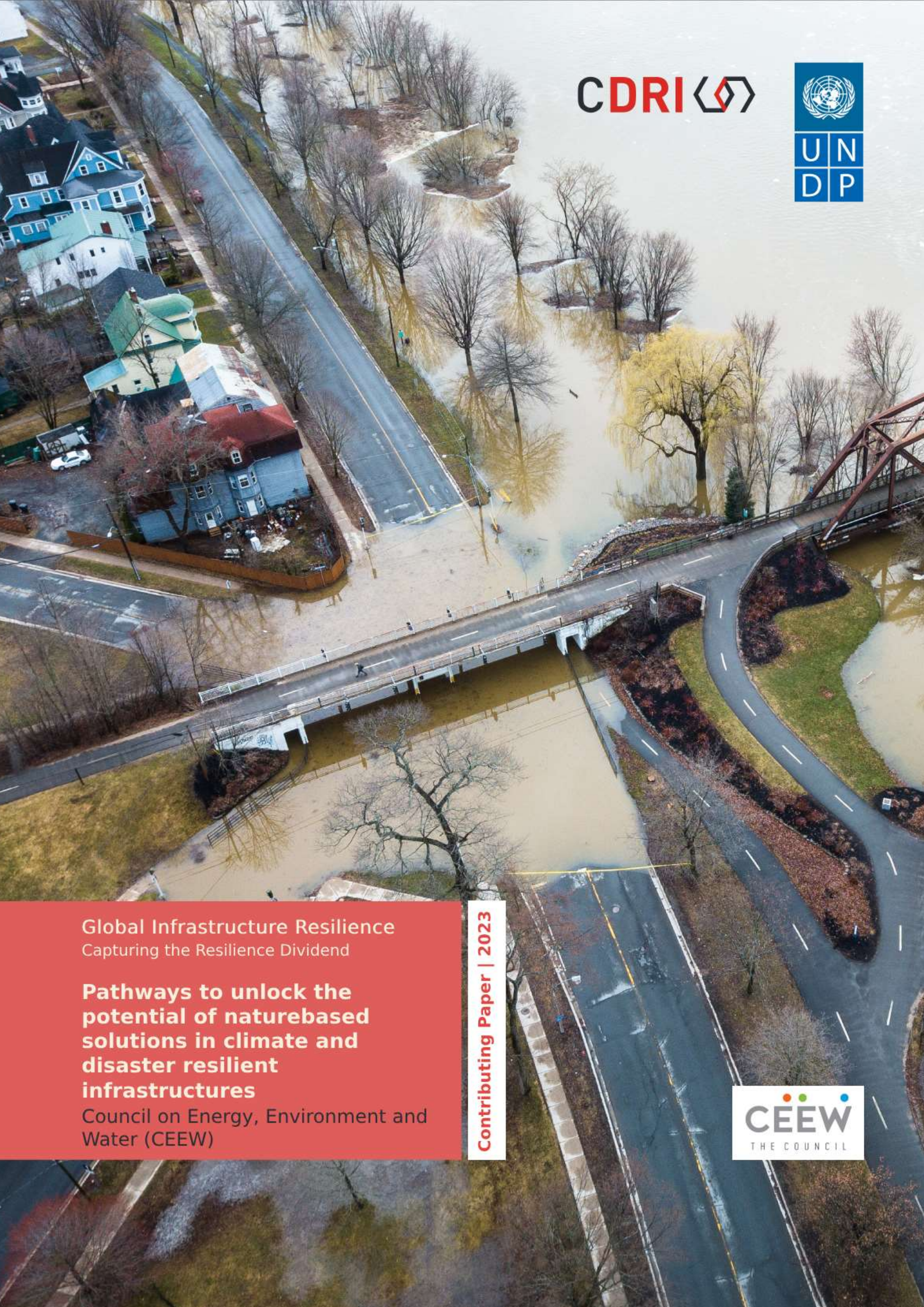

CDRI

UNDP

Global Infrastructure Resilience
Capturing the Resilience Dividend

Pathways to unlock the potential of naturebased solutions in climate and disaster resilient infrastructures

Council on Energy, Environment and Water (CEEW)

Contributing Paper | 2023

CEEW
THE COUNCIL

Pathways to unlock the potential of nature-based solutions in climate and disaster resilient infrastructures

Shreya Wadhawan and Aryan Bajpai

Council on Energy, Environment and Water

1. Introduction

The impacts of climate change are being increasingly felt across the globe. Millions of people face large-scale real-life consequences as the temperatures have risen by 1.1 degree Celsius (World Meteorological Organization (WMO), 2022). Increased temperatures, rising sea levels, and increased frequency and intensity of climate hazards have led to widescale disruptions and irreversible damages in the form of economic and non-economic losses. Approximately 30 per cent of the world's population lives in areas exposed to the impacts of extreme weather and climate events (WWAP, 2018). These impacts have been accelerated and compounded due to anthropogenic factors leading to loss of lives, livelihoods, infrastructures and economies. Yet, the actions to adapt and mitigate such risks are sparse and seldom mainstreamed.

