ecosystems. Eco-DRR/CCA projects and technical assistance can be supported through: Green Climate Fund Climate Technology Centre and Network (CTCN)
Other Multi-lateral Environmental Agreements with direct references to the post-2015 sustainable development agenda				

3 https://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf

Policy agreement	Summary description	Number of signatory parties (Member States)	Key provisions on Ecosystem-based DRR/CCA in the Agreement	National-level instruments/mechanisms for implementing the Agreement and scope for promoting Eco-DRR/CCA through these instruments
Convention on Biological Diversity (CBD), 12th Conference of the Parties, Decision XII/20[4]	The CBD recognised for the first time in international law that the conservation of biological diversity is a universal concern for humankind and is integral to sustainable development. It covers all ecosystems, species and genetic resources. The CBD is a legally binding agreement.	Under the CBD, there are 168 signatory Member States	Decision XII/20 on Biodiversity and Climate Change and DRR recognises that while biodiversity and ecosystems are vulnerable to climate change, the conservation and sustainable use of biodiversity and restoration of ecosystems can play a significant role in climate change mitigation and adaptation, combating desertification and disaster risk reduction. It calls on governments and other relevant organisations to promote Eco-DRR/CCA approaches and integrate these into their respective policies and programmes. Decision XII/20 supports implementation of the Aichi Targets, specifically Target 15: By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of at least 15 per cent of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification.	168 countries are obligated to develop, implement and regularly review their National Biodiversity Strategic Action Plans (NBSAPs), which should take into account Decision XII/20 and integrate DRR and climate change actions in their respective NBSAPs. CBD signatory Member States can leverage Decision XII/20 to advocate for a stronger role for biodiversity conservation and ecosystem-based approaches in local and national DRR strategies as well as in National Adaptation Plans (NAPs).
Ramsar Convention (or formally the Convention on Wetlands of International Importance), 12th Conference of the Parties, Resolution 13[5]	The Ramsar Convention provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. It is a non-binding agreement. The Convention uses a broad definition of wetlands. It includes all lakes and rivers, underground aquifers, swamps and marshes, wet grasslands, peatlands, oases, estuaries, deltas and tidal flats, mangroves and other coastal areas, coral reefs, and all human-made sites such as fishponds, rice paddies, reservoirs and saltpans.	There are 169 signatory Member States, also referred to as Contracting Parties.	Resolution 13 on wetlands and disaster risk reduction strongly encourages countries to mainstream disaster risk reduction measures in wetland management plans, especially Ramsar Sites, which integrate the principles of ecosystem-based management and adaptation against natural hazards and accelerated sea level rise. It further calls for integration of DRR in all relevant policies, action plans and programmes. It further calls on countries to integrate ecosystem management related considerations, in particular relating to wetland and water management, in their national disaster risk reduction and climate change adaptation strategies.	169 countries can promote Eco-DRR/CCA approaches through wetland management plans, which cover 2,231 Ramsar-designated sites with a total surface area of 214,936,005 ha. Ramsar Contracting Parties can leverage Resolution 13 to promote Eco-DRR/CCA in wetland management policies and plans (in both Ramsar and non-Ramsar wetland sites), as well as in national and local DRR and CCA strategies, plans and programmes.

4 https://www.cbd.int/decision/cop/default.shtml?id=13383; For CBD's Aichi Targets, see: https://www.cbd.int/sp/targets/
5 http://www.ramsar.org/sites/default/files/documents/library/cop12_res13_drr_e_0.pdf

Policy agreement	Summary description	Number of signatory parties (Member States)	Key provisions on Ecosystem-based DRR/CCA in the Agreement	National-level instruments/mechanisms for implementing the Agreement and scope for promoting Eco-DRR/CCA through these instruments
United Nations Convention to Combat Desertification – UNCCD , 12th Conference of the Parties[6]	The UNCCD provides the global framework for tackling the issue of land degradation and desertification. It is the only legally-binding international agreement with a focus on sustainable land management. The Convention addresses specifically the arid, semi-arid and dry sub-humid areas, known as drylands. It seeks to improve the living conditions for people on drylands, to maintain and restore land and soil productivity, and to mitigate the effects of drought.	194 countries and the European Union are Contracting Parties to the UNCCD	At the 12th CoP in October 2015, Parties to the UNCCD reached a breakthrough, with the adoption of the land degradation neutrality (LDN) target. This means that Parties have agreed that the amount of healthy and productive land should stay stable starting in 2030. Parties also agreed to develop indicators for measuring progress in LDN and for enhancing land resilience to climate change and halting biodiversity loss linked to ecosystem degradation. Outcomes of CoP-12 strengthen implementation of the UNCCD's 10-year Strategic Plan and Framework (2008-2018), which was adopted in 2007 at CoP-8.[7] This Strategic Plan seeks to reverse and prevent land degradation and desertification, and specifically recognises the important services provided by ecosystems, especially in dryland ecosystems, for drought mitigation and the prevention of desertification. The following strategic objectives and expected impacts outlined in this Strategic Plan have direct relevance to Eco-DRR/CCA , calling for enhanced measures on sustainable land management : Objective 1 - Expected impacts: 1.1., 1.2 Objective 3 - Expected impact 3.1	National Action Programmes (NAPs) are the key instruments to implement the Convention, which are often supported by action programmes at sub-regional (SRAP) and regional (RAP) levels. The UNCCD urges Parties to align their action programmes, as well as other relevant implementation activities relating to the Convention, to the UNCCD's 10-Year Strategy. With the adoption of the LDN target, countries will have to formulate their own respective strategies for achieving LDN and integrate them into their NAPs. Countries can thus leverage the agreements reached at CoP-12 to promote the sustainable use, conservation and restoration of ecosystems and biodiversity in the context of reducing the risk of desertification and drought.

6 http://www.unccd.int/en/about-the-convention/the-bodies/the-cop/COP_12/Pages/default.aspx
7 http://www.unccd.int/Lists/SiteDocumentLibrary/10YearStrategy/Decision%203COP8%20adoption%20of%20The%20Strategy.pdf

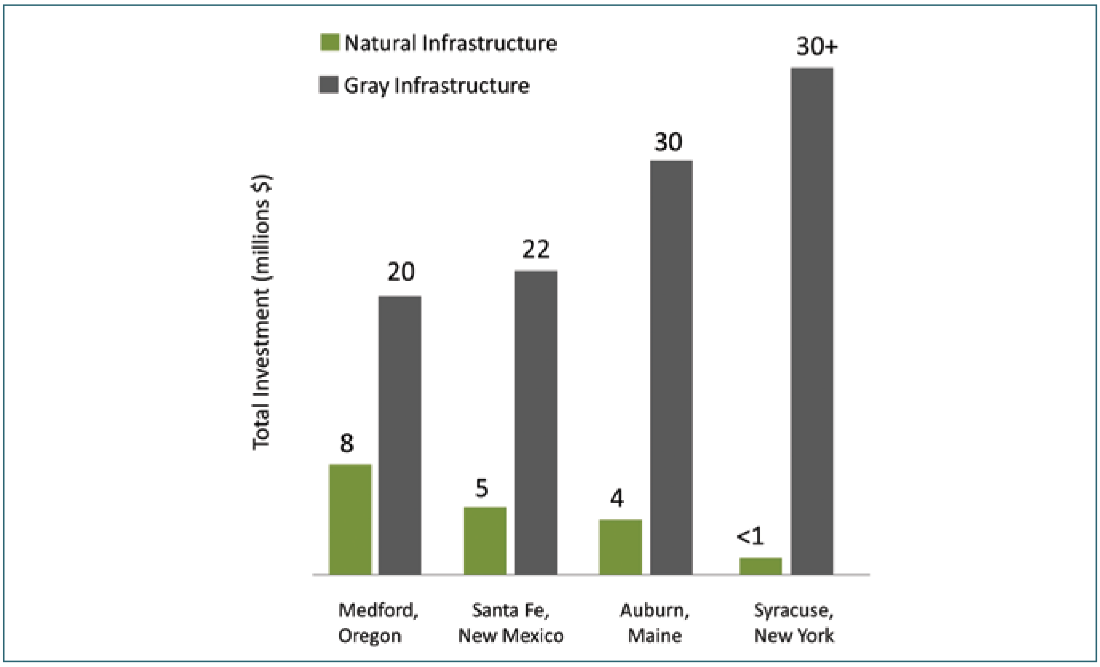


Figure 13. Comparison of costs for utilising natural infrastructure versus grey infrastructure (Source: WRI, 2013).

DRR, despite uncertainties. In the past decade much research and analysis has also been conducted in the economic analysis, including through TEEB and other similar studies (TEEB, 2010). Figure 13 below displays a simple graph of the costs of preserving natural infrastructure compared to the cost of building grey infrastructure for the purposes of various ecosystem services.

As countries establish their disaster management and sustainable development targets, the challenge now is to support member states in establishing agreed and aligned regional national plans that enable cross sectoral coordination in order to achieve multiple national commitments that are possible through Eco-DRR (conservation, sustainable development, disaster management and climate change adaptation targets).

4.2 Regional and national policy alignment opportunities

The European Commission revealed its strategy on Green Infrastructure in 2013 (EC, 2013), which incorporates disaster risk reduction as one of the major roles of the Green Infrastructure. To build on this, the Mid-Term Review of the EU Biodiversity Strategy to 2020 adopted in December 2015 and its associated resolution by the European Commission in February 2016 calls on the development of a trans-European network for green infrastructure (TEN-G) by 2017. In order to support these policies, EU's new research framework "Horizon 2020" starting from 2014 supports research topics related to Green Infrastructure, which includes Eco-DRR (EC, 2016).

Similar developments took place in various countries, especially following a major disaster. The United States of America established the Hurricane Sandy Rebuilding Task Force, which developed a Rebuilding Strategy in 2013 (Government of the United States of America, 2013). The strategy and its guidelines emphasised the need for environmentally sustainable and innovative solutions that consider ecosystem-based options in all Federal Sandy infrastructure investments. In August 2015, the Committee on Environment, Natural Resources, and Sustainability of the National Science and Technology Council of the US Federal government revealed a report titled *Ecosystem-service assessment: research* *need for coastal green infrastructure* (CENRS and NSTC, 2015). This was a response to the Recommendation 22 of the Hurricane Sandy Rebuilding Strategy and was designed to help institutionalise the best practice learned from the Hurricane Sandy rebuilding efforts on integrating ecosystem-based approaches into coastal resilience strategies, including beyond the Sandy-affected region. To build on this, in October 2015, the White House released a memorandum directing Federal agencies to factor the value of ecosystem services into Federal planning and decision-making (Executive Office of the President of the United States of America, 2015).

Another example of Eco-DRR national policy development was observed in Japan after the Great East Japan Earthquake (GEJE) in 2011. After the GEJE, the Ministry of the Environment of Japan (MOEJ) decided to upscale a national park along the coastline affected by the tsunami and use this national park as a symbol for reconstruction efforts by promoting eco-tourism programmes to contribute to the local economy while preserving natural ecosystems as a buffer zone for future natural hazards (The Government of Japan, 2016a). The role of ecosystems was also recognised in the National Resilience Act approved by the Cabinet and its Basic Plan and Action Programme, which incorporates the basic principle of symbiosis with nature and harmony with the environment in accordance with the characteristics of each region and to promote land-use using ecosystem functions of DRR (Cabinet Secretariat, Government of Japan, 2016) among other measures. In order to help implementation, MOEJ developed a handbook for Eco-DRR for practitioners in March 2016 (Government of Japan, 2016b). Other ministries and agencies also joined this effort. The Ministry of Land, Infrastructure and Transport of Japan (MLITJ) developed a new National Spatial Development Plan in August 2015 and the 4th National Infrastructure Development Plan in September 2015, both of which recognise the important role of ecosystems for DRR. The Japan International Cooperation Agency (JICA) also started to integrate Eco-DRR into their mid-term programme for overseas development aid (JICA, 2016).

Conservation implementation has had a strong national focus through management practices such as protected areas, species and habitat regulation, environment protection regulations for impact assessments during development and infrastructure planning. DRR has focused more on local governance to make pre and post disaster services more easily accessible and to have quicker mobilisation in times of crisis. Meanwhile, countries have invested a lot in national level climate change scenarios and projections; these need further research to be translated into site-specific conditions

Box 4: Hurricane Sandy Rebuilding Strategy (2013) Recommendations on Ecosystem Services

Recommendation 19	Consider green options in all Sandy infrastructure investments.
Recommendation 20	Improve the understanding and decision-making tools for green infrastructure through projects funded by the Sandy Supplemental.
Recommendation 21	Create opportunities for innovations in green infrastructure technology and design using Sandy funding, particularly in vulnerable communities.
Recommendation 22	Develop a consistent approach to valuing the benefits of green approaches to infrastructure development and develop tools, data, and best practices to advance the broad integration of green infrastructure.

and impacts. All of this poses many challenges for scaling up Eco-DRR in a coherent way, across the multiple global frameworks and the multiple national commitments. Eco-DRR provides an opportunity to target a wide range of national policy platforms, due to its application and relevance across ecosystem types, hazard types, sectors and themes. Table 9 summarises some of the national and local policy achievements from IUCN's EPIC project, in order to demonstrate the value Eco-DRR can add to wide ranging areas of work.

Conclusion

The MEA (2005) identified regulatory and supporting services to be decreasing over a decade ago. Within this decade, humanity has seen some of the worst disasters, including due to climate change impacts (IPCC, 2014). Major disasters have left stark reminders that healthy and intact ecosystems can serve as effective infrastructure for directly reducing exposure to hazards as well as in reducing underlying vulnerabilities such as poverty. With climate predictions of hazards becoming more frequent, intense and of greater magnitudes in addition to more unpredictable weather patterns, ecosystem management for disaster risk reduction has never been more critical for the safety, resilience and sustainable development of humanity.

In recognising the role of ecosystem services for risk reduction, it is also urgent that we establish a stronger knowledge base on the opportunities and limits that nature poses. Within this debate, it is important to further our understanding of whether, and how, biodiversity enhances the critical ecosystem

Table 9. Summary of mainstreaming of Eco-DRR into national and local policy mechanisms in Chile, Senegal, Nepal and Thailand (Source: Buyck, 2016)

Country	Policy	Level
Chile	The revision process of the national territorial planning for biodiversity and conservation provides a good opportunity for mainstreaming Eco-DRR.	National
	The national Plan for Adaptation to Climate Change in Biodiversity, prepared by the Ministry of Environment and published in 2014, considers EPIC to be an exemplary measure of adaptation to climate change that contributes to the strengthening of the National System of Protected Areas to the implementation of measures for adaptation to climate change at an ecosystem and species level.	National
	Integration of hazard maps that promotes use of protection forests for avalanche and rockfalls in regional and local land use planning, in progress. Road management authorities increasingly regard Eco-DRR and risk management as their priorities in future road development projects.	Local/ Bio Region
Senegal	Established a commission in charge of prevention and disaster risk management in the department of Foundiougne (in August 2015).	Local/ Department of Foundiougne
Nepal	Integration of Eco-DRR into the new National Strategic Framework for Nature Conservation (NSFNC), an umbrella framework for conservation in the country.	National
	In 2014, the Department of Soil Conservation and Watershed Management drafted the National Watershed Management Policy Act based on the Eco-DRR pilot EPIC project.	National
Thailand	Scaling up of Eco-DRR through mangrove protection and restoration based on the newly established Marine and Coastal Resources Management Promotion Act.	National

services for DRR. The numerous benefits of high versus low biodiversity ecosystems have been well documented and whether this applies to ecosystem-based disaster risk reduction needs a stronger research agenda. While this publication serves as a step towards enhancing such an agenda, it already indicates that higher biodiversity levels provide important resources for more effective and adaptive services for risk reduction.