As the impacts of climate change rise exponentially, South Asia is one of the most vulnerable regions as 750 million people have been affected by at least one natural disaster in the past two decades (WWAP, 2018). India is increasingly facing large-scale disasters and socio-economic upheaval due to extreme weather events, which puts investments in infrastructure, housing, transport and industries, as well as vulnerable communities with low adaptive capacity, at extreme risk. An analysis by the Council on Energy, Environment and Water (CEEW) suggests that 75 per cent of districts in India are extreme event hotspots, with more than 80 per cent of India's population living in districts highly vulnerable to extreme hydro-met disasters (Mohanty & Wadhawan, 2021).

In this age, when the world is facing an impending climate crisis on one end and socio-economic turmoil at the other end, the symbiotic practices of living with nature hold the potential to solve a multitude of these problems. During the latter half of the 20th century, the idea of such solutions started gaining more attention and developed a formal understanding in the international community. The International Union for Conservation of Nature (IUCN), in 2016, defined such solutions as **Nature-based solutions (NbS)** - *"Nature-based solutions are actions to protect, sustainably manage and restore natural and modified ecosystems in ways that address societal challenges effectively and adaptively, to provide both human well-being and biodiversity benefits"*. (Cohen-Shacham, Walters, Janzen, & Maginnis, 2016)

To mitigate and adapt to the impact of such extreme events, it is crucial to scale up climate action at the national and sub-national levels, however, if not applied appropriately, maladaptation can push the impacts beyond projected limits. Nature-based solutions (NbS) are increasingly being seen as the means through which long-term climate sustainability and adaptation can be achieved. Further, this paper sheds light on how NbS acts as a bouquet of solutions against a myriad of problems; the challenges in scaling and implementation of these solutions; and the need to invest in them.

1.1 Purpose and scope

Given the gambit of climate change adaptation and mitigation, nature-based solutions (NbS) offer effective, multi-faceted and targeted answers to a multitude of issues. The NbS address four key areas of climate change: i) climate change adaptation ii) climate change mitigation iii) environmental management iv) disaster risk reduction (UNDRR, 2021). While, it is well established through literature that NbS provide a wide range of solutions, their implementation and scalability for disaster risk reduction still pose a great challenge. This paper aims to identify hazard-specific interventions in the form of NbS that are available, accessible, effective, affordable, implementable and scalable.

A study finds that hydro-meteorological hazards are the largest cause of recorded economic damages due to natural disasters (OECD, 2015). An IPCC report on climate impacts emphasised how economic damage resulting from floods and cyclones, as well as slow-onset events like heatwaves would severely affect the world especially the South-Asian region (Shaw, et al., 2022). In 2019, India was hit by massive floods causing damages worth USD 10 billion, claiming 1,800 lives and displacing 1.8 million people (Sarkar, 2021). Thus, making it imperative to identify science-based empirical evidence approaches to building resilience against these hazards. NbS ensure targeted reduction of vulnerability by significantly enhancing the adaptive capacity of the region and its communities.

In spite of the thrust behind NbS, investments in the domain still lie low. Lack of empirical evidence and economic quantification adds fuel to this problem. A recent report by UNEP identified that inadequacy of data collection and systematic data analysis pose significant barriers in the implementation and scaling of NbS (United Nations Environmental Programme, 2021). This paper aims to identify hazard-specific NbS for floods, cyclones and droughts while establishing their scalability and economic viability through a robust cost-benefit analysis based on a set of indicators. Incorporating climatological deliberations into the cost-benefit analysis of NbS is crucial for long-term, disaster-resilient and climate-proof planning.

Following on this introductory note, Section 2 highlights NbS as an umbrella concept and the multitude of solutions that come under it. Section 3 identifies the gaps and establishes the challenges faced to implement NbS at scale. Section 4 focuses on the hazard-specific interventions and their targeted benefits in DRR. Section 5 undertakes an elaborate literature review to identify suitable indicators for conducting a CBA analysis of the proposed solutions to assess their scalability and viability. Finally, Section 6 concludes while emphasising on the need to scale NbS and a few recommendations or pathways to unlock the potential of nature-based solutions.

2. NbS as an umbrella concept

The concept of NbS encompasses multiple closely-related terms which are often used interchangeably, however, NbS is a broader term encapsulating such approaches. Thus, NbS acts as an umbrella concept to address the conglomerate of challenges including disaster risks, climate change, water insecurity, environmental degradation and biodiversity loss faced by our society and community today (IUCN, 2020). Further, NbS have the ability to take several different forms. They can be implemented as unique and different projects as well as can be integrated into ongoing national and sub-national strategies.

In this paper, we attempt to highlight all the possible solutions under the umbrella term of NbS considering the two larger heads i.e., Ecosystem-based approaches (EbA) and Ecosystem-based disaster risk reduction (Eco-DRR) which are also acknowledged by the IUCN and UNDRR (Cohen-Shacham, Walters, Janzen, & Maginnis, 2016; UNDRR, 2021). However, what we are trying to achieve is not novel as this has been attempted by several researchers already. According to an analysis by BiodivERsA ERA-NET[1], NbS can be understood as two different gradients of solutions:

1. The level of engineering of biodiversity and ecosystems involved in the NbS
2. The level of enhancement of ecosystem services achievable by the NbS (Eggermont, et al., 2015)

Their analysis further describes the different kinds of NbS within the matrix of the above-mentioned gradients. These include:

I. Type 1: Solutions that involve making better use of existing natural or protected ecosystems
II. Type 2: Solutions based on developing sustainable management protocols and procedures for managed or restored ecosystems
III. Type 3: Solutions that involve creating new ecosystems

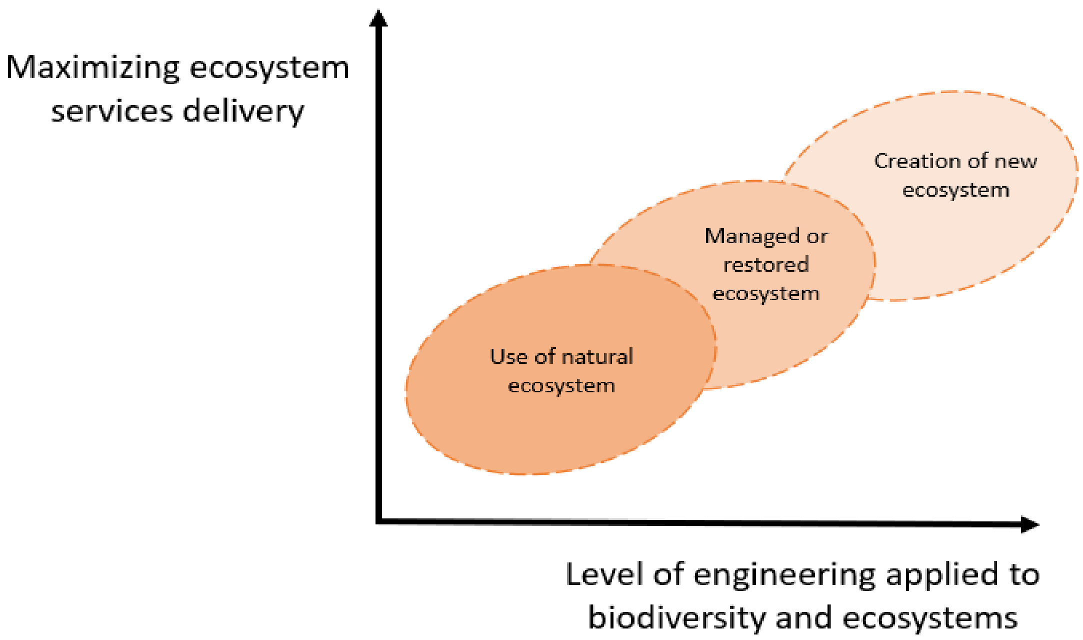

Figure 1: Different kinds of NbS based on the matrix (Authors' compilation based on (Eggermont, et al., 2015))

As mentioned earlier, a large number of solutions come under the scope of NbS. Even though the classification provided above supports identifying solutions based on two unique gradients, it remains inadequate to identify the large domain of NbS. A more defined categorization and grouping of NbS is

[1] A network of national and regional funding organizations that support pan-European research on biodiversity and ecosystem services

required not just to advocate the right solutions to the large mix of environmental and socio-economic problems but also to attract finances from relevant stakeholders who might be interested in specific categories of NbS.

Our paper builds on a thorough analysis by E. Cohen-Shacham, G. Walters and P. Lamarque of existing literature and case studies around NbS that led to the categorization of such practices into 5 unique groups with nine different approaches (Cohen-Shacham, Walters, Janzen, & Maginnis, 2016). Figure 2 provides an overview of NbS as an umbrella concept and all the approaches that fall under it.