In implementing and scaling up action for ecosystem management in DRR, unconventional partnerships need to be facilitated across sectors such as conservation and humanitarian aid. Relationships need to be strengthened at national, sub-national and local levels, due to the different levels of centralisation and decentralisation amongst sectors. With the recent positive developments, current global level policy coherence amongst various frameworks, such as disaster management, biodiversity conservation and sustainable development, provides a strong basis to support countries and communities to come together and work for the most pressing common agenda – protecting our lives, families, development investments and environment from the increasing risks of disasters.

Part 2

Regional lessons

Exchanges between Burkinabe and Senegalese farmers on best practices for sustainable land management.
Photo credits: © IUCN/ Fabiola Monty

Part 1 of the report makes a case for the implementation of integrated approaches with a focus on biodiversity conservation and disaster risk reduction. As this agenda is taken forward, documentation and analysis of the different regional and national contexts is needed to start identifying priorities, experiences on which new actions can build on, entry points to scale-up and integrate Eco-DRR with other sectors as well as existing gaps that need to be addressed. These are covered in Part 2, using information from the six regional assessments.

While there are differences across the regions, several common lessons and recommendations can also be extracted as summarised below.

Experiences with Eco-DRR

- Eco-DRR projects are not always labelled as such and without a standard framework to help distinguish between projects, identification and mapping of initiatives can be a difficult task
- There are few projects that have Eco-DRR as the main goal although several EbA projects are essentially Eco-DRR in nature
- Eco-DRR outcomes can currently be mostly achieved as co-benefits of other environmental management projects such as ecosystem restoration and protected area management
- While Eco-DRR is implemented at small scales, the capacities available for these environmental practices that provide co-benefits for risk reduction are key resources that need to be capitalised and transferred into Eco-DRR practice for scaling up
- Significant evidence on Eco-DRR has been established in the past 5-10 years and these provide a strong basis for urgently needed pilots and scaling up in the different regions.

Linkages between biodiversity and Eco-DRR

- There is a lack of documentation on the role of different levels of biodiversity in DRR and in the absence of clear literature on the subject, the link between a higher level of diversity and risk reduction in a specific region is not easily identified
- There is a lack of empirical research on the contribution of Eco-DRR to biodiversity conservation and vice-versa. However the co-benefits between the two are easily identifiable based on the overlap in environmental measures used
- The limited literature shows positive trends, and merits a stronger research agenda on this topic

Policy preparedness and opportunities for integration of biodiversity conservation and DRR

- In disaster management plans, ecosystems are generally not included as a tool to reduce risks
- National Biodiversity Strategies and Action Plans (NBSAPs) provide key entry points for Eco-DRR as ecosystem management is part of the recommended measures and in several cases, the importance of ecosystem in risk reduction is recognised . But across all regions there is a lack of specific Eco-DRR targets and proposed actions
- Similarly, to NBSAPs, National adaptation plans (NAPs) and National adaptation programmes of action (NAPA) provide entry points for integration of conservation and risk reduction, given the recognition of ecosystems and ecosystem management as part of the adaptation strategy.

Key recommendations:

- To develop a user-friendly standard framework for Eco-DRR that will make its identification easier and also assist environmental practitioners in identifying the DRR added value of their projects
- Strengthening of inter-sectoral collaboration at national and regional level is key for the scaling of Eco-DRR through integrated approaches
- To take advantage of recent policy developments to 1) include Eco-DRR as a tool to implement these and 2) initiate and develop inter-sectoral actions
- To take advantage of NBSAP as an entry point to propose actionable integrated measures that target both risk reduction and biodiversity conservation as action plans are updated to incorporate new decisions and recommendations
- Adequate ecosystem-based approaches that can be used to address priority disaster risks need to be recognised and integrated as a key component of national disaster management plans
- To take advantage of the importance of conservation and Eco-DRR for climate change adaptation to mainstream integrated approaches into climate change policies

South America

Karen Podvin, James McBreen and Fabiola Monty

FOCAL COUNTRIES

- Argentina
- Bolivia
- Chile
- Colombia
- Ecuador
- Peru

Background

South America has a land area equivalent to one-eighth of the Earth's land surface, and is home to approximately 18 per cent of the world's population. The region boasts rich cultural and natural diversity and includes five of the global biodiversity hotspots and five of the seventeen megadiverse countries that harbour the majority of the Earth's species. However, biodiversity in the region faces several threats including deforestation, alien invasive species, mining, natural hazards and climate change.

Extreme climatic events have adverse effects not only on biodiversity but also undermine key economic activities including fisheries, forestry and agriculture. Consequences of climate change such as acidification of the oceans, rising sea levels, increased intensity and frequency of hurricanes are expected to have a severe impact on coastal livelihoods, tourism, health, and food and water security. The dependency of many countries in South America on (degrading) natural resources and the agriculture, forestry and fisheries sectors for incomes and livelihoods, combined with inadequate economic and technological development, weak governance and institutions, and rapid growth, make it a particularly vulnerable region to climate change. Climate variability further increases this vulnerability due to the increasing frequency of El Niño and La Niña events.

In the face of a changing climate and consequent increase in frequencies and magnitudes of climatic hazards such as floods,

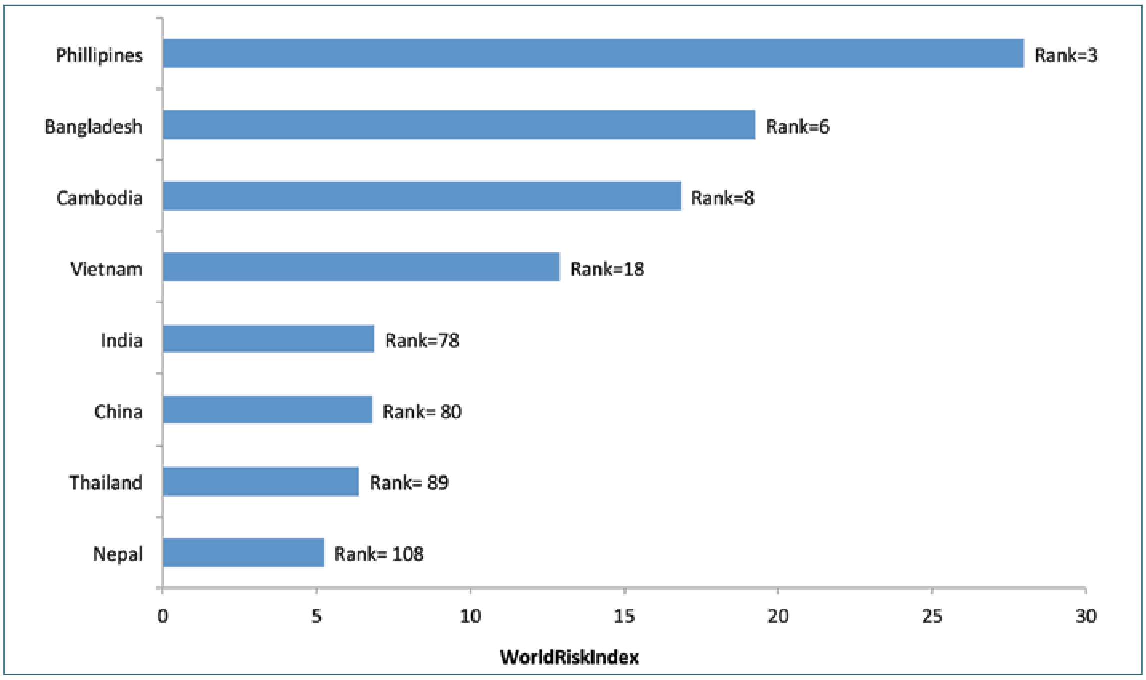


Figure 14. WorldRiskIndex and world ranking of the focal countries out of 171 (Note: Higher index values and lower ranking indicate higher disaster risks; Source=World Risk Report, 2015)

the well-being and livelihoods of humans and ecosystems are not only threatened but vulnerability to natural hazards has also increased.

Priority hazards and disaster impacts

In the period 1980–2015, the countries in the region reported a total of 878 disaster events, affecting around 96 million people, claiming an estimated 96,000 lives, and causing around US$ 87.7 billion in economic damages. Over the last 15 years, the number of climate-induced disasters in the region has increased significantly. Among the main hazards affecting the region, floods and droughts affect the agricultural sector the most, which is one of the main livelihoods in the region.

Experiences with Eco-DRR

The mapping exercise of Eco-DRR initiatives in the region revealed that there are few cases relating specifically to Eco-DRR. In practice, Eco-DRR is mostly achieved as co-benefits of several other environmental initiatives, namely climate change adaptation or mitigation and conservation. Climate change adaptation projects were important in providing key Eco-DRR outcomes, and targeted some of the priority hazards in the region, namely floods and droughts.

Eco-DRR as a tool for conservation

The National Biodiversity Strategy and Action Plans (NBSAPs) of the focal countries reveal little or no specific DRR targets or goals. While

For the period 1980-2015, it is reported that there were 35 disaster events caused by floods in the focal countries that resulted in the following impacts:

- 6,914 people died
- 1,374,199 people were made homeless
- Around US$ 18 billion of economic losses

Source: CRED EM-DAT-database, 2016

Table 10. Examples of projects and activities that contribute to Eco-DRR outcomes in the region (based on regional assessment)

Project type	Natural hazards	Ecosystems	Activities contributing to Eco-DRR
Eco-DRR	Avalanches	Forest	Vulnerability risk assessments
	Floods	Urban	Forest management
	Drought	Agricultural	Water resource management
	Landslides		Restoration of rivers
Climate change adaptation	Floods	Freshwater	Habitat protection
	Droughts	Forest	Restoration of wetlands and forests
	Landslides	Wetlands	Creation of private nature reserves
	Avalanches	Grasslands	Integrated water management
	Drought	Mountains	Sustainable grassland management
			Vulnerability assessment and mapping
			Sustainable livestock production
			Strengthening capacities of local stakeholders
Climate change mitigation	Floods	Forests	Habitat protection and restoration
Conservation	Soil erosion	Forest	Promoting ancient soil management systems
			Protected area management
			Strengthening local governance
			Capacity building

there may not be specific action plans for Eco-DRR, through the social benefits that they provide, they can be used to add weight to the implementation of management measures such as restoration of degraded lands and integrated water resources and watershed management that are proposed to implement biodiversity policy commitments.

For example, in Colombia, the land-use zoning of the Arroyo Carolina micro-watershed actively promotes the creation of exclusive areas for protection and restoration of the natural ecosystems in the micro-watershed. Likewise, within the management plan, mitigation measures designed to improve conditions in the watershed are proposed to protect biodiversity.

Potential economic benefits of Eco-DRR

- **Disasters are costly:** For example, the Economic Commission for Latin America and the Caribbean (ECLAC) revealed that the economic impact of natural disasters between 1972 and 1999 in a few countries of the region (Chile, Colombia and Nicaragua) reached more than US$ 50 billion.
- **Ecosystem-based approaches can be cost-effective:** For example, a qualitative cost-benefit analysis of an EbA/Eco-DRR project in Peru confirmed that the benefits are higher than the costs. The study revealed that the benefit to cost ratio in two communities were 2.8 and 2.25 respectively (Alvaro, 2015a; Alvaro, 2015b).

Moving towards integrated approaches

Challenges that need to be addressed:

- There is a need to strengthen the inter-sectoral and multi-stakeholder efforts for mainstreaming Eco-DRR within the disaster risk management strategies, as well as effective enabling conditions for this.
- There is a need to ensure a solid case in favour of ecosystem-based approaches for CCA and DRR, including the need to make an economic case for decision making.
- There is a need for greater investment in Eco-DRR to build resilient livelihoods and food production systems, as well as overcoming the barriers in multi-sectoral public funding for climate change.
- Eco-DRR does not lend itself to the easy identification of measurable targets or goals; thus the existence of data gaps represents a significant challenge.
- There are capacity and knowledge gaps in ecosystem-based approaches for CCA and DRR, as well as a lack of recognition and capacity on the role of biodiversity and DRR amongst civil society, and especially local communities.
- There is also a gap in monitoring of Eco-DRR practices and documentation on how it matches current vulnerability.
- Eco-DRR does not lend itself to easy identification of measurable targets and goals.

Opportunities to capitalise on:

- There are existing Eco-DRR and EbA initiatives and strategies in the region, these provide valuable evidence and lessons learnt, and serve as a solid foundation on which to build; however, these initiatives and strategies are often not named as such.
- There is enormous scope for integrating Eco-DRR initiatives into biodiversity elements of risk reduction; as there is also much supporting evidence in the region of policies and legislation for biodiversity conservation especially relevant for DRR.
- The EbA approach is already either integrated or has much potential to be integrated and up-scaled within overall adaptation and DRR strategies (which are already underway in countries of the region).
- Nature-based solutions including ecosystem management and biodiversity conservation generate multiple benefits besides DRR; ecosystem-based approaches for mitigation and adaptation provide collateral benefits for DRR.

Recommendations for actions:

- Promote and strengthen inter-sectoral and multi-stakeholder/ multidisciplinary efforts and the enabling conditions for mainstreaming Eco-DRR.
- Take opportunity of NBSAP as an entry point to scale-up Eco-DRR by proposing new integrated measures that target both risk reduction and biodiversity conservation as action plans are updated to incorporate new decisions and recommendations.
- Clarify and adapt institutional frameworks to articulate and facilitate collaboration among different institutions related to the environment and DRR.
- Gather and systematise experiences and arguments in favour of ecosystem-based approaches for CCA and DRR, including economic assessments that will make a stronger case for decision-making and investment.
- Raise awareness and infuse the ecosystem-based approaches for CCA and DRR among governments, civil society (including local communities and conservation and development practitioners), academia and the public sector.
- Rigorous DRR based on biodiversity should include cross-sector coordination to prioritise conservation interventions through the assessment of threats to biodiversity and natural ecosystems.
- Generate and share solid evidence and cost-effectiveness of ecosystem-based approaches among diverse stakeholders.

CASE STUDY

Private Nature Reserve Network and flood mitigation, Argentina

Photo credit: © Ernesto Gamboa

In accordance with the CBD, Argentina has a target of conserving at least 10% of natural regions. Agricultural and productive lands in Argentina are largely owned by private individuals and companies, therefore private conservation can play a significant role in achieving this target. The Private Nature Reserve Network (*Red Hábitat de Reservas Naturales Privadas*) was created in recognition of the importance of such conservation initiatives and their contribution towards sustainable development in the country.

For the last twelve years, the *Fundación Hábitat & Desarrollo* —together with Argentina's National Parks Administration (*Administración de Parques Nacionales* – APN), Masisa Argentina, and the Uruguay River Forestry Consortium— have been working in the drainage basin of the Uruguay River, which, together with the Paraná River, forms the Río de la Plata estuary. Work has focused on the creation of a network of private nature reserves for the conservation of the riparian vegetation and important grassland areas; protected area planning and management, biodiversity monitoring and environmental education are all prevalent activities.

These riparian forests absorb and reduce water flow and provide space for flood attenuation, but the river and its wetlands are also the source of water that supports all forms of life, and are an important resource for livestock farming, agriculture, fisheries and transport. The crucial role of flood plain forests as breeding grounds for fish, whilst preventing erosion, highlights the importance of such a network of private nature reserves for conservation in terms of promoting healthy ecosystems and their role in DRR.

The conservation of these wetlands not only provides effective flood defences, but also safeguards the many other benefits that these ecosystems provide. An initiative to control invasive species is also an important restoration component of the work, and includes the elaboration of a protocol to control the wild boar population, thus providing an opportunity for an emblematic indigenous species found in the grassland of Corrientes to thrive. In terms of reducing disaster risk, such restoration of freshwater wetlands offers protection to life and property from flooding and drought in the River Uruguay drainage basin.

Source: Fundación Hábitat & Desarrollo (2016)

Mesoamerica and the Caribbean

Fabiola Monty, Milena Berrocal, Kevin Lloyd and Alberto Salas

FOCAL COUNTRIES

- Belize
- Costa Rica
- Cuba
- Dominican Republic
- El Salvador
- Guatemala
- Honduras
- Jamaica
- Nicaragua
- Panama
- Trinidad and Tobago

Background

Mexico, Central America and the Caribbean cover an area of approximately 6,046,233 km2 with a population of nearly 200 million people. The region possesses a wide range of biological diversity due to its geographic location and young geological territories. The Central American countries represent less than 1% of the surface of the planet, yet they are home to approximately 7% of the world's known species; more than 20 life zones and approximately 33 ecoregions form the territory. These natural resources provide important ecosystem services to the region's population. But this is being undermined by environmental challenges such as ecosystem loss and degradation, illegal logging, pollution, overexploitation of marine resources and climate change.