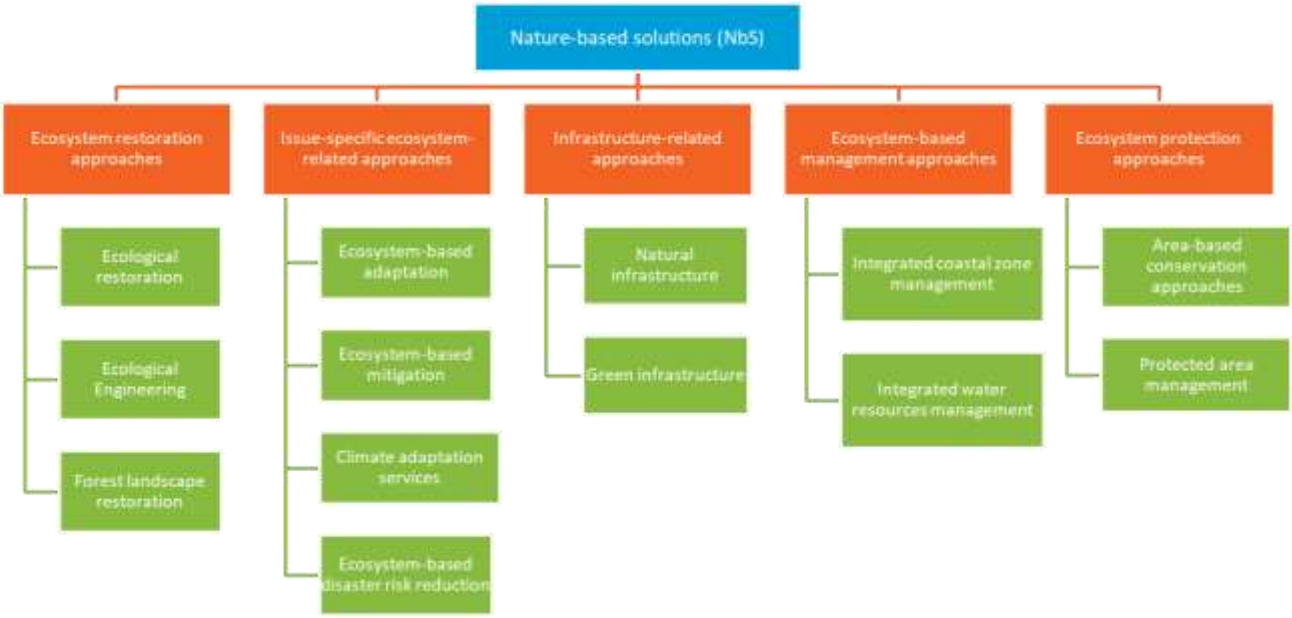

Figure 2: NbS as an Umbrella Concept (*Authors' compilation based on (Cohen-Shacham, Walters, Janzen, & Maginnis, 2016)*)

These categories represent a myriad of solutions which are observed all over the globe. It is important to note that each of these approaches have linkages with the other and are often used interchangeably. While there are more evidences of certain types of NbS (Fisher, et al., 2008; Girot, Ehrhart, & Oglethorpe, 2011), nevertheless, it is important to explore and strengthen every category of NbS to address different environmental and socio-economic issues. Some categories tend to overlap with others in terms of scope and impact but are guided by unique characteristics which are explained below:

1) Ecosystem restoration approaches

Ecosystem restoration is defined as "*the process of halting and reversing degradation, resulting in improved ecosystem services and recovered biodiversity. Ecosystem restoration encompasses a wide continuum of practices, depending on local conditions and societal choices*" (UNEP, 2021). The United Nations General Assembly has declared the decade of 2021-30 as the UN Decade of Ecosystem Restoration. Several ecosystems such as farmlands, forests, freshwater, coastlines and oceans, etc. are suffering from problems such as erosion and degradation (FAO, 2021). According to a report by Food and Agriculture Organization (FAO), approximately 420 million hectares of forest-land has been converted to other land uses since 1990s (FAO, 2020). Another report suggests that there is a 35% decline in area of natural inland wetlands since 1970 with 87% total loss since 1700 (Davidson, 2016). Ecosystem restoration is not just necessary for reducing environment degradation but also to support economy, health and food security in a post-COVID world. Ecosystem restoration could be further divided into the following categories:

i) Ecological Restoration

This term is synonymously used with ecosystem restoration. The unique difference between the two terms is that ecological restoration is specifically focused on objectives pertaining to environmental conservation and protection. The Society of Ecological Restoration defines ecological restoration as "*the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed*" (Gann, et al., 2019). One successful example of ecological restoration can be the community-based floodplain resource management of Haor Basin in Bangladesh, through revegetation and protection. This integrated approach of habitat restoration and social organisation is addressing the changing flooding patterns which impact the crops as well as the malpractice of overfishing in the region (Pisupati, 2010). Such an approach is adopted to repair habitats for humans or other organisms, revive declining populations of species, building resource pools essential for the functioning of the society, etc. (Suding, 2011)

ii) Ecological Engineering

Ecological engineering represents a more scientific approach of solving environmental problems while conserving the nature. This approach has primarily found its uses in the sphere of urban development (Mitsch & Jørgensen, 2004; Barot, Lata, & Lacroix, 2012). The term is defined as "*management of systems of human and environmental self-design or light management that joins human design and environmental self-design, so that they are mutually symbiotic*". (Odum, 1996) The examples of ecological engineering range across domains of wastewater treatment, recycling and pollution problems. Ecological engineering has also been noticed in South Asian countries in the form of green roofs observed in the cities of India such as New Delhi and Bengaluru which aim to create entire ecosystems on small areas which provide both a means of sustenance to humans and a habitat for a variety of organisms which otherwise suffer because of city pollution (Pandey, 2015). These solutions utilize the optimum technological resources which hold the potential to address severely damaged ecosystems and restore substantially disturbed ecosystems by human activities. (Mitsch, 2012)

iii) Forest landscape restoration

The forest landscape restoration approach does not necessarily refer to just the restoration of forests and related ecosystems. This approach is among the most renowned approaches and has gained focus in recent years. The Indian Government adopted forest landscape restoration as one of its mission under the National Action Plan on Climate Change (Ministry of Information and Broadcasting, Government of India, 2021). The government has also made several efforts to adopt similar efforts at the state as well as district levels. Forest Landscape Restoration is defined as "*the long-term process of regaining ecological functionality and enhancing human well-being across deforested and degraded landscapes"* (Beatty, Cox, & Kuzee, 2018). Such approaches lead to a reduction in erosion of soil and increases resilience of areas exposed to extreme weather events such as drought and flood. Several agencies have adopted these measures to increase the green space which provides benefits beyond the environmental advantages such as alternative livelihoods and recreational benefits. Another example of forest landscape restoration can be the use of Restoration Opportunities Assessment Methodology (ROAM) in Myanmar where forest landscape techniques are being used to address the challenge of deforestation in the country (IUCN, 2018).

2) Issue-specific ecosystem-related approaches

As discussed previously, climate crisis is one of the biggest challenges faced by the human race in the 21st century. Over the years, the leading body on climate change action, United Nations Framework Convention on Climate Change (UNFCCC) has categorized climate change actions into two broad categories of mitigation and adaptation. The potential of NbS has been recognized in both of these categories which has led to the formation of solutions, specifically addressing the issue of climate change.

i) Ecosystem based adaptation

Many NbS such as mangrove plantations, management of watershed vegetation, agroforestry, etc. have the ability to adapt certain ecosystems to extreme events such as drought, cyclones, floods, intense precipitation, heatwaves, etc. (Batmanian, 2022) A large number of solutions which come under this bracket are observed to create impact at a local level (Locatelli, Evans, Wardell, Andrade, & Vignola, 2011). Ecosystem-based adaptation has also been presented as an operational tool for adaption at UNFCCC and is defined as "*the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change*" (Kapos, et al., 2021). Using climate resilient crops such as millets is another example of ecosystem-based adaptation. Countries like Pakistan and India which are experiencing a shortage of groundwater, have recently incorporated millets in their agricultural policies which is not only consumes less water but also provides other benefits being a pest-resistant and heat tolerant (Bhogal, Green, Petrie, & Dixit, 2022).

ii) Ecosystem-based mitigation

NbS which cater to climate change mitigation often take the role of carbon sinks. The primary objective of such solutions is to reduce greenhouse gas emissions by sequestration of carbon from the atmosphere. The UN included identified NbS as important practices under the programme, Reducing Emissions from Deforestation and Degradation (REDD+) (UNDP: Climate and Forests Programme, 2021). Ecosystem-based mitigation has been defined as "*the enhancement of benefits and avoiding negative impacts on biodiversity from reducing emissions, while taking into account the need to ensure the full and active participation of indigenous and local communities in relevant policy-making and implementation processes*" (Convention on Biological Diversity (CBD), 2010).

Most of the existing solutions within the framework of ecosystem-based mitigation emphasize the role of forest ecosystems since they are considered as the primary carbon sinks. This practice is witnessing the addition of the new domain of restoring marine and coastal ecosystems as research indicates their potential of sequestering carbon (UNISDR/UNDP, 2012). For example, coral reef restoration projects in Sri Lanka have not only helped in sequestering carbon but has also led to the revival of population of several important species, boosting both the fisheries as well as tourism industry (Conservation in Sri Lanka, n.d.).

iii) Ecosystem-based disaster risk reduction

Though similar to ecosystem-based adaptation approach, ecosystem-based disaster reduction is solely focused on solutions which minimize impacts of disasters such as earthquakes, tsunamis, floods, cyclones, etc. Such approaches are defined as *"the sustainable management, conservation and restoration of ecosystems to provide services that reduce disaster risk by mitigating hazards and by increasing livelihood resilience*" (Pedrr, 2010).

These approaches are increasingly being linked with early warning systems as nature itself has been used for early warning since before the technological innovations we see today. Some solutions have also focused on being the areas of safety during certain disasters. For example, local communities in Bolivia use bio-indicators as a kind of local agro-meteorological service to predict extreme weather events (Loma, Quispe, & Studer, 2017).

iv) Climate adaptation services

Climate adaptation services is the broader term under which ecosystem-based adaptation resides. While the latter focuses on the importance of the ecosystem in providing services catering to adaptation, the former focuses on the benefits to humans from that ecosystem. These services are defined as "*benefits to people from the increased social ability to respond to change, provided by the capacity of ecosystems to moderate and adapt to climate change and variability*". (Lavorel, et al., 2015)

3) Infrastructure related approaches

The conventional 'grey' infrastructure not only fails to accommodate the growing environmental and socio-economic issues but is also contributing to these problems. Elements of nature can also be identified as the counterparts of the infrastructures built by humans. In other words, the roles performed by grey infrastructure are also being performed by ecosystems around the globe. One such example can be soil which acts as a habitat for millions of organisms providing both shelter and food (Campari, 2021). NbS have been found to conserve, protect and restore such natural elements. These solutions can be further categorized based on the type of natural resource they target.