Due to its high vulnerability to climate change effects, the region faces additional socio-economic challenges due to disasters. Natural hazards such as hurricanes and floods occur frequently and cause losses worth millions in crops, infrastructure and economic activities.

Priority hazards and disaster impacts

The most frequent natural hazards in the region are hurricanes, tropical storms, low-pressure systems, floods, landslides, rockslides and droughts, as well as hailstorms and frosts to a lesser degree. The Center for Research on the Epidemiology of Disasters (CRED) of the University of Leuven (Belgium) mentions that in Central America alone between 1970 and 2011, 69% of the disasters that occurred originated from hydro meteorological processes, 21% from volcanism and tectonism, while 9% came

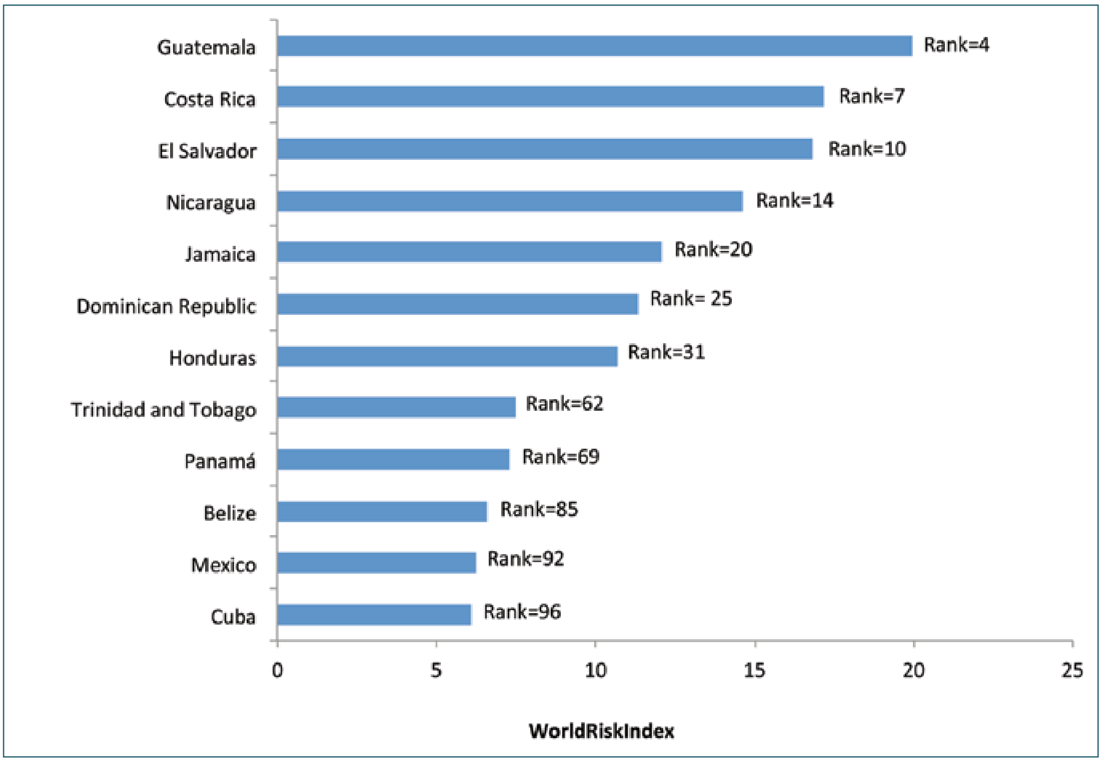


Figure 15. WorldRiskIndex and world ranking of the focal countries out of 171 countries ((Note: Higher index values and lower ranking indicate higher disaster risks; Source=World Risk Report, 2015)

from biological threats. Several drought periods in the region have had a negative impact mainly on sectors such as energy, agriculture, access to drinking water and sanitation. For example, the 2001 drought affected 23.5 million people. In 2009, Nicaragua lost 30% in basic grains, while in Costa Rica the losses were estimated at US$ 6.25 million. Regarding agriculture, drought has affected several types of crops, among them corn and beans, which are staple foods of the population. Among the 13 countries that consume the most beans in the world, six are in this region (Nicaragua, Belize, Costa Rica, Guatemala, Honduras and Mexico).

Nature-based solutions for disaster risk reduction

Experiences with Eco-DRR

Because Eco-DRR is a relatively new concept, relatively few projects in the region are being implemented to achieve specified Eco-DRR outcomes or are simply not explicitly identified as Eco-DRR. However, Eco-DRR is being achieved as co-benefits of several other environmental initiatives, namely CCA and conservation of natural resources. Examples of the tools being used in the region that bring benefits for risk reduction include the following:

For the period 1980-2015, it is reported that there were 31 disaster events caused by storms in the focal countries that resulted in the following impacts:

- 22,767 people died
- 693,448 people were made homeless
- Around US$ 26 billion of economic losses

Source: CRED EM-DAT-database, 2016

- Forest ecosystem management, for example, in the Dominican Republic
- Agroforestry and integrated water management, for example, El Salvador
- Community-based protected area management, for example, Guatemala
- Participatory vulnerability assessment, for example, Trinidad and Tobago
- Protected area management

Eco-DRR as a tool for conservation

While disaster risk reduction is mentioned in the NBSAPs/NR5 of Costa Rica, Nicaragua and Belize, except for the latter there is little or no clear Eco-DRR targets. However, Belize's fifth national report provides clear examples of how the Eco-DRR can be integrated in the NBSAP to contribute to conservation targets.

For example, Belize recognises the importance of several environmental measures for risk reduction including protection of mangrove ecosystems and protected area management. Its NR5 also highlights that "there are very few national campaigns that promote the value of biodiversity and environmental services", accounting for the low progress towards Aichi target 1 which is "By 2020, at the latest, people are aware of the values of biodiversity and the steps they can take to conserve and use it sustainably." Communicating the role of ecosystems in DRR has a strong potential to increase public awareness, as it is a relatable benefit and also provides an opportunity for countries to progress with policy commitments.

Potential economic benefits of Eco-DRR

- **Disasters are costly:** For example, a study on the economics of climate change in Barbados reveals that in 2009, economic losses from disasters were about US$ 139 million (4% of GDP) and under climate change, these losses will increase to US$ 279 million in 2030.
- **Ecosystem-based approaches can be cost-effective:** For example, in the case of Barbados mentioned above, the use of effective adaptation measures revealed that the potential damage from climate change could be reduced by 35%. Coral reef restoration in the Folkestone Marine Park is estimated to contribute to lowering the annual losses by US$ 20 million

Moving towards integrated approaches

Challenges that need to be addressed:

- Eco-DRR is a relatively new concept in the region and the absence of a clear framework and criteria to identify this approach makes it difficult to document local experiences and introduce the concepts
- Good governance at both local and regional level is needed for the uptake of Eco-DRR at large scale
- Poverty is a big challenge for many of the countries and development of Eco-DRR projects will need to ensure that addressing social vulnerabilities is a key component
- Progress with conservation and sustainable land management is limited by economic resources
- Lack of awareness on the importance of ecosystems for disaster risk education

Opportunities to capitalise on:

- National and regional policies and strategies are in continuous construction, resulting in the opportunity to introduce and stream Eco-DRR as a key tool for disaster risk reduction
- Eco-DRR provides an opportunity to stream environmental issues in a variety of legislations and policies that are not always considered in conservation policy influences, for example, regarding economic development and territorial planning
- Apply the legal, technical and scientific instruments that have so far been built for

climate change adaptation and mitigation to integrate Eco-DRR

Recommendations for actions:

- Strengthen local understanding and capacities on Eco-DRR
- Develop a systematic approach to identify and monitor Eco-DRR targets and build a strong regional case on lessons learned, effectiveness and economic benefits
- Raise awareness among policy-makers and local communities on the importance of ecosystem-based approaches
- Identify and target key national and regional policies of relevance for Eco-DRR that will be either under revision or yet to have the action plan developed.

CASE STUDY

Shade-grown coffee, El Salvador

This project was implemented by IUCN to reduce pressures of change in land use in the southern region of Ahuachapán, El Salvador and included a combination of agroforestry and integrated water management. The project was born out of concern due to a decrease in shaded coffee plantations, a product of the coffee crisis in the decade of the 1990s.


Photo credit: © IUCN / Claire Warmenbol

Shaded coffee has proven to be an important element in water conservation and biodiversity due to its agricultural ecosystem characteristics. For example, it helps mitigate the force with which raindrops hit the ground, decreasing laminar erosion; the abundance of trees generates better conditions for an increase in the number of animal and vegetative species, and they also capture carbon.

In this type of agricultural ecosystem, a great number of insects, many of them bio indicators and pollinators have been found. Shaded coffee plantations also provide ecosystem services; they reduce the risk of erosion, landslides, and depletion of water sources and springs, and they serve as small biological corridors that different animal and vegetative species can move through avoiding being confined to a small area where their vulnerability increases.

The project not only succeeded in raising awareness among coffee producers about the importance of this type of agricultural ecosystem, but also about the hazards for the environment that would be a result of a massive change in land use. On the other hand, the coffee producers were assisted in seeking alternatives and diversifying their production by including fruit trees, and experimenting.

West and Central Africa

Bora Masumbuko and Fabiola Monty

FOCAL COUNTRIES

- Burkina Faso
- Togo
- Senegal
- Mali
- Ghana
- Nigeria
- Cameroon
- Democratic Republic of Congo

Background

The Central and Western African region harbours a variety of ecosystems including savannahs, forests, deserts, mangroves, oceans and wetlands that confer its great biodiversity. The forest ecosystems of Upper Guinea, the Congo Basin, the Afromontane forests between Nigeria and Cameroon and of the Albertine Rift are considered areas of high biodiversity.

Ecosystems provide important goods and services that benefit the region's population. In West Africa, cereals and tubers constitute the staple diet of the rural communities. Small wild game also often constitutes an important source of animal protein. Other resources, particularly non-timber forest products (NTFP), are a source of income for people and their families; they include, for instance, honey, shea butter and wild fruits. These ecosystems and the associated ecosystem services are, however, facing many pressures and threats including poaching, bush fires, land conversion for agriculture, as well as climate change.

Extreme climatic events pose a threat to both the natural and social capital. According to the Intergovernmental Panel on Climate Change, Africa is amongst "the most vulnerable continents due to its high exposure and low adaptive capacity" (Niang et al., 2014). The consequences of climate are already being experienced, for example threatening agriculture, a major livelihood and income source in the region. The Sahel region and its population, is particularly exposed and vulnerable to natural hazards because of the climate conditions, its location

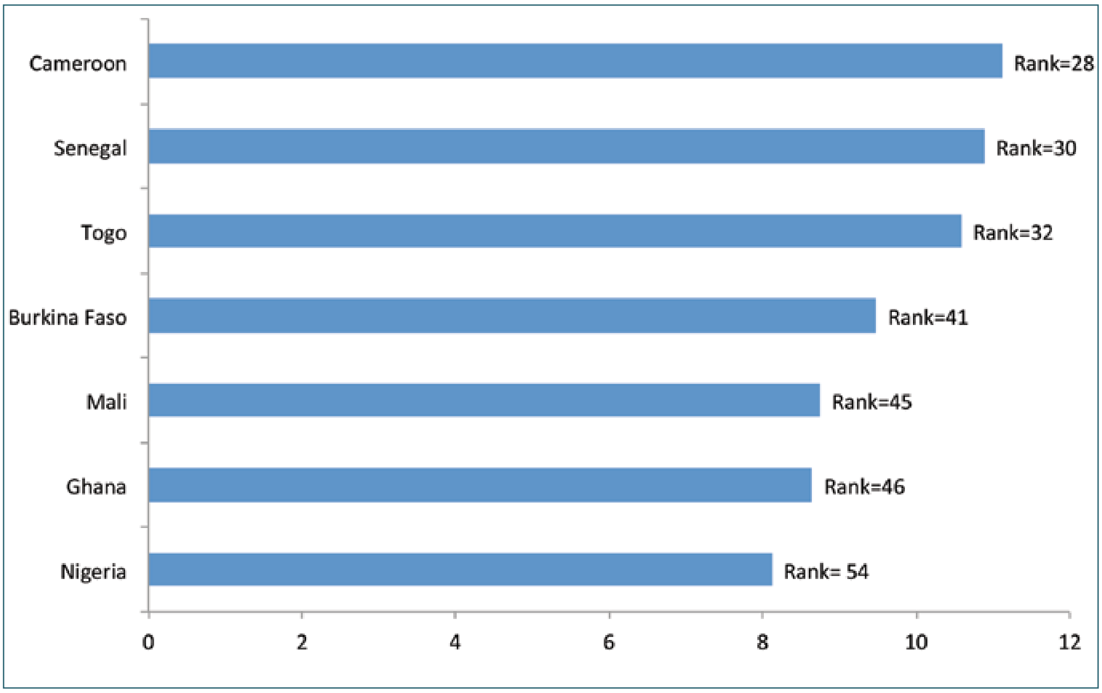


Figure 16. WorldRiskIndex and world ranking of the focal countries out of 171 countries (Note: Higher index values and lower ranking indicate higher disaster risks; Source=World Risk Report, 2015; Missing information for the Republic of Congo)

and its social, economic and demographic characteristics. It has to cope with the increase, over the last decade, in the frequency and intensity of extreme climatic events such as droughts and floods.

Priority hazards and disaster impacts

During the last four decades, more than 1,000 disasters occurred in sub-Saharan Africa, among which 300 disasters between 2005 and 2010 affected more than 330 million people. Drought and floods together account for 80 per cent of loss of life and 70 per cent of economic losses linked to natural hazards in Sub-Saharan Africa (World Bank, 2010). Main hazards in West and Central Africa include: floods, droughts, landslides, sea level rise, invasive species and locust invasion, extreme temperature (heat waves), windstorms (violent winds) and gullies erosion. Strong coastal erosion, driven by sea level rise, can be seen along the whole West Africa coastline, from Mauritania to Nigeria. At the same time, soil erosion and desertification, which also threaten food security, continue to develop due to these extreme weather events.

Using nature-based solutions to address priority hazards

Experiences with Eco-DRR

In the region, many countries do not implement Eco-DRR activities or projects per se. There is

For the period 1980-2015, it is reported that there were 27 disaster events caused by floods in the focal countries that resulted in the following impacts:

- 2,462 people died
- 1,447,443 people were made homeless
- Almost US$ 1 billion of economic losses

Source: CRED EM-DAT-database, 2016

a wide range of projects across the region that contributes to Eco-DRR but it is not necessarily the main expected outcome. Nature-based options can, however, play an important part in reducing exposure and risks, for instance, the rehabilitation of mangroves to reduce coastal flooding, thus reducing their impacts on ecosystems and people, or tree plantation to increase infiltration rates and reduce runoff, especially in urban areas. While there is already a wide range of environmental management tools being used, for example targeting biodiversity conservation and CCA and that also have DRR co-benefits, these practices still need to be recognised and streamlined into the disaster management sector. Similarly, the environmental sector needs to be able to identify and document the DRR co-benefits of their projects to ensure that these are enhanced through strategic spatial planning, including DRR as a criterion for prioritisation for example.

Eco-DRR as a tool for conservation

Through the commonality in practice with conservation measures and resulting biodiversity benefits, Eco-DRR has a great potential to be an alternative non-market incentive for biodiversity conservation.