i) Natural Infrastructure

The concept of designing infrastructure to address environmental and socio-economic challenges by using natural elements has been at the centre of conversation about NbS. This approach has not been limited to classify solutions but altogether create a new field of planning. Natural infrastructure is considered as a "*strategically planned and managed network of natural lands, such as forests and wetlands, working landscapes, and other open spaces that conserve or enhance ecosystem values*". (Benedict & McMahon, 2002)

It must be noted that natural infrastructure refers to the solutions which can only be implemented at the landscape level. Several solutions such as barrier islands, restoration of aquifers, managing wetlands come under the scope of natural infrastructure. India, for example, has linked the conservation and restoration of water resources to a temporary employment scheme which has led to multiple benefits of better water security and less migration, earlier occurring due to unemployment. (Bhagirath, 2021; Down to Earth, 2021)

ii) Green Infrastructure

Green infrastructure has a broader scope of application than its previous counterpart. This category includes solutions which can be implemented both at a landscape level as well as an urban level. It is looked upon as a "*strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas".* (European Commission, 2013)

Such type of approach presents the challenge of introducing completely new practices in an environment which has already been occupied the conventional infrastructure (European Environment Agency, 2015). This has led to the growth of solutions which present the possibility of incorporating green infrastructure and designs into the already existing conventional structures. A major emphasis has been given to include NbS in building green spaces within the city.

4) Ecosystem-based Management Approaches

As discussed earlier, seldom NbS develop out of already existing programs which revolve around natural resources or the communities which consume and protect such resources. Ecosystem-based management approaches presents the users with the optimum pathways to utilize the resources in a sustainable manner while addressing the current issues. They are defined as "*integrated science-based approach to the management of natural resources that aims to sustain the health, resilience and diversity of ecosystems while allowing for sustainable use by humans of the goods and services they provide*" (Garcia, Zerbi, Aliaume, Do Chi, & Lasserre, 2003). Solutions which focus on coastal zone, water resources and forest land management come under the bracket of ecosystem-based management approaches. Bangladesh, for example, has increasingly started investing in coastal zone management (World Bank, 2021) in the light of erosion and loss of large areas of land (Ahmed, Howlader, Hoque, & Pradhan, 2021; Jui, 2021).

5) Ecosystem protection approaches

Ecosystems have the unique capability to heal themselves. The pandemic saw several ecosystems revive in the light of less human interaction and other external influence. This was also highlighted by organizations such as IUCN and appreciated globally across countries (UNEP, 2019). NbS which focus on protecting ecosystems and minimizing risks from external influences belong to the category of ecosystem protection approaches. These include interventions such as defining a restricted space in the form of national parks and wildlife sanctuaries to protect an ecosystem including several species of flora and fauna. For example, certain national parks such as the Bwindi Impenetrable Forest National Park in Uganda allows local communities to collect medicinal plants from designated areas, which keep rotating periodically to ensure that the species of those plants do not get over-collected (Wild & Mutebi, 1996).

Different ecosystems have different needs, which calls for mainstreaming of ecological engineering (Ruangpan, et al., 2020). Characterising all the interventions under one bucket with similar outcomes and approaches has hindered the implementation of NbS. Further, one of the major reasons for this is dearth of evidence on the effectiveness of NbS for combating climate change and its impacts, especially when compared to other scientific approaches (Seddon, et al., 2021). A one-size-fits-all approach, impedes the process of scaling and implementing a particular NbS. On the contrary, NbS should be categorised on the basis of geography, typology, hazard-profiles, and should further be integrated into the planning and policy documents at a local level to build resilience at a regional level (Romnee & De Herde, 2015; Zhang & Chui, 2018).

3. Issues with scaling and implementation of NbS

Nature-based solutions have gained international recognition for their potential to deal with a myriad of problems ranging across various domains of society. Many nations are exploring such solutions primarily to address the challenge of the climate crisis, the ripple effects of which are already being experienced all around the globe. Even though organisations such as IUCN and UNEP have released guidelines to accelerate the adoption of NbS (IUCN, 2020; UNEP, 2021), countries and smaller organisations face several challenges. After a robust and in-depth literature review, we were able to identify a few gaps and challenges which have been recognised commonly across different users of NbS. Figure 3 provides an overview of the major gaps and challenges identified.