For example, in Senegal a new project "*Renforcement de la résilience des écosystèmes et des communautés par la restauration des bases productives des terres salées*" is being implemented in the Fatick and Foundiougne *départements* (Districts) that will focus on salt-affected areas, mangroves and forests to build both ecosystem and community resilience to disasters. Through targeted activities such as the establishment of a forest reserve, forest landscape restoration and mangrove rehabilitation, the project will also greatly contribute to biodiversity conservation.

Potential economic benefits of Eco-DRR

- **Disasters are costly:** For example, during the period 2000-2015, flood events have caused more than US$ 830 million of economic losses in the region.
- **Ecosystem-based approaches can be cost-effective:** In Waza Logone floodplain, Cameroon, scientists evaluated the economic effects of floodplain degradation in the Waza Logone region by evaluating the economic benefits of wetland restoration. The benefit cost ratio of investment with restoration ranged from 4.66 to 6.57 indicating the benefits were higher than costs associated with no restoration.

Scaling-up Eco-DRR and integrating biodiversity

Challenges that need to be addressed:

- Lack of information availability on the links between biodiversity/ecosystems and natural hazards/disasters
- Improve availability and accessibility to the most up-to-date information on biodiversity, ecosystems, natural hazards and disasters
- Countries do not have many examples of biodiversity/ecosystem cases for Eco-DRR or initiatives that protect biodiversity using Eco-DRR activities. If Eco-DRR is to be achieved for a specific country, group of countries or the region, this will require more thorough research including field visits
- There is a gap in policies regarding the integration of biodiversity conservation and DRR

Opportunities to capitalise on:

- Sensitisation and awareness raising, information sharing and training on Eco-DRR and tools can enhance the understanding and perception of the issue/concept.
- Forest regeneration and protected areas management (especially forest protected areas) would lead to ecosystems rich in

carbon; they would therefore be eligible for inclusion in national REDD+ strategies.

Development of new research agenda

- Test some of the methods that use biodiversity to address Eco-DRR: especially examples were lacking regarding crop wild relatives, and soil bioengineering. Another aspect that could be explored is how we could use the biodiversity from the soil (biodiversity of microorganisms) to reduce the effects of natural hazards; for instance those microorganisms that participate in soil formation, nutrient cycling and therefore play an important role in maintaining the structure of the soil that supports ecosystem services.
- Explore how animal biodiversity can also play a role in Eco-DRR. For instance, species like mountain gorillas, which are endemic to eastern DRC, Uganda and Rwanda disseminate specific seeds in their excrement, thus participating in the natural regeneration of specific tree species that might play an important role in Eco-DRR.

Recommendations for actions:

- Increase investments in generating greater awareness and understanding of Eco-DRR and the role of biodiversity, particularly amongst local government and local communities
- Integrate biodiversity and ecosystems concepts in early warning systems as important tools to increase the resilience of local communities
- Integrate both social and biodiversity information into vulnerability assessments methodologies
- Enhance the use of protected areas as a way to reduce disaster risks and minimise the effects of hazards. Protected areas, if well managed, are powerful buffers against storms, erosion, strong winds and floods
- Promote inter-sectoral collaboration to improve policy implementation
- Promote interdisciplinary research to generate new and much needed applied knowledge that can be translated into actions

CASE STUDY

Ecosystem-based approaches against floods, salt intrusion and drought – Burkina Faso and Senegal


Photo credit: © IUCN/ Radhika Murti

In Senegal and Burkina Faso, the Ecosystems Protecting Infrastructure and Communities (EPIC) project, implemented by IUCN is documenting the role of and improving ecosystem management for DRR. Since its inception in 2013, the project is working with local communities to respond to climate change impacts and restore arable lands that have been degraded by droughts, salinisation, floods and soil erosion. Community resilience is being built through two main activities: 1) strengthening of local capacities to understand vulnerabilities and taking action by using best practices and 2) promoting effective policies for integrated approaches to disasters, climate change and environment management. Endogenous land practices to restore the land and increase agricultural output are implemented in six villages in each country. For example, anti-salt bunds that reduce salt intrusion and contribute to retain freshwater have been installed to recover more than 180 ha of cultivated land in villages in Senegal. In Burkina Faso, traditional practices like stone lines and Zaï that conserve water resources have been established to restore 150 ha of land. In countries, assisted natural regeneration and reforestation is also carried out to increase tree cover and improve soil quality.

Eastern and Southern Africa

Mine Pabari and Fabiola Monty

FOCAL COUNTRIES

- Kenya
- South Africa
- Zimbabwe
- Zambia
- Madagascar
- Mozambique
- Ethiopia
- Malawi
- Uganda
- Namibia

Background

The countries of eastern and southern Africa host a vast variety and abundance of the world's biological and natural resources, including seven of the world's biodiversity hotspots. Across the 24 countries – from the Horn of Africa to the Cape and including the Western Indian Ocean Islands, the region contains several centres of endemism where species of birds, mammals and plants reside nowhere else in the world. The region is also incredibly socially diverse, with a rich mix of cultures, ethnicities, religions and languages and a colourful blend of traditional customs and beliefs with contemporary societal practices.

Today, there is much optimism across eastern and southern Africa. Many of the countries have registered or are anticipating growth, contributed to by increased investments in infrastructure and extractive industries as well as improvements in political and social stability. However, it is also widely acknowledged that critical challenges remain, amongst them inequality and vulnerability to economic, social and environmental risks.

The region experiences a high rate of loss of biodiversity as a result of multiple threats, including illegal wildlife trade, habitat loss, climate change, air and water pollution as well as invasive alien species. This notwithstanding, significant efforts are being made by multiple actors to conserve biodiversity. Sixty-nine per cent of the Key Biodiversity Areas in sub-Saharan Africa are included in a protected area, even if only partially (Belle et al., 2015). The total (reported) area under protection across eastern and southern Africa is 2,247,367.4 km2 (1,955,315.6 km2

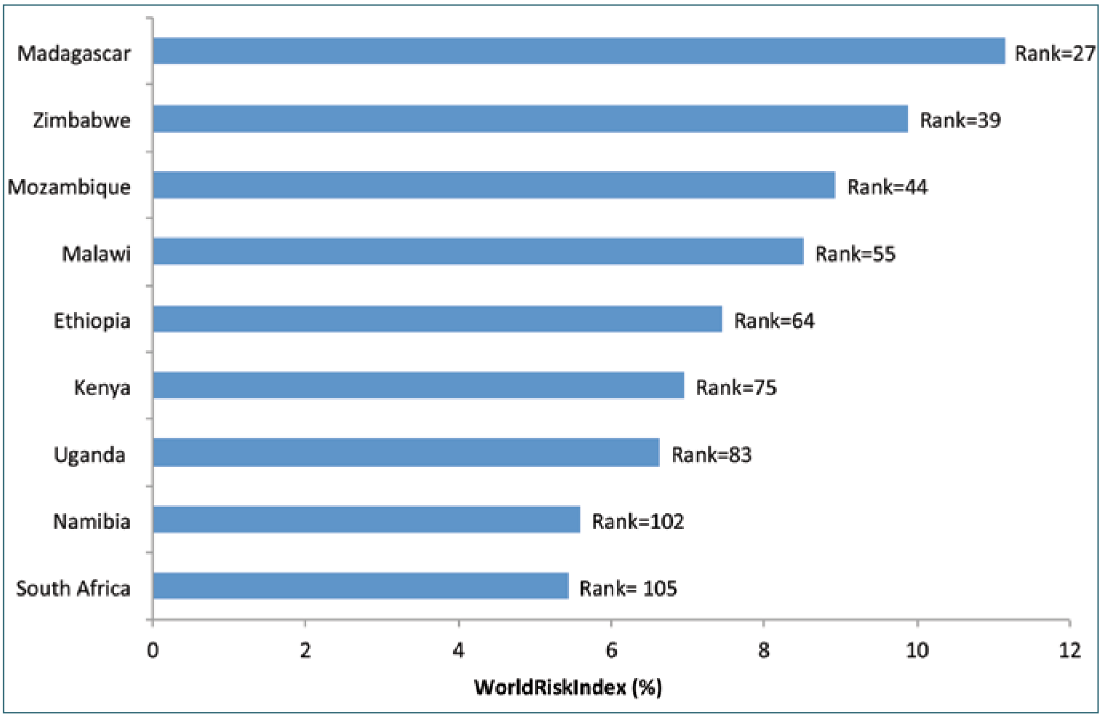


Figure 17. WorldRiskIndex and world ranking of the focal countries out of 171 countries (Note: Higher index values and lower ranking indicate higher disaster risks; Source=World Risk Report, 2015)

terrestrial and 292,051.8 km2 marine). Using indicator data sets from the World Bank, this translates to 15% and 2% respectively.

A critical obstacle to Africa's progress is climate variability with temperatures projected to rise faster than the global average increase in the 21st century (IPCC, 2012). According to the Intergovernmental Panel on Climate Change, Africa is amongst "the most vulnerable continents due to its high exposure and low adaptive capacity" (Niang et al., 2014). Impacts of increased warming are already being experienced across much of the continent and are further amplifying existing vulnerabilities.

With a growing global population, changing demographics and diets, food security is of increasing concern across the region, leading to increasing pressures on land and water. A direct threat to food security is land degradation – a threat that Sub-Saharan Africa is particularly impacted by with yield reductions due to soil erosion ranging from 2% to 40% and approximately 95 million hectares of land threatened with irreversible degradation (UNEP, 2007). This situation is exacerbated by a number of other stressors, including risks to freshwater ecosystems and the vulnerability of coastal and ocean systems – both of which are critical to the economies and livelihoods of African countries. The impacts of these non-climate stressors are compounded by shifting ranges of species and ecosystems due to elevated carbon dioxide and climate variability.

Priority hazards and disaster impacts

Natural and hydro-meteorological disasters are a key concern across the region, further eroding coping and adaptive capacities of both local communities as well as national economies. Between 2000 and 2015, there were a total of 413 recorded occurrences (primarily floods, droughts and landslides) affecting ~185 million individuals, resulting in total damages estimated at over US$ 5 million. Droughts and riverine floods are the most significant hazards in the region, with recorded occurrences (between 2000 and 2015) of 79 and 250 respectively. However, the impact of drought is far higher – affecting a total of ~159 million as compared to the ~2.8 million affected by riverine floods. Countries most affected by droughts include Ethiopia, Kenya, Malawi, Somalia, South Africa and Zimbabwe. While the overall impact of riverine floods (in terms of numbers affected) is not as high as that of drought, the occurrence is across a greater number of countries in the region. Countries with over a million affected between 2000 and 2015 include Angola, Ethiopia, Malawi, Mozambique, Namibia and South Sudan; and more than 2 million in Kenya, Sudan and Zambia.

Using nature-based solutions to address priority hazards

Experiences with Eco-DRR

There is a wide range of projects across the region that contributes to Eco-DRR but they are either not explicitly identified as Eco-DRR or the co-benefits are not recognised. Eco-DRR requires the implementation of several environmental measures. For example in the Eastern and Southern Africa region, forest restoration and sustainable land management would be key tools to address land degradation and the impacts of droughts and floods. Environmental management tools that contribute to DRR are already being implemented through diverse project portfolios targeting biodiversity conservation, climate change adaptation (including improving community resilience), climate change mitigation and food security. However, these practices need to be streamlined into the disaster management sector. Similarly, the environmental sector needs to be able to identify and document the DRR co-benefits of their projects to ensure that these are enhanced, for example, through strategic spatial planning and including DRR as a criterion for prioritisation.

Eco-DRR as a tool for conservation

Through the commonality in practice with conservation measures and resulting biodiversity benefits, Eco-DRR has a great potential to be an alternative non-market incentive for Biodiversity conservation.

For example, the Southern African Development Community (SADC) Crop Wild Relatives project being implemented in Mauritius, Zambia and South Africa is conducting an inventory of the potential use of indigenous plants as crop wild relatives that can be used for crop improvement, “to underpin regional food security and mitigate predicted adverse impact of climate change” (SADC-CWR, 2016). Through spatial mapping, the project also aims to identify priority conservation areas to protect these native CWR.

Potential economic benefits of Eco-DRR

- **Disasters are costly:** For example, the 2000 flood in Mozambique lowered the country’s GDP by an estimated 12% and estimated economic losses as a result of drought in Djibouti over the period 2008-2011 were equivalent to 3.9% GDP/annum with the total mitigation costs amounting to US$ 318 million.
- **Ecosystem-based approaches can be cost-effective:** It is estimated that Africa would generate about US$ 71.8 billion if all countries take action against soil erosion, by investing in sustainable land management interventions (UNEP, 2015).

For the period 1980-2015, it is reported that there were 31 disaster events caused by droughts in the focal countries that resulted in the following impacts:

- 402,525 people died
- 107,394,917 people were affected
- Around US$ 3 billion of economic losses

Source: CRED EM-DAT-database, 2016

Scaling-up Eco-DRR and integrating biodiversity

Challenges that need to be addressed:

Institutional challenges

- While many regional and national policies for disaster risk reduction call for cross-sectoral approaches, coordination and integration continue to be a significant challenge. Contributing factors include (Pasquini and Cowling, 2015):
    I. Insufficient clarity around the division of roles and responsibilities
    II. There is often a misalignment between the owners of critical areas for the conservation of biodiversity and ecosystems, those that have the mandate for compliance of environmental regulations and those that have a stake in preserving ecosystem functions for DRR (for example, municipalities and local governments)
    III. Often, financed programmes and projects are compartmentalised into sectors – limiting the incentives for effective collaboration

Knowledge

- Insufficient investment and know-how (including methodological approaches) around integrated assessments – drawing on multiple sources of information on impacts, vulnerabilities and adaptation priorities (Ziervogel, et al., 2014)
- Access to knowledge and information in a manner that is readily usable by institutional bodies responsible for DRR

Capacities

- Limited understanding of institutional bodies responsible for DRR on biodiversity and ecosystem-based approaches
- Lack of financial resources necessary to enable partnerships and collaboration across sectors provided there is shared agenda

Opportunities to capitalise on:

- There is substantive evidence today to demonstrate that community-based management and governance can be highly effective in managing the natural resource base and, currently, there is considerable experience and know-how across the region with participatory modelling and planning approaches. These experiences should be built upon, ensuring a strong and enabling policy and institutional environment to better incentivise sustainable use and management of ecosystems.
- The economic and developmental values of the environment and natural resources are increasingly being recognised, with a number of countries having developed their strategies for a green economy. At the continental level, a key example of this is the Cairo Declaration, which recognises "*… that disaster risk reduction is a pillar for the integration of ecosystems and climate change requiring a multisectoral approach in order to be effective and that disasters are increasingly causing ecosystem degradation leading to loss of lives and investment*" (African Ministerial Conference on the Environment (AMCEN), 2015).
- Despite the lack of integration between the different policies that cover disaster risk reduction and environmental management, as countries update their different action plans, e.g. NBSAPs to cover new decision points, these can be used as entry-points to stream Eco-DRR as a win-win approach for both risk reduction and conservation.

Recommendations for actions:

- Increased investments in generating greater awareness and understanding of Eco-DRR and the role of biodiversity, particularly amongst local government and local communities.
- Funding modalities and mechanisms should be reviewed to better incentivise cross-sectoral (and stakeholder) coordination and

collaboration in programme design and delivery.
- Establishment of “bridging (or boundary) organisations, i.e. organisations designed to facilitate collaboration and knowledge coproduction and exchange among organisations belonging to different communities, scales and policy areas” (Pasquini and Cowling, 2015).
- Identify national and regional action plans related to development, disaster risk reduction and environmental management that are either planned or being updated and target these to stream Eco-DRR and its scaling-up.

CASE STUDY

Eco-DRR as a flood mitigation strategy – An example from Kenya and Uganda


Photo credit: © Adonia Kamukasa Bintoora

Mt. Elgon straddles eastern Uganda and western Kenya and forms an extensive trans-boundary ecosystem, covering an area of about 772,300ha. The slopes of the mountain support a population of approximately 4 million people who rely heavily on the ecosystems goods and services, primarily to support subsistence agriculture. The mountain is densely populated, particularly on the Ugandan side, the impacts of which are exacerbated by the use of inappropriate agricultural practices resulting in severe land degradation and deforestation. Both countries are already experiencing climate change related hazards and the Ugandan side is particularly vulnerable to landslides leading to the loss of lives and livelihood assets.

IUCN’s programme in eastern and southern Africa has had a long standing presence in the Mt. Elgon region, with a number of recent projects focusing on promoting and supporting the use of ecosystem based approaches to reduce vulnerabilities and enhance resilience to climate. These include, “The Ecosystem Based Adaptation (EbA) to Climate Change”; and the “Implementing a resilience framework to support climate change adaptation (RFCC)” project.

A key strategy employed by both projects has been restoring the natural river banks to increase the capacity of rivers to cope with floods. This has been through planting of appropriate tree species as well as creating buffer zones through assisting local communities to establish rules and by-laws to prevent farming and grazing along river banks (which increases erosion and sediment build up in the river).

Oceania

Fabiola Monty and Milika Naqasima Sobey

FOCAL COUNTRIES

- Tuvalu
- Vanuatu
- Solomon Islands
- Fiji
- Papua New Guinea (PNG)
- Samoa
- Republic of Marshall Islands

Background

The Oceania region covers twenty-three Pacific Island Countries and Territories (PICTs) spread over an area of ocean 30 million square kilometres in size. There are five sub-regions: Australia, New Zealand, Melanesia, Polynesia and Micronesia and these islands vary in size from continental Australia to the high volcanic islands of Melanesia to the coral atolls and sand cays of Micronesia. The islands of Melanesia in the western part of the region include Papua New Guinea, Solomon Islands, Vanuatu, New Caledonia and Fiji. Of the Pacific Island Countries and Territories (PICT), PNG is by far the largest and most populous with its land area and population exceeding that of all the other PICTs combined. To the north and east of Melanesia lie the smaller islands of Micronesia and Polynesia. The Micronesian cluster includes the Federated States of Micronesia, the Commonwealth of the Northern Mariana Islands, Guam, Kiribati, Republic of Marshall Islands, Palau and Nauru. These islands are generally very small, low lying, resource-poor and scattered geographically. The sub-region of Polynesia includes American Samoa, Tuvalu, Tonga, Samoa, Cook Islands, French Polynesia, Niue, Tokelau and Wallis and Futuna. The islands of Polynesia are a mixture of raised limestone islands and atolls.

While the region covers an area of approximately 30,000,000 km2, only 2% is covered by land (SPREP, 2012). However it harbours a variety of important cultural systems and natural terrestrial, freshwater and marine ecosystems. The array of ecosystems in the region have extremely high levels of biodiversity and endemism owing to their insular nature

(Wardell-Johnson et al., 2011; SPREP, 2012). Some species groups have endemism levels of up to 90% (SPREP, 2012). The region harbours two main biodiversity hot spots, namely the East Melanesian Islands and Polynesia-Micronesia (CEPF, 2016). Some of the islands are also part of the Coral Triangle, the most diverse marine biodiversity region in the world (Veron et al., 2009).

Oceania region not only hosts some of the richest biodiversity but also one of the most threatened in the world (Kingsford et al., 2009). Tropical ecosystems in the region are particularly fragile and threatened by a variety of factors including logging, deforestation, pollution, fire, shifting agriculture, etc. Anthropogenic climate change particularly represents a major challenge for the protection of natural resources in Oceania with Polynesia-Micronesia being the biodiversity hotspot that is most vulnerable to global changes (Bellard et al., 2014).

Climate change and disasters also pose a major problem for the region's social capital. The region is not only highly exposed to natural hazards but it is also one of the most disaster-prone regions in the world (Asia-Pacific Disaster Report, 2015).

Oceania is particularly vulnerable to disasters and climate-related risks (Figure 18). Excluding Australia and New Zealand, all of the countries in the region are Small Island Developing States (SIDS), which are known to be particularly vulnerable to disasters. Sea-level rise and associated impacts such as coastal erosion and inundation poses a serious threat to the islands and coastal zones (Gero et al., 2010). Several factors contribute to the vulnerability of SIDS including their small size, isolation and limited migration capability during disasters (Pelling and Uitto, 2001).

Priority hazards and disaster impacts

In the past thirty-five years, 5,549 people are reported to have been killed by disasters caused by natural hazards in the region. Furthermore, around 23 million people have been affected by such disasters. Storms are the most common hazards with 213 reported

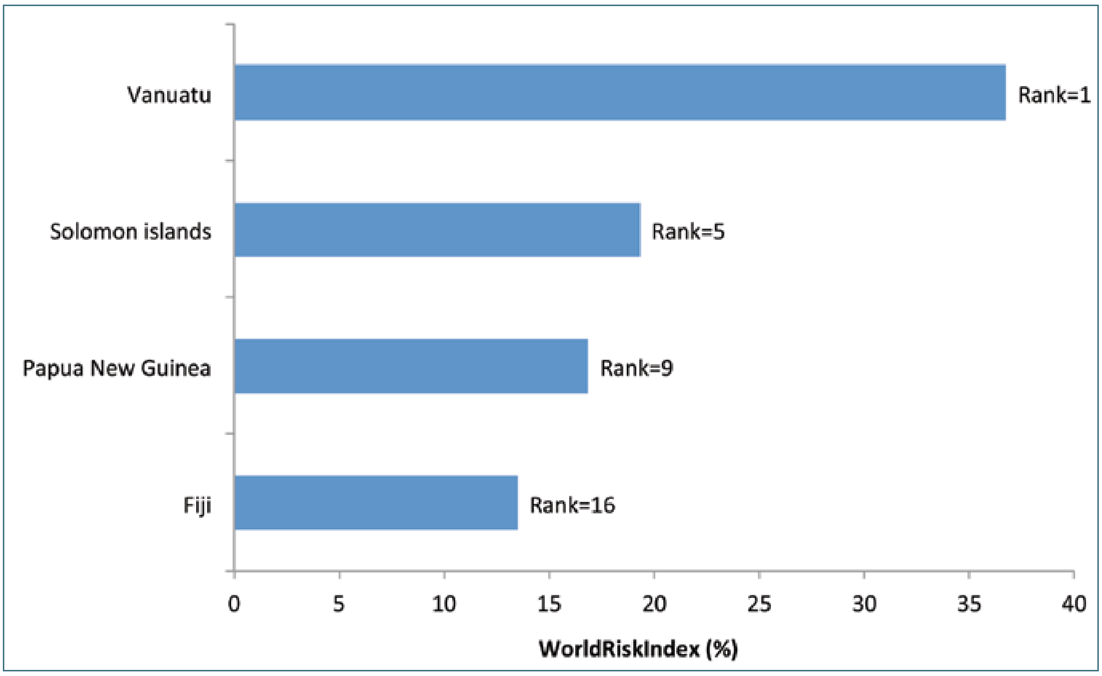


Figure 18. WorldRiskIndex and world ranking of the focal countries out of 171 countries (Note: Higher index values and lower ranking indicate higher disaster risks; Source=World Risk Report, 2015; Missing information for Marshall Islands, Samoa and Tuvalu).

For the period 1980-2015, it is reported that there were 33 disaster events caused by storms in the focal countries that resulted in the following impacts:

- 793 people died
- 154,445 people were affected
- Around US$ 4 billion of economic losses

Source: CRED EM-DAT-database, 2016

for the period 1980-2015. Earthquakes are the most deadly hazards in the region contributing to 51% of the reported deaths, while droughts have the most widespread impact contributing to 44% of the reported number of 6,249,235 people affected by disasters. Disasters have also caused huge economic losses in the region. It is estimated that around US$ 75 billion of economic damages has been caused by disasters in the past 25 years mostly attributed to earthquakes and storms.

Nature-based solutions for disaster risk reduction

Experiences with Eco-DRR

There is a wide range of projects across the region that contribute to Eco-DRR but they are not clearly identified as such. For many of the small Pacific Island countries, the only link between the environment and climatic events is made when discussing climate change adaptation interventions. Eco-DRR in Oceania is essentially the same as EbA, as in practice EbA targets the priority hazards and disaster type in the region, for example, storms and floods. CCA interventions cover activities like mangrove and coral reef restoration, reforestation in upland areas and watershed rehabilitation, which also contribute to risk reduction. Likewise there is a wide range of EbA projects in the Oceania region that are mostly targeting building resilience of coastal communities and the protection of important coastal ecosystems. Eco-DRR as an approach, still needs to be recognised as a possible tool for EbA and also needs to be integrated.

Eco-DRR as a tool for conservation

For example, catchment rehabilitation in Fiji and Samoa has included the removal of invasive species like *Merremia peltata*, an invasive vine in the Pacific, and the planting of native vegetation to prevent soil erosion and allow water retention. It has also involved the planting of native fruit trees in the riparian zone to prevent riverbank erosion. The native fruit trees also provide food and a means of livelihood. Similarly, catchment rehabilitation in Nakasaleka district, Kadavu and in Nadi, saw seedlings of native trees sourced from the wild and reared in community nurseries before being planted in upland areas. Catchment management plans also involved baseline surveys, which led to the discovery of a plant new to science, *Medinilla sp.*, in Kadavu, Fiji.

Potential economic benefits of Eco-DRR

- **Disasters are costly:** The Economic and Social Commission for Asia and the Pacific estimated that the economic loss from natural disasters surged significantly in the Asia-Pacific region from US$ 5 billion in the 1970s to around US$ 75 billion in recent years.
- **Ecosystem-based approaches can be cost-effective:** In Lami town, Fiji, a cost benefit analysis was conducted for ecosystem-based adaptation versus engineered options to address the town's vulnerability to flooding. The study revealed that the benefit to cost ratio for ecosystem-based options was US$ 19.5 as compared to US$ 9 for engineered options (Rao et al., 2013).

Moving towards integrated approaches

Challenges that need to be addressed:

- The national biodiversity policies and action plans rarely mention Eco-DRR except in countries like Samoa where the Environment Department and NDMO are housed in the same Ministry
- Conversely, the Disaster Management Plans and DRR policies of the focal countries do not mention biodiversity and ecosystem-based approaches.
- There is a need to ensure a solid case in favour of ecosystem-based approaches for CCA and DRR, including the need to make an economic case for decision making.

Opportunities to capitalise on:

- There is enormous scope for integrating Eco-DRR with conservation through using and providing evidence for their role in EbA.
- With the exception of Fiji whose mangrove forests are under the custodianship of the State, the mangroves in the other Melanesian countries are owned by the traditional landowners providing opportunities for participatory Eco-DRR initiatives.
- The Samoa Pathway and the Strategy for Climate and Disaster Resilient Development in the Pacific (SRDP) are the two regional frameworks that provide entry points for the mainstreaming of Eco-DRR initiatives in the region. The region will be setting the pace for the rest of the world when the SRDP is endorsed by the Pacific leaders, as it will then be the first regional framework to fully integrate climate change and disaster risk management.
- There is a proliferation of MPAs in the Pacific that have been set up to conserve biodiversity and their establishment and promotion are evident from action plans associated with the CBD. For these MPAs to be seen as part of Eco-DRR, they need to be incorporated into a larger seascape or ridge to reef approach to ecosystem management. Ecological connectivity is perhaps under-recognised.
- The regional policy illustrates a shift from emergency response to proactive integrated approaches. The region, however, remains vulnerable and continued support needs to be provided towards the integration of efforts and its co-funding, i.e. biodiversity benefits DRR and DRR benefits biodiversity.

Recommendations for actions:

- Promote inter-sectoral collaboration to improve policy implementation and translate knowledge into actions
- Raise awareness on the importance of integrated ecosystem-based approaches for CCA and DRR among governments, civil society and practitioners
- Both biodiversity and Eco-DRR to be integrated into national planning for sustainable development
- For government buy-in, more regional and national evidence is needed to prove that Eco-DRR and the maintenance of ecosystem structure and function can provide cost-effective options for DRR. This evidence can be furnished by Cost-Benefit Analysis of the different options.
- The role of people and their social systems must be recognised in Eco-DRR as traditional knowledge and practices of Pacific indigenous peoples have contributed to their coping strategies during times of natural disasters.

CASE STUDY

Mangrove rehabilitation in Papua New Guinea

The MARSH project implemented in PNG had as its overarching goal to empower communities and build capacities of national institutions in the rehabilitation and management of mangrove forests to increase resilience to the impacts of climate change. Like MESCAL, it too involved floral inventories and a mangrove taxonomy guide was prepared in draft form. The communities were taught basic mangrove taxonomy and a booklet prepared for community-based mangrove replanting and rehabilitation. A household use survey of mangrove goods and services conducted among 1,268 households in 52 villages, in 12 Local Level Government areas (LLG)s across three provinces showed a very high dependence on mangroves. The results of the survey spurred communities to include mangrove management in their community resource plans. The value of the mud clam, *Polymesoda erosa*, or kina fishery, was determined for the first time through market surveys and is estimated to be worth between PGK 300,000 – 1 million per year depending on whether the market is in Port Moresby or in a provincial town. It is thus a very important source of revenue for the resource owners. Over 13,000 mangrove seedlings were planted in degraded mangrove areas in 45 villages in 11 LLGs across five provinces of PNG. Mangrove and coral planting are means of biodiversity conservation whilst also providing coastal protection. Carbon accounting was also done at two mangrove sites to calculate carbon stocks at undisturbed sites thus proving their ability to sequester carbon and mitigate climate change.


Photo credit: © IUCN

Source: IUCN, 2016

Asia

Anshuman Saikia, Shreema Rana and Fabiola Monty

FOCAL COUNTRIES

- Bangladesh
- Cambodia
- China
- India
- Nepal
- Philippines
- Thailand
- Viet Nam

Background

The Asia region, as defined in this synthesis, comprises the sub-regions of South Asia, Southeast Asia and Northeast Asia and together accounts for 60% of the world's population. This region includes some of the most diverse ecosystems on the planet, from the large high-altitude Himalayan ecosystem to the Indo-Burma hotspot, Heart of Borneo rainforest ecosystem and the Coral Triangle ecosystem. The region is also home to five of the world's megadiverse countries: People's Republic of China, Indonesia, India, Malaysia and the Philippines.

This biodiversity is, however, under increasing pressure with rapid economic growth in the region leading to expansion of industrial agriculture, large-scale infrastructure development and rapid land-use change. In addition, drivers such as illegal wildlife trade, invasive alien species and climate change have further exacerbated the loss of biodiversity.

Additional major challenges in the region that have impacts on both the social and natural capital are the frequent occurrences of disasters. While Asia occupies 30% of the world's land mass, it has accounted for the occurrence of 40% of the world's disasters in the past decade, resulting in a disproportionate 80% of the world's disaster related deaths. Both natural and social factors characterise the probability that extreme events will occur and their impacts.