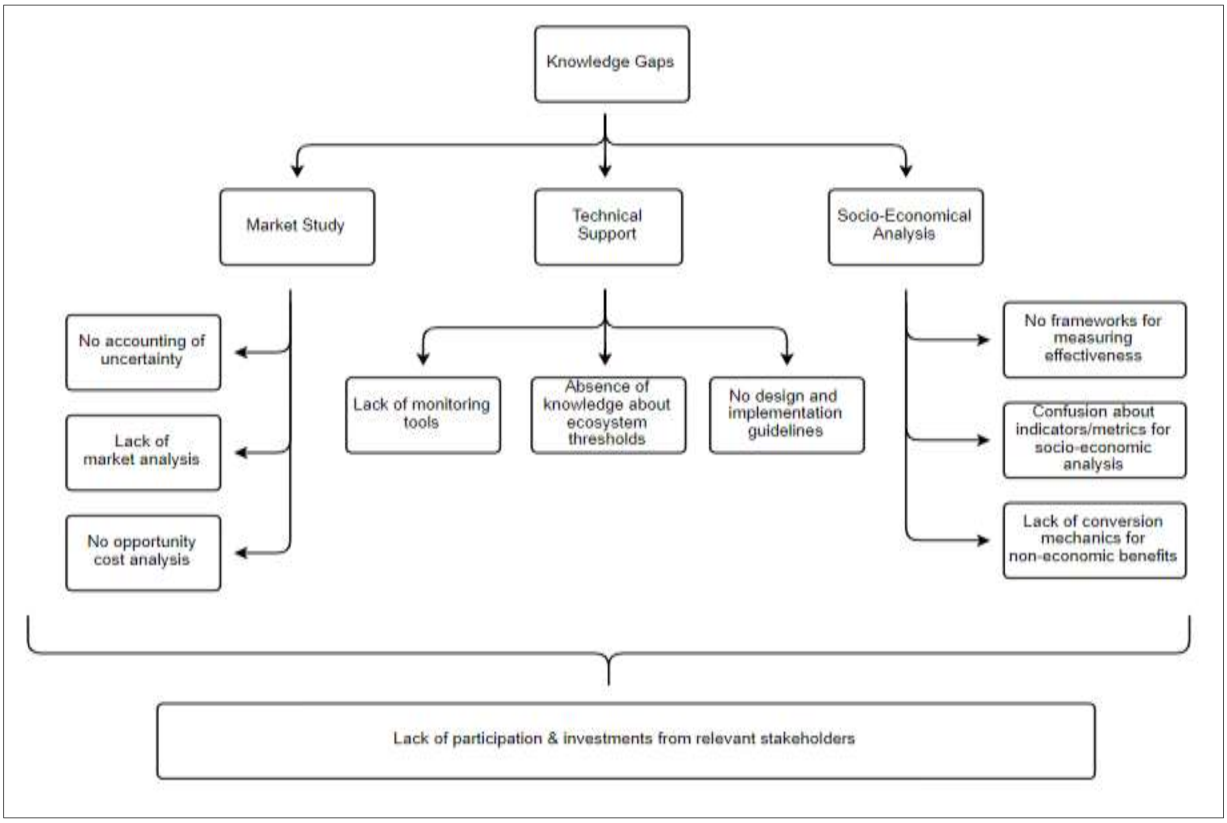

Figure 3: Major gaps and challenges identified in the NbS discourse (*Authors' compilation)*

A large number of studies, especially from the global south, mention the lack of knowledge while implementing NbS in local contexts (Kabisch, Frantzeskaki, Pauleit, & Naumann, 2016). A large number of countries depend on natural resources for their role of providing livelihoods as well as protection against extreme events. Knowledge gaps, including a lack of substantial evidence to present the effectiveness of NbS, inadequate technological resources and the absence of guidance on integrating NbS into policy; results in these countries failing to attract the necessary finances to boost such solutions and improve their economy while improving resilience to climate change-induced impacts.

South and South-East Asia is highly vulnerable to climate change-induced impacts such as cyclones, floods, and rising sea levels among others due to their geographical placement, low capacities and lack of available resources. To build their capacities through readily available resources, the government of the Philippines, for example, has integrated NbS such as mangrove plantations, coral reef restoration and watershed management approaches in their national action plan for climate change (Matthews & Cruz, 2022). A report identifies the benefits of these solutions but also points out the gaps in such projects including the absence of studies to account for the increasing number of extreme events and lack of knowledge on the role of such solutions on livelihoods (Rizvi, Baig, & Verdone, 2015). According to a report by The Internal Displacement Monitoring Centre, the South and South-East Asian region alone had around 19 million internal migrants displaced due to the climate crisis 2021 (Internal Displacement Monitoring Centre (IDMC), 2022). In such a case, it becomes pertinent for countries to identify the full potential of NbS and fill any knowledge gaps to enhance action on adopting best practices for the development of NbS.

The gaps in knowledge around NbS can be further categorized into the following domains:

A. Market Study

Investments play a key role in strengthening action in adopting suitable NbS. Both public and private players require relevant information such as the benefits produced and opportunity costs to make informed financial decisions. Certain solutions are more attractive in terms of benefits produced which may be non-economic in nature (Kopsieker, et al., 2021). Context-specific analysis is crucial in the case of NbS as mainstreaming the wrong solutions holds the risk of increased maladaptation, further deteriorating the conditions of an ecosystem (Veerkamp, et al., 2021). The gaps within market study include:

a. **No accounting of uncertainty:** It is essential for an investor to know the future potential of solutions. The current available knowledge lacks an integration of climate change projections and their impact on the NbS (Watkiss, Downing, & Dyszynski, 2010). Some solutions which are effective today might not be able to cope with the extreme climatic conditions of the future and vice versa. This makes it pertinent to understand uncertainty in the context of climate change and NbS and integrate it into future relevance of NbS, making it clearer for an investor to plan about funding a particular NbS.