Priority hazards and disaster impacts

In the Asia region, between 1980 and 2015, the most significant natural hazards were floods, storms, earthquakes and droughts

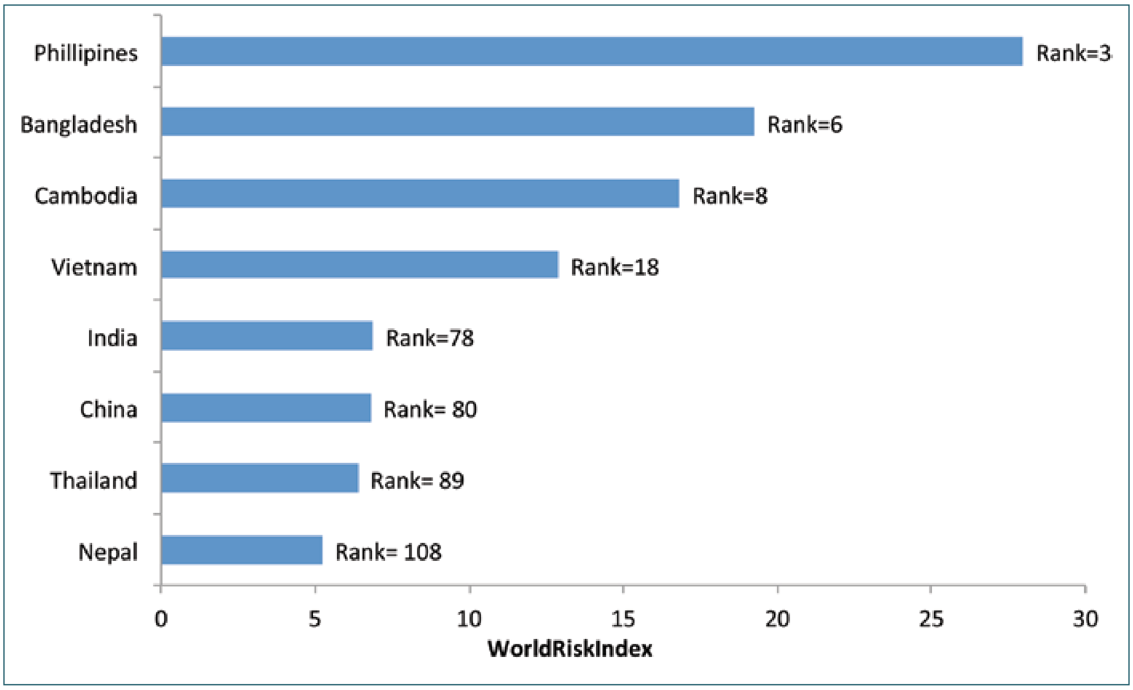


Figure 19. WorldRiskIndex and world ranking of the focal countries out of 171 countries (Note: Higher index values and lower ranking indicate higher disaster risks; Source=World Risk Report, 2015)

in the descending order of magnitude in terms of occurrences and people affected.

In the Southern, Eastern and South-Eastern regions, these affected almost 6 billion people and claimed an estimated 1.2 million lives. In terms of economic damage in the same period, losses are reported to be more than US$ 500 billion.

Nature-based solutions for disaster risk reduction

Experiences with Eco-DRR

There are several Eco-DRR initiatives being implemented in the region including pilot projects, with IUCN being a leader in supporting the initiation of Eco-DRR in the region. Following the 2004 tsunami, there has been an increasing recognition of the importance of ecosystem-based approaches for risk reduction at least in practice. For example the Mangroves for the Future Initiative, the largest flagship programme of IUCN in Asia was developed as a long-term response to address the impacts of the Indian Ocean tsunami by demonstrating that coastal ecosystems play a major role in buffering the impacts of coastal hazards and also provide vital ecosystem goods and services. While several projects are promoting ecosystem-based approaches for DRR and CCA in several countries, for example the use of Community-Based Ecological Mangrove Restoration in Thailand or bioengineering to stabilise slopes in

For the period 1980-2015, it is reported that there were 36 disaster events caused by earthquakes in the focal countries that resulted in the following impacts:

- 164,992 people died
- 6,739,140 people became homeless
- Around US$ 117 billion of economic losses

Source: CRED EM-DAT-database, 2016

Nepal, these practices are still being adopted by the environmental sector and need streaming into other sectors.

Eco-DRR as a tool for conservation

For example in Bangladesh, '*baira*', a local practice that involves the use of plants to construct a floating platform, on which vegetables and other crops are cultivated, contributes to both socio-economic development but also provides ecological benefits with a potential impact on biodiversity, as the practice entails the removal and utilisation of water hyacinths, the primary invasive species affecting the wetlands of Bangladesh.

Potential economic benefits of Eco-DRR

- **As a tool to reduce economic losses:** The Economic and Social Commission for Asia and the Pacific estimated that the economic loss from natural disasters surged significantly in the Asia-Pacific region from $ 5 billion in the 1970s to around US$ 75 billion in recent years.
- **Cost-effectiveness:** In Viet Nam, it was estimated that investing in 12,000 hectares of mangroves to protect the coast is much cheaper, being about US$ 1.1 million compared to what it would cost for the maintenance of dykes, i.e. US$ 7.3 million.

Moving towards integrated approaches

Challenges that need to be addressed:

- Inter-sectoral collaboration in improvement of policy and translating knowledge into action is required.
- Lack of integration with global and national climate change policy. Disaster management is primarily focused on post-disaster emergency relief, with little integration with global climate change policies. This gap in the policy environment is not favourable to progressing effective implementation of EbA approaches.
- It is important for Eco-DRR and EbA to be prioritised into not only the national development plans/vision/strategy but also sub-national and local development plans at the state or local level.
- It is vital to fill in various gaps in policy and awareness of hazards and disasters.
- The policy linkages between Eco-DRR, agencies and protected area creation and management need to be strengthened.
- There is inadequate in-depth understanding of hazard, vulnerability and disaster.
- There is inadequate capacity to implement all policies and frameworks and integrate Eco-DRR.

Opportunities to capitalise on:

- There is enormous scope for integrating DRR initiatives into biodiversity elements of risk reduction. Legislation and policies regarding biodiversity conservation for disaster risks have been developed and frameworks have often been put in place on a national scale. Implementing and managing the DRR framework at a local scale involving all stakeholders would need further action.
- New government programmes offer opportunities for integrating Eco-DRR into climate change policies and priorities.
- Local stakeholders are seeking increased engagement with DRR. There is a need to raise the currently low public awareness and understanding on hazards and disasters and on how ecosystem-based solutions have huge benefits for DRR.
- Growing interest in funding and investing in DRR related projects. This can add value to the sustainable development path by integrating ecosystem, climate change and biodiversity specific aspects to the DRR approaches, thus, putting biodiversity conservation, ecosystems and people's welfare at the heart of the new strategy with awareness on the multidimensional benefits of Eco-DRR.

- Applying Eco-DRR measures can also indirectly help protect major ecosystems such as watersheds.

Recommendations for actions:

- Promote inter-sectoral collaboration to improve policy implementation and translate knowledge into actions
- Increase awareness on the importance of Eco-DRR and systemise arguments and evidence for its effectiveness for its adoption and implementation
- Reframing of DRR concepts with ecosystem-based approaches so that ecosystem-based approaches are recognised as effective constituents of DRR and CCA by policy makers at the national level and community at the local level
- Implement Eco-DRR as a means to achieve multiple sustainable development.

CASE STUDY

Ecosystem-based approaches to climate change adaptation, Koh Kong and Preah Sihanouk in south-western Cambodia

Coastal wetlands, including mangroves, serve as carbon stores and sinks. Here mangrove restoration along the wetland and floodplain is providing a wide range of ecosystem services, including coastal defence, flood inundation, carbon sequestration, protection against extreme weather events, trapping sediment and providing nutrients and nurseries for coastal fisheries. Koh Kong and Preah Sihanouk in the south-western region of Cambodia are the site of projects designed to build the resilience of the coastal communities by incorporating mangrove restoration and identifying other biodiversity conservation aspects in terms of fisheries in the same project (Chong, 2014).

These projects are supported by NAPA to deliver biodiversity conservation co-benefits, with the primary foundation to restore mangrove ecosystems as buffers against climate change hazards. These NAPA projects are implemented with the sponsorship of government agencies and donors organised by the Cambodian Climate Change Alliance (CCCA).

The projects are promoting biodiversity conservation with mangrove restoration for climate resilient water management as part of the agricultural practices among the communities of Koh Kong and Preah Sihanouk (D’Agostino & Sovacool, 2011) with a major focus on the intensification of fishery production as a direct benefit of the role of ecosystem services. Consequently, the vegetation plantation project to build the resilience of the coastal communities in Koh Kong and Preah Sihanouk has great potential to incorporate the ecosystem-based elements of mangrove restoration and biodiversity conservation.

Source: Chong, 2014; D’Agostino and Sovacool, 2011

Additional Bibliography

Berrocal, M., Lloyd,K. and Salas, A. 2016. *Regional Assessment on Ecosystem-based Disaster Risk Reduction and Biodiversity in Mesoamerica and the Caribbean*. IUCN, ORMACC.

Dewald v.N.,, Murphree, M., Prinsloo, V., Lunga, W., Kruger, L., Bredenkamp, P.W., Nemakonde, L. and Coetzee, C. 2016. *Regional Assessment on Ecosystem-based Disaster Risk Reduction and Biodiversity in Eastern and Southern Africa*. IUCN, ESARO.

Masumbuko, B. 2016. *Regional Assessment on Ecosystem-based Disaster Risk Reduction and Biodiversity in West and Central Africa*. IUCN, PACO.

McBreen, J. 2016. *Regional Assessment on Ecosystem-based Disaster Risk Reduction and Biodiversity in South America*. IUCN, SUR.

Saikia, A. and Rana, S. 2016. *Regional Assessment on Ecosystem-based Disaster Risk Reduction and Biodiversity in Asia*. IUCN, Asia.

Sobey, M.N.and Monty, F. 2016. *Regional Assessment on Ecosystem-based Disaster Risk Reduction and Biodiversity in Oceania.* IUCN Gland, Switzerland.

References

Adger, W.N., 2000. Social and ecological resilience: are they related?. *Progress in human geography*, 24(3), pp.347-364. http://dx.doi.org/10.1191/030913200701540465

Adger, W.N., 2006. Vulnerability. *Global environmental change*, 16(3), pp.268-281. http://dx.doi.org/10.1016/j.gloenvcha.2006.02.006

Adger, W.N., Hughes, T.P., Folke, C., Carpenter, S.R. and Rockström, J. 2005. Social-ecological resilience to coastal disasters. *Science*, *309*(5737), pp.1036-1039. https:/doi.org/10.1126/science.1112122

African Ministerial Conference on the Environment (AMCEN).2015. Cairo Declaration on Managing Africa's Natural Capital for Sustainable Development and Poverty Eradication. Available at: http://www.un.org/en/africa/osaa/pdf/au/cap_naturalcapital_2015.pdf.

Allen, C.D., Macalady, A.K., Chenchouni, H., Bachelet, D., McDowell, N., Vennetier, M., Kitzberger, T., Rigling, A., Breshears, D.D., Hogg, E.T. and Gonzalez, P. 2010. A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. *Forest Ecology and Management*, 259(4), pp.660-684. https:/doi.org/10.1016/j.foreco.2009.09.001

Allen, R.B., Bellingham, P.J. and Wiser, S.K. 1999. Immediate damage by an earthquake to a temperate montane forest. *Ecology*, 80(2), pp.708-714.

Aquilino, K.M. and Stachowicz, J.J. 2012. Seaweed richness and herbivory increase rate of community recovery from disturbance. *Ecology*, *93*(4), pp.879-890. https:/doi.org/10.1890/11-0457.1

Asia-Pacific Disaster Report. 2015. *Disasters without Borders - Regional Resilience for Sustainable Development*. United Nations Publications.

Bahuguna, A., Nayak, S. and Roy, D. 2008. Impact of the tsunami and earthquake of 26th December 2004 on the vital coastal ecosystems of the Andaman and Nicobar Islands assessed using RESOURCESAT AWiFS data. *International Journal of Applied Earth Observation and Geoinformation*, *10*(2), pp.229-237. https:/doi.org/10.1016/j.jag.2008.02.010

Balvanera, P., Pfisterer, A.B., Buchmann, N., He, J.S., Nakashizuka, T., Raffaelli, D. and Schmid, B. 2006. Quantifying the evidence for biodiversity effects on ecosystem functioning and services. *Ecology Letters*, *9*(10), pp.1146-1156.https:/doi.org/10.1016/j.jag.2008.02.010

Bellard, C., Leclerc, C., Leroy, B., Bakkenes, M., Veloz, S., Thuiller, W. and Courchamp, F. 2014. Vulnerability of biodiversity hotspots to global change. *Global Ecology and Biogeography*, 23(12), pp.1376-1386.

Belle E., Wicander S., Bingham H. and Shi Y. 2015. *Governance of Protected Areas in Africa*, *A Global Review.* UNEP-WCMC, Cambridge, UK.

Bengtsson, J., Angelstam, P., Elmqvist, T., Emanuelsson, U., Folke, C., Ihse, M., Moberg, F. and Nyström, M. 2003. Reserves, resilience and dynamic landscapes. *AMBIO: A Journal of the Human Environment*, *32*(6), pp.389-396. http://dx.doi.org/10.1639/0044-7447(2003)032[0389:rradl]2.0.co;2

Bennett, E.M., Peterson, G.D. and Gordon, L.J. 2009. Understanding relationships among multiple ecosystem services. *Ecology Letters*, *12*(12), pp.1394-1404. https:/doi.org/10.1111/j.1461-0248.2009.01387.x

Blankespoor, B., Dasgupta, S. and Lange, G.M. 2016. Mangroves as protection from storm surges in a changing climate. *World Bank Policy Research Working Paper*, (7596). https:/doi.org/10.1111/j.1461-0248.2009.01387.x

Bond, N.R., Lake, P.S. and Arthington, A.H. 2008. The impacts of drought on freshwater ecosystems: an Australian perspective. *Hydrobiologia*, *600*(1), pp.3-16. https:/doi.org/10.1007/s10750-008-9326-z

Brooks, M.L., D'antonio, C.M., Richardson, D.M., Grace, J.B., Keeley, J.E., DiTomaso, J.M., Hobbs, R.J., Pellant, M. and Pyke, D. 2004. Effects of invasive alien plants on fire regimes. *BioScience*, 54(7), pp.677-688. https:/doi.org/10.1641/0006-3568(2004)054[0677:EOIAPO]2.0.CO;2

Burke, M.B., Lobell, D.B. and Guarino, L. 2009. Shifts in African crop climates by 2050, and the implications for crop improvement and genetic resources conservation. *Global Environmental Change*, *19*(3), pp.317-325. https:/doi.org/10.1016/j.gloenvcha.2009.04.003

Buyck, C. 2016. *Ecosystems Protecting Infrastructure and Communities (EPIC): lessons from implementation*. Mid-term review report.

Cabinet Secretariat, Government of Japan, 2016. *Building National Resilience*. Available at: http://www.cas.go.jp/jp/seisaku/kokudo_kyoujinka/index_en.html.

Cardona, O.D., M.K. van Aalst, J., Birkmann, M., Fordham, G., McGregor, R., Perez, R.S., Pulwarty, E.L.F., Schipper, and B.T. Sinh 2012. 'Determinants of risk: exposure and vulnerability', in Field, C.B., V. Barros, V., T.F. Stocker, T.F., D. Qin, D., Dokken, D.J., Ebi, K.L., Mastrandrea, M.D., Mach, K.J., Plattner, G.K., Allen, S.K., Tignor, M., and Midgley, P.M (Eds). *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* . IPCC, Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 65 – 108.

Carvalho, P., Thomaz, S., Kobayashi, J.T. and Bini, L. 2013. Species richness increases the resilience of wetland plant communities in a tropical floodplain. *Austral Ecology*, *38*(5), pp.592-598. http://dx.doi.org/10.1111/aec.12003

Castañeda-Álvarez, N.P., de Haan, S., Juárez, H., Khoury, C.K., Achicanoy, H.A., Sosa, C.C., Bernau, V., Salas, A., Heider, B., Simon, R. and Maxted, N. 2015. Ex situ conservation priorities for the wild relatives of potato (Solanum L. section Petota). *PloS One*, *10*(4), p.e0122599. https:/doi.org/10.1371/journal.pone.0122599

CBD (Convention on Biological Diversity) Secretariat. 1992. *The convention on biological diversity*. Secretariat of the Convention on Biological Diversity, United Nations Environment Programme, Montreal. Available at: www.biodiv.org/convention/convention.shtml.

CBD (Convention on Biological Diversity Secretariat). 2004. *The Ecosystem Approach, CBD Guidelines*. Secretariat of the Convention on Biological Diversity, Montreal.

CBD (Convention on Biological Diversity) Secretariat. 2010. X/33 Biodiversity and climate change, Decision Adopted by the Conference of the Parties to the Convention on Biological Diversity at its Tenth Meeting; UNEP/CBD/COP/DEC/x/33; 29 October 2010, Nagoya, Japan.

Cedfeldt P.T., Watzin M.C., and Richardson B.D. 2000. Using GIS to identify functionally significant wetlands in the Northeastern United States. *Environmental Management* 26: 13–24. https:/doi.org/10.1007/s002670010067

CENRS and NSTC, 2015 Ecosystem-service assessment: research need for coastal green infrastructure. Available at: https://www.whitehouse.gov/sites/default/files/microsites/ostp/cgies_research_agenda_final_082515.pdf.

Chong, J. 2014. Ecosystem-based approaches to climate change adaptation: progress and challenges. *International Environmental Agreements*, 14(4), 391–405.

Cohen-Shacham, E., Walters, G., Janzen, C. and Maginnis, S. (eds.) 2016. *Nature-based solutions to address global societal challenges*. Gland, Switzerland: IUCN. xiii + 97pp.

Conservation Evidence. Providing evidence to improve practice. Available at: http://www.conservationevidence.com/ [Accessed October 2016]

Costanza, R., d'Arge, R., De Groot, R., Faber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'neill, R.V., Paruelo, J. and Raskin, R.G. 1997. The value of the world's ecosystem services and natural capital. *Nature,* 387(6630), pp253-260. http://dx.doi.org/10.1038/387253a0

Costanza, R., de Groot, R., Sutton, P., van der Ploeg, S., Anderson, S.J., Kubiszewski, I., Farber, S. and Turner, R.K., 2014. Changes in the global value of ecosystem services. *Global Environmental Change*, *26*, pp.152-158. https:/doi.org/10.1016/j.gloenvcha.2014.04.002

CRED EM-DAT database. Available at: http://www.emdat.be/database [Accessed 21 October 2016].

Critical Ecosystem Partnership Fund(CEPF). 2016. CEPF.net. Available at: http://www.cepf.net/Pages/default.aspx [Accessed April 2016].

Cutter, S.L. 1996. Vulnerability to environmental hazards. *Progress in Human Geography*, 20(4), pp.529 – 539. http://dx.doi.org/10.1177/030913259602000407

Cutter, S.L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E. and Webb, J. 2008. A place-based model for understanding community resilience to natural disasters. *Global Environmental Change*, *18*(4), pp.598-606. http://dx.doi.org/10.1016/j.gloenvcha.2008.07.013

D'Agostino, A.L. and Sovacool, B.K. 2011. Sowing climate-resilient seeds: implementing climate change adaptation best practices in rural Cambodia. *Mitigation and Adaptation Strategies for Global Change*, 16(6), 699–720.

Das, S. and Crépin, A.S. 2013. Mangroves can provide protection against wind damage during storms. *Estuarine, Coastal and Shelf Science*, *134*, pp.98-107. https:/doi.org/10.1016/j.ecss.2013.09.021

dela Cruz, D.W., Villanueva, R.D. and Baria, M.V.B. 2014. Community-based, low-tech method of restoring a lost thicket of Acropora corals. *ICES Journal of Marine Science: Journal du Conseil*, *71*(7), pp.1866-1875. https:/doi.org/10.1093/icesjms/fst228

Dempewolf, H., Eastwood, R.J., Guarino, L., Khoury, C.K., Müller, J.V. and Toll, J. 2014. Adapting agriculture to climate change: A global initiative to collect, conserve, and use crop wild relatives. *Agroecology and Sustainable Food Systems*, *38*(4), pp.369-377. https:/doi.org/10.1080/21683565.2013.870629

Doswald, N. and Estrella, M. 2015. *Promoting ecosystems for disaster risk reduction and climate change adaptation: Opportunities for Integration*. UNEP discussion paper.

Downing, A.S., van Nes, E.H., Mooij, W.M. and Scheffer, M. 2012. The resilience and resistance of an ecosystem to a collapse of diversity. *PloS One*, *7*(9), p.e46135. https:/doi.org/10.1371/journal.pone.0046135

Dudley, N., Buyck, C., Furuta, N., Pedrot, C., Renaud, F. and Sudmeier-Rieux, K. 2015. *Protected areas as tools for disaster risk reduction: a handbook for practitioners.* Tokyo and Gland, Switzerland: MOEJ and IUCN. 44pp.

Duncan, J.M.M., Dash, J. and Thompkins,E.L. 2015. 'Mangroves forests enhance rice cropland resilience to tropical cyclones: evidence from the Bhitarkanika Conservation Area', in Murti,R. and Buyck, C.(Eds.) *Safe Havens: Protected Areas for Disaster Risk Reduction and Climate Change Adaptation*. Gland, Switzerland: IUCN. xii + 168 pp.

EC, 2013. Communication from the European Commission: Green Infrastructure (GI) – Enhancing Europe's natural capital, Com (2013) 249 final. Available at : http://ec.europa.eu/environment/nature/ecosystems/index_en.htm

EC, 2016. Horizon 2020 . Available at: https://ec.europa.eu/programmes/horizon2020/.

Estrella, M. and N. Saalismaa. 2013. 'Ecosystem-based Disaster Risk Reduction (Eco-DRR): An Overview', in Renaud, F., Sudmeier-Rieux, K. and M. Estrella (eds.) *The role of ecosystem management in disaster risk reduction*. Tokyo: UNU Press, pp. 26-54.

Executive Office of the President of the United States of America, 2015 Incorporating Ecosystem Services into Federal Decision Making . Available at: https://www.whitehouse.gov/sites/default/files/omb/memoranda/2016/m-16-01.pdf

FAO. 2015. *Coping with climate change – the roles of genetic resources for food and agriculture.* Rome.

Folke, C., Carpenter, S., Walker, B., Scheffer, M., Elmqvist, T., Gunderson, L. and Holling, C.S. 2004. Regime shifts, resilience, and biodiversity in ecosystem management. *Annual Review of Ecology, Evolution, and Systematics*, pp.557-581. https:/doi.org/10.1146/annurev.ecolsys.35.021103.105711

Furuta, N. and Satoquo, S. 2016. 'Progress and Gaps in Eco-DRR Policy and Implementation after the Great East Japan Earthquake', in Renaud, F.G. Sudmeier-Rieux, K. and Estrella, M. 2016 (Eds).

Ecosystem-Based Disaster Risk Reduction and Adaptation in Practice. Springer, pp. 295-313. https:/doi.org/10.1007/978-3-319-43633-3_13

Geertsema, M., Highland, L. and Vaugeouis, L. 2009. 'Environmental impact of landslides', in Sassa, K. and Canuti, P(eds). *Landslides–Disaster Risk Reduction*. Heidelberg, Berlin: Springer, pp. 589-607. https:/doi.org/10.1007/978-3-540-69970-5_31

Geist, H.J. and Lambin, E.F. 2004. Dynamic causal patterns of desertification. *Bioscience*, 54(9), pp.817-829.

https:/doi.org/10.1641/0006-3568(2004)054[0817:DCPOD]2.0.CO;2

Gero, A., Meheux, K. and Dominey-Howes, D. 2010. *Disaster risk reduction and climate change adaptation in the Pacific: The challenge of integration.*University of New South Wales, Sydney.

Ghestem, M., Cao, K., Ma, W., Rowe, N., Leclerc, R., et al. 2014. A Framework for Identifying Plant Species to Be Used as 'Ecological Engineers' for Fixing Soil on Unstable Slopes. *PLoS ONE* 9(8): e95876. https:/doi.org/10.1371/journal.pone.0095876

Godfray, H.C.J., Beddington, J.R., Crute, I.R., Haddad, L., Lawrence, D., Muir, J.F., Pretty, J., Robinson, S., Thomas, S.M. and Toulmin, C. 2010. Food security: the challenge of feeding 9 billion people. *Science*, *327*(5967), pp.812-818. http://dx.doi.org/10.1126/science.1185383

Gomez, E.D., Yap, H.T., Cabaitan, P.C. and Dizon, R.M. 2011. Successful transplantation of a fragmenting coral, Montipora digitata, for reef rehabilitation. *Coastal Management*, *39*(5), pp.556-574. https:/doi.org/10.1080/08920753.2011.600240

Government of Japan, 2016 Ecosystem-based Disaster Risk Reduction in Japan – A handbook for practitioners. Available at: https://www.env.go.jp/en/nature/biodiv/eco-drr.pdf.

Government of Japan, 2016 Green Reconstruction: Creating a new National Park . Available at: https://www.env.go.jp/jishin/park-sanriku/green-reconstruction/images/sanriku_fukkou_project_eng.pdf.

Government of the United States of America, 2013 Hurricane Sandy Rebuilding Task Force - Hurricane Sandy Rebuilding Strategy: Stronger Communities, A Resilience Region. Available at: http://portal.hud.gov/hudportal/documents/huddoc?id=hsrebuildingstrategy.pdf .

Guariguata, M.R. 1990. Landslide disturbance and forest regeneration in the upper Luquillo Mountains of Puerto Rico. *The Journal of Ecology*, pp.814-832. https:/doi.org/10.2307/2260901

Gunderson, L., 2010. Ecological and human community resilience in response to natural disasters. *Ecology and Society*, 15(2), p.18.

Hall-Spencer, J.M., Rodolfo-Metalpa, R., Martin, S., Ransome, E., Fine, M., Turner, S.M., Rowley, S.J., Tedesco, D. and Buia, M.C., 2008. Volcanic carbon dioxide vents show ecosystem effects of ocean acidification. *Nature*, *454*(7200), pp.96-99. https:/doi.org/10.1038/nature0705

Hilton, R.G., Meunier, P., Hovius, N., Bellingham, P.J. and Galy, A., 2011. Landslide impact on organic carbon cycling in a temperate montane forest. *Earth Surface Processes and Landforms*, *36*(12), pp.1670-1679. https:/doi.org/10.1002/esp.2191

Huenneke, L.F., Anderson, J.P., Remmenga, M. and Schlesinger, W.H., 2002. Desertification alters patterns of aboveground net primary production in Chihuahuan ecosystems. *Global Change Biology*, *8*(3), pp.247-264. https:/doi.org/10.1046/j.1365-2486.2002.00473.x

International Recovery Platform. 2009. Environment Issues in Recovery. Executive Briefs for Recovery: Extracts from key documents series 16 November 2009. Available at: http://www.gdrc.org/uem/disasters/disenvi/environment-recovery.pdf.

IPCC (Intergovernmental Panel on Climate Change). 2012. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A special report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press. 582 pp.

IPCC, 2014: Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability.Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J.

Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32.

IPCC. 2014. Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability.

Isbell, F., Calcagno, V., Hector, A., Connolly, J., Harpole, W.S., Reich, P.B., Scherer-Lorenzen, M., Schmid, B., Tilman, D., van Ruijven, J. and Weigelt, A. 2011. High plant diversity is needed to maintain ecosystem services. *Nature*, *477*(7363), pp.199-202. http://dx.doi.org/10.1038/nature10282

Isbell, F., Craven, D., Connolly, J., Loreau, M., Schmid, B., Beierkuhnlein, C., Bezemer, T.M., Bonin, C., Bruelheide, H., De Luca, E. and Ebeling, A. 2015. Biodiversity increases the resistance of ecosystem productivity to climate extremes. *Nature*, 526(7574), pp.574-577. https:/doi.org/10.1038/nature15374

IUCN and UNIL 2016. *Ecosystems Protecting Infrastructure and Communities – Nepal. Eco-safe roads through nature-based solutions: soil bio-engineering, ecosystem management and community resilience.* Policy Brief, International Union for Conservation of Nature (IUCN) Nepal and the University of Lausanne: Kathmandu, 4 pp.

IUCN. 2013. *The First Asia Parks Congress: Report on the Proceedings* , 3th-17th November 2013, Sendai, Japan. Available at: https://portals.iucn.org/library/sites/library/files/documents/2014-052.pdf.

IUCN.2016. Mangrove Rehabilitation for Sustainably-Managed Healthy Forests (MARSH) Project, Final Report 2016.

Jaramillo, E., Dugan, J.E., Hubbard, D.M., Melnick, D., Manzano, M., Duarte, C., Campos, C. and Sanchez, R. 2012. Ecological implications of extreme events: footprints of the 2010 earthquake along the Chilean coast. *PLoS One*, *7*(5), p.e35348. https:/doi.org/10.1371/journal.pone.0035348

JICA. 2016. Ecosystem-based Disaster Risk Reduction (Eco-DRR): JICA's Eco-DRR Cooperation in Developing Countries. Available at : http://gwweb.jica.go.jp/km/FSubject0301.nsf/b9ebd9a793e2456249256fce001df569/3958a0a725aba98549257a7900124f29/$FILE/ATTMIPSG.pdf/Ecosystem-based%20Disaster%20Risk%20Reduction.pdf.

Jokiel, P.L., Hunter, C.L., Taguchi, S. and Watarai, L. 1993. Ecological impact of a fresh-water "reef kill" in Kaneohe Bay, Oahu, Hawaii. *Coral Reefs*, *12*(3-4), pp.177-184. https:/doi.org/10.1007/BF00334477

Juffe-Bignoli, D., Bhatt, S., Park, S., Eassom, A., Belle, E.M.S., Murti, R., Buyck, C., Raza Rizvi, A., Rao, M., Lewis, E., MacSharry, B., Kingston, N. 2014. *Asia Protected Planet 2014*. UNEP-WCMC: Cambridge, UK.

Kell, S.P., Maxted, N., Bilz, M. 2012. European crop wild relative threat assessment: Knowledge gained and lessons learnt. In: Maxted, N., Dulloo, M.E., Ford-Lloyd, B.V., Frese, L.L., Iriondo, J.M. and Pinheiro de Carvalho, M.A.A. (Eds.), *Agrobiodiversity Conservation: Securing the Diversity of Crop Wild Relatives and Landraces*. CAB International, Wallingford, pp. 218–242. https:/doi.org/10.1079/9781845938512.0218

Kellett, J. and Sparks, D. 2012. *Disaster Risk Reduction: spending where it should count*. Briefing paper. Global Humanitarian Assistance.

Khoury, C.K., Bjorkman, A.D., Dempewolf, H., Ramirez-Villegas, J., Guarino, L., Jarvis, A., Rieseberg, L.H. and Struik, P.C. 2014. Increasing homogeneity in global food supplies and the implications for food security. *Proceedings of the National Academy of Sciences*, *111*(11), pp.4001-4006. https:/doi.org/10.1073/pnas.1313490111

Kingsford, R.T., Watson, J.E., Lundquist, C.J., Venter, O., Hughes, L., Johnston, E.L., Atherton, J., Gawel, M., Keith, D.A., Mackey, B.G. and Morley, C., 2009. Major conservation policy issues for biodiversity in Oceania. *Conservation Biology*, 23(4), pp.834-840. http://dx.doi.org/10.1111/j.1523-1739.2009.01287.x

Lewis, S.L., Brando, P.M., Phillips, O.L., van der Heijden, G.M. and Nepstad, D. 2011. The 2010 amazon drought. *Science*, *331*(6017), pp.554-554. https:/doi.org/10.1126/science.1200807

Livingston, A.C., Varner, J.M., Jules, E.S., Kane, J.M. and Arguello, L.A. 2016. Prescribed fire and conifer removal promote positive understorey vegetation responses in oak woodlands. *Journal of Applied Ecology*. doi: 10.1111/1365-2664.12703.

Lo, V. 2016. *Synthesis report on experiences with ecosystem -based approaches to climate change adaptation and disaster risk reduction*. CBD Secretariat.

Maxted, N., Ford-Lloyd, B.V., Jury, S., Kell, S. and Scholten, M. 2006. Towards a definition of a crop wild relative. *Biodiversity & Conservation*, *15*(8), pp.2673-2685. https:/doi.org/10.1007/s10531-005-5409-6

Mellin, C., Bradshaw, C.J.A., Fordham, D.A. and Caley, M.J. 2014. Strong but opposing β-diversity–stability relationships in coral reef fish communities. *Proceedings of the Royal Society of London B: Biological Sciences*, *281*(1777), p.20131993. https:/doi.org/10.1098/rspb.2013.1993

Millennium Ecosystem Assessment (MEA) .2005. *Ecosystems and Human Well-Being: Synthesis*. Island Press, Washington, DC.

Mori, A.S., Furukawa, T. and Sasaki, T. 2013. Response diversity determines the resilience of ecosystems to environmental change. *Biological Reviews*, *88*(2), pp.349-364. https:/doi.org/10.1111/brv.12004

Munang, R., Thiaw, I., Alverson, K., Liu, J. and Han, Z., 2013. The role of ecosystem services in climate change adaptation and disaster risk reduction. *Current Opinion in Environmental Sustainability*, 5(1), pp.47-52. http://dx.doi.org/10.1016/j.cosust.2013.02.002

Murti, R. and Buyck, C. (ed.) 2014. *Safe Havens: Protected Areas for Disaster Risk Reduction and Climate Change Adaptation*. Gland, Switzerland: IUCN. xii + 168 pp.

NatCatService. Munich Re. 2016. Annual statistics. Available at: https://www.iucn.org/downloads/disaster_risk_reduction_and_climate_change_issues_brief_cop21_031215.pdfhttps://www.munichre.com/en/reinsurance/business/non-life/natcatservice/annual-statistics/index.html .

Natural Capital Project 2016. Available at: http://www.naturalcapitalproject.org/software/#collaborate .

Niang, I., O.C. Ruppel, M.A. Abdrabo, A. Essel, C. Lennard, J. Padgham, and P. Urquhart, 2014: Africa. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1199-1265.

Oldfield, S. and Olwell, P. 2015. The Right Seed in the Right Place at the Right Time. *BioScience* 65(10): 955-956. https:/doi.org/10.1093/biosci/biv127

Oliver, T.H., Heard, M.S., Isaac, N.J., Roy, D.B., Procter, D., Eigenbrod, F., Freckleton, R., Hector, A., Orme, C.D.L., Petchey, O.L. and Proença, V. 2015. Biodiversity and resilience of ecosystem functions. *Trends in Ecology & Evolution*, 30(11), pp.673-684. https:/doi.org/10.1016/j.tree.2015.08.009

Ouyang Z., Xu, W.,Wang, X., Wang, W., Dong, R., Zheng, H., Li, D., Zhang, H., and Zhuang, C . 2008. Impact assessment of Wenchuan earthquake on ecosystems. *Acta Ecologica Sinica* 28:5801–5809.

Pasquini, L. and Cowling, R.M., 2015. Opportunities and challenges for mainstreaming ecosystem-based adaptation in local government: evidence from the Western Cape, South Africa. *Environment, Development and Sustainability*, 17(5), pp.1121-1140. http://dx.doi.org/10.1007/s10668-014-9594-x

PEDRR, 2011. Ecosystem based Disaster Risk Reduction (Eco-DRR) definition. Available at: www.pedrr.org .

PEDRR, 2016. Partnership for Environment and Disaster Risk Reduction. Available at: http://pedrr.org/ .

Pelling, M. and Uitto, J.I. 2001. Small island developing states: natural disaster vulnerability and global change. *Global Environmental Change Part B: Environmental Hazards*, 3(2), pp.49-62. http://dx.doi.org/10.1016/s1464-2867(01)00018-3

Phillips, O.L., Aragão, L.E., Lewis, S.L., Fisher, J.B., Lloyd, J., López-González, G., Malhi, Y., Monteagudo, A., Peacock, J., Quesada, C.A. and Van Der Heijden, G. 2009. Drought sensitivity of the Amazon rainforest. *Science*, *323*(5919), pp.1344-1347. https:/doi.org/10.1126/science.1164033

Philpott, S.M., Lin, B.B., Jha, S. and Brines, S.J. 2008. A multi-scale assessment of hurricane impacts on agricultural landscapes based on land use and topographic features. *Agriculture, Ecosystems & Environment*, *128*(1), pp.12-20. https:/doi.org/10.1016/j.agee.2008.04.016

Ramachandran, S., Anitha, S., Balamurugan, V., Dharanirajan, K., Vendhan, K.E., Divien, M.I.P., Vel, A.S., Hussain, I.S. and Udayaraj, A. 2005. Ecological impact of tsunami on Nicobar Islands (Camorta, Katchal, Nancowry and Trinkat). *Current Science*, *89*(1), pp.195-200.

Rao, N.S., Carruthers, T.J.B., Anderson, P., Sivo, L., Saxby, T., Durbin, T., Jungblut, V., Hills, T., Chape, S. 2013. *An economic analysis of ecosystem-based adaptation and engineering options for climate change adaptation in Lami Town, Republic of the Fiji Islands*. A technical report by the Secretariat of the Pacific Regional Environment Programme. Apia, Samoa: SPREP.

Raudsepp-Hearne, C., Peterson, G.D., Tengö, M., Bennett, E.M., Holland, T., Benessaiah, K., MacDonald, G.K. and Pfeifer, L. 2010. Untangling the environmentalist's paradox: why is human well-being increasing as ecosystem services degrade? *BioScience*, 60(8), pp.576-589. https:/doi.org/10.1525/bio.2010.60.8.4

Renaud, F.G. and Murti, R. 2013. *Ecosystems and disaster risk reduction in the context of the Great East Japan Earthquake and Tsunami: a scoping study Report to the Keidanren Nature Conservation Fund*. UNU-EHS Working Paper. UNU-EHS.

Renaud, F.G., Sudmeier-Rieux, K. and Estrella, M. 2016. *Ecosystem-Based Disaster Risk Reduction and Adaptation in Practice*. Springer. https:/doi.org/10.1007/978-3-319-43633-3

Renaud, F.G., Sudmeier-Rieux, K. and Estrella, M., 2013. *The role of ecosystems in disaster risk reduction*. United Nations University Press.

Restrepo, C., Walker, L.R., Shiels, A.B., Bussmann, R., Claessens, L., Fisch, S., Lozano, P., Negi, G., Paolini, L., Poveda, G. and Ramos-Scharrón, C. 2009. Landsliding and its multiscale influence on mountainscapes. *BioScience*, *59*(8), pp.685-698. https:/doi.org/10.1525/bio.2009.59.8.10

RICS. 2009. *The Built Environment Professions in Disaster Risk Reduction and Response*. A guide for humanitarian agencies. London.

Robinson, C.T. and Uehlinger, U. 2008. Experimental floods cause ecosystem regime shift in a regulated river. *Ecological Applications 18*(2): 511-526. https:/doi.org/10.1890/07-0886.1

Rodrigues, A.S., Akcakaya, H.R., Andelman, S.J., Bakarr, M.I., Boitani, L., Brooks, T.M., Chanson, J.S., Fishpool, L.D., Da Fonseca, G.A., Gaston, K.J. and Hoffmann, M., 2004. Global gap analysis: priority regions for expanding the global protected-area network. *BioScience*, 54(12), pp.1092-1100. http://dx.doi.org/10.1641/0006-3568(2004)054[1092:ggaprf]2.0.co;2

Crop Wild Relatives: SADC-CWR project. Available at: http://www.cropwildrelatives.org/sadc-cwr-project/ [Accessed September 2016].

Secretariat of the Pacific Regional Environmental Programme (SPREP). 2012. Pacific Environment and Climate Change Outlook- Apia, Samoa. SPREP.

Sgro, C.M., Lowe, A.J. and Hoffmann, A.A. 2011. Building evolutionary resilience for conserving biodiversity under climate change. *Evolutionary Applications*, *4*(2), pp.326-337. https:/doi.org/10.1111/j.1752-4571.2010.00157.x

Smith, T.J., Anderson, G.H., Balentine, K., Tiling, G., Ward, G.A. and Whelan, K.R. 2009. Cumulative impacts of hurricanes on Florida mangrove ecosystems: sediment deposition, storm surges and vegetation. *Wetlands*, *29*(1), pp.24-34. https:/doi.org/10.1672/08-40.1

Stokes, A., Atger, C., Bengough, A.G., Fourcaud, T. and Sidle, R.C. 2009. Desirable plant root traits for protecting natural and engineered slopes against landslides. *Plant and Soil*, *324*(1-2), pp.1-30. https:/doi.org/10.1007/s11104-009-0159-y

Sudmeier-Rieux, K., Ash, N. and Murti, R. 2013. *Environmental Guidance Note for Disaster Risk Reduction: Healthy Ecosystems for Human Security and Climate Change Adaptation*. Gland, Switzerland: IUCN, iii+34 pp.

Sudmeier-Rieux, K., Devkota, S., Penna, I., Leibundgut, G., Jaboyedoff, M., Adhikari, A., Khanal, R., Derron, M-H. 2014. *Community based bio-engineering for reducing erosion along rural roads in Nepal*. International Conference Analysis and Management of Changing Risks for Natural Hazards 18-19 November 2014, Padua, Italy.

Sutton-Grier, A.E., Wowk, K. and Bamford, H. 2015. Future of our coasts: the potential for natural and hybrid infrastructure to enhance the resilience of our coastal communities, economies and ecosystems. *Environmental Science & Policy*, *51*, pp.137-148. https:/doi.org/10.1016/j.envsci.2015.04.006

Tanaka, N., Sasaki, Y., Mowjood, M.I.M., Jinadasa, K.B.S.N. and Homchuen, S. 2006. Coastal vegetation structures and their functions in tsunami protection: experience of the recent Indian Ocean tsunami. *Landscape and Ecological Engineering*, 3(1), pp.33-45. https:/doi.org/10.1007/s11355-006-0013-9

TEEB 2010. The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A synthesis of the approach, conclusions and recommendations of TEEB.

Tignor, and Midgley, P.M. (eds.) *A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC)*. pp. 65-108. Cambridge, UK, and New York, NY: Cambridge University Press.

Tilman, D. and El Haddi, A. 1992. Drought and biodiversity in grasslands. *Oecologia*, 89(2), pp.257-264. http://dx.doi.org/10.1007/bf00317226

Tilman, D., Reich, P.B. and Isbell, F. 2012. Biodiversity impacts ecosystem productivity as much as resources, disturbance, or herbivory. *Proceedings of the National Academy of Sciences*, 109(26), pp.10394-10397. http://dx.doi.org/10.1073/pnas.1208240109

Twigg, J. 2004. *Good Practice Review. Disaster Risk Reduction: Mitigation and preparedness in development and emergency programming*. Humanitarian Practice Network. Available at: http://www.ifrc.org/PageFiles/95743/B.a.05.%20Disaster%20risk%20reduction_%20Good%20Practice%20Review_HPN.pdf

UNEP. 2007. *Environmental and Disaster Risk: Emerging perspectives*. UNISDR.

UNEP.2015. *The Economics of Land Degradation in Africa*. ELD Initiative, Bonn, Germany. Available at www.eld-initiative.org.

UNISDR. 2005. Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters. In Extract from the final report of the World Conference on Disaster Reduction (A/CONF. 206/6) (Vol. 380).

UNISDR. 2009a. Global Assessment Report on Disaster Risk Reduction. Geneva, Switzerland: United Nations Office for Disaster Risk Reduction (UNISDR).

UNISDR. 2009b. UNISDR terminology on disaster risk reduction. United Nations, Geneva, Switzerland.

UNISDR. 2015. Global Assessment Report on Disaster Risk Reduction. *Making Development Sustainable: The Future of Disaster Risk Management*. Geneva, Switzerland: United Nations Office for Disaster Risk Reduction (UNISDR).

UNISDR. 2016. Sendai Framework for Disaster Risk Reduction - http://www.unisdr.org/we/coordinate/sendai-framework.

Urabe, J., Suzuki, T., Nishita, T. and Makino, W. 2013. Immediate ecological impacts of the 2011 Tohoku earthquake tsunami on intertidal flat communities. *PLoS One*, *8*(5), p.e62779. https:/doi.org/10.1371/journal.pone.0062779

van Wesenbeeck, B.K., Balke, T., van Eijk, P., Tonneijck, F., Siry, H.Y., Rudianto, M.E. and Winterwerp, J.C. 2015. Aquaculture induced erosion of tropical coastlines throws coastal communities back into poverty. *Ocean & Coastal Management*, *116*, pp.466-469.

https:/doi.org/10.1016/j.ocecoaman.2015.09.004

Veron, J.E.N., Devantier, L.M., Turak, E., Green, A.L., Kininmonth, S., Stafford-Smith, M. and Peterson, N., 2009. Delineating the coral triangle. *Galaxea, Journal of Coral Reef Studies*, 11(2), pp.91-100. http://dx.doi.org/10.3755/galaxea.11.91

Vincent, H., Wiersema, J., Kell, S., Fielder, H., Dobbie, S., Castañeda-Álvarez, N.P., Guarino, L., Eastwood, R., León, B. and Maxted, N. 2013. A prioritized crop wild relative inventory to help underpin global food security. *Biological Conservation*, *167*, pp.265-275.

https:/doi.org/10.1016/j.biocon.2013.08.011

Wardell-Johnson, G.W., Keppel, G. and Sander, J., 2011. Climate change impacts on the terrestrial biodiversity and carbon stocks of Oceania. *Pacific Conservation Biology*, 17(3), pp.220-240. http://dx.doi.org/10.1071/pc110220

Wehrli, A. and Dorren L. 2013. 'Protection forests: A key factor in integrated risk management in the Alps', in Renaud, F.G., Sudmeier-Rieux, K. and Estrella, M (eds.). *The Role of Ecosystems in Disaster Risk Reduction*. Tokyo: United Nations University Press, pp. 321-342.

Winsemius, H.C., Jongman, B., Veldkamp, T., Hallegatte, S., Bangalore, M. and Ward, P. 2015. *Disaster risk, climate change, and poverty: assessing the global exposure of poor people to floods and droughts*. World Bank Policy Research Working Paper, (7480).

Wisner, B., Gaillard, J.C. and Kelman, I. eds., 2012. *Handbook of hazards and disaster risk reduction and management*. Routledge.

World Bank .2010. *Natural hazards, unnatural disasters: The economics of effective prevention*. The World Bank and The United Nations.

World Bank .2010. *Report on the status of Disaster Risk Reduction in Sub Sahara Africa*. The International Bank for Reconstruction and Developmentand the World Bank.

World Risk Report. 2012. *Focus: Environmental degradation and disasters*. Alliance Development Works.

World Risk Report. 2015. *Focus: food security. United Nations University*. Alliance Development Works.

Worm, B., Barbier, E.B., Beaumont, N., Duffy, J.E., Folke, C., Halpern, B.S., Jackson, J.B., Lotze, H.K., Micheli, F., Palumbi, S.R. and Sala, E. 2006. Impacts of biodiversity loss on ocean ecosystem services. *Science*, *314*(5800), pp.787-790. http://dx.doi.org/10.1126/science.1132294

WRI. 2013. Natural Infrastructure, Investing in Forested Landscapes for Source Water Protection in the United States. Available at: https://www.wri.org/sites/default/files/wri13_report_4c_naturalinfrastructure_v2.pdf .

Zedler, J.B. 2003. Wetlands at your service: reducing impacts of agriculture at the watershed scale. *Frontiers in Ecology and the Environment*, 1(2), pp.65-72.

https:/doi.org/10.1890/1540-9295(2003)001[0065:WAYSRI]2.0.CO;2

Zhang, J., Hull, V., Xu, W., Liu, J., Ouyang, Z., Huang, J., Wang, X. and Li, R. 2011. Impact of the 2008 Wenchuan earthquake on biodiversity and giant panda habitat in Wolong Nature Reserve, China. *Ecological Research*, *26*(3), pp.523-531. https:/doi.org/10.1007/s11284-011-0809-4

Ziervogel, G., New, M., Archer van Garderen, E., Midgley, G., Taylor, A., Hamann, R., Stuart-Hill, S., Myers, J. and Warburton, M., 2014. Climate change impacts and adaptation in South Africa. *Wiley Interdisciplinary Reviews: Climate Change*, 5(5), pp.605-62

INTERNATIONAL UNION
FOR CONSERVATION OF NATURE

WORLD HEADQUARTERS
Rue Mauverney 28
1196 Gland, Switzerland
Tel: +41 22 999 0000
Fax: +41 22 999 0002
www.iucn.org