b. **Lack of market analysis:** As more and more NbS are being recognized around the globe, investors might be interested in specific solutions based on factors such as investment rates, rate of return, non-economic benefits, etc. Some regions recognise traditional solutions more due to recognition and support across generations whereas other regions tend to skew more towards modern solutions having technological significance (Russo & Cirella, 2021). Such different receptions of NbS in different parts of the world makes it necessary to understand the local context and market dynamics, to understand the direction of investments (Throp, Yang, & Sherman, 2021). Several solutions might produce countless benefits but fail to even establish due to a lack of interest and investments from relevant stakeholders (WWF, 2022).

c. **No opportunity cost analysis:** This analysis holds relevance in the context of NbS which either look to establish new systems or aims to get integrated into the existing grey infrastructure (Hagedoorn, Koetse, & Beukering, 2021). Investors need to know about the costs and benefits of the other NbS or interventions to compare all the relevant information. There have been several cases where NbS with a higher opportunity cost of time were not selected even though they were creating a larger impact (Hagedoorn L., Koetse, van Beukering, & Brander, 2020).

B. Technical support

Even though NbS have been existing for a very long period of time, it is only recently that such solutions have begun to get integrated into the policies of nations and organizations. Establishing the roles of different agencies and ensuring effective communication and participation by local communities would require a defined approach to adopting NbS (Eggermont, Le Roux, Tannerfeldt, Enfedaque, & Zaunberger, 2021). Currently, the literature around NbS suggests a lack of clarity around NbS in terms of design and implementation. The technical gaps can be better addressed in the following categories:

a. **Lack of monitoring tools:** Monitoring plays an important role in any project as not only do they provide information on the different factors influencing a solution but also makes it easier for a stakeholder to check if the desired path by the NbS is on track or not (Raymond, 2017). The current knowledge, however, lacks any monitoring framework for NbS. In other words, there is no defined way to assess the performance of an NbS at different stages of its lifecycle. Moreover, a few cases have also shown the large costs involved in maintaining a monitoring system for longer periods of time (European Commission. Directorate General for Research and Innovation, 2020). Even solutions involving the community as a monitoring system have demonstrated irregularities in tracking the progress of NbS (European Commission, Directorate-General for Research and Innovation, 2021).

b. **Absence of knowledge about ecosystem thresholds:** The unique benefit of using NbS over the conventional grey infrastructure is the symbiotic relationship between humans and ecosystems. But at the same time, the degree of intervention also plays a key role in defining the progress of any NbS (White, Collier, & Stout, 2021). There have been cases where excessive intervention by humans in the form of NbS has led to undesired impacts (Gokhale, 2021). Hence, it is important to understand not just the resources but also the thresholds of an ecosystem to ensure that any NbS would not lead to reversed impacts.

c. **No design and implementation guidelines:** Several countries, especially developing nations, which have yet not explored the potential of NbS or lack the resources to do so face challenges in identifying sustainable solutions to address environmental and socio-economic problems. In the absence of any defined framework or support, these nations require longer periods of time and heavy external support in terms of finances to adopt NbS (Mulongoy & Gidda, 2008). Even though there have been incentives and support mechanisms established for developing nations around NbS (Morita & Matsumoto, 2021), these countries still find it difficult to define and integrate NbS in policies and climate change action.

C. Socio-Economical Analysis

NbS produce a variety of benefits which have been mapped extensively across the literature. The impact of NbS on both economic and non-economic benefits have been studied thoroughly with a myriad of case studies replicating similar results. Even after the presence of a large amount of literature, a common analysis has not been formulated which could be adapted to local contexts. The gaps in the socio-economic analysis can be explained further as:

a. **No frameworks for measuring effectiveness:** Most NbS solutions cater to specific needs of either the environment or humans. It is necessary to understand the degree to which an NbS has created an impact to make decisions around scaling the interventions or replicating such solutions across similar geographies. The current literature, however, indicates that there is no common framework for measuring the effectiveness of an NbS across either economic or non-economic benefits. A vast majority of the literature has attempted to calculate the economic benefits of various NbS but considers the analysis of non-economic benefits as a challenging task which requires more effort (Kuhl & Boyle, 2021; Vicarelli, Kamal, & Fernandez, 2016). Moreover, the lack of framework also prevents any comparison between different NbS since their effectiveness cannot be measured, which may vary across ecosystems (Horvathova, Duchkova, & Vackarova, 2019).

b. **Confusion about indicators/metrics for socio-economic analysis:** As mentioned previously, there is no defined framework for measuring the effectiveness of NbS. One of the primary reasons behind the absence of such a framework is the confusion revolving around indicators in terms of economic and non-economic benefits. In other words, nations and organizations do not know the exact list of factors which need to be analysed to assess the benefits. Several pieces of literature have attempted to perform economic analysis, with the most common method being the **cost-benefit analysis**, by quantifying chosen indicators and comparing them with costs (Dicks, Dellaccio, & Stenning, 2020). Such studies have seldom considered non-economic benefits. Different studies have produced unique results due to a difference in the indicators chosen for the study. This has created more confusion among stakeholders as they fail to select relevant solutions required for the targeted ecosystem.

c. **Lack of conversion mechanics for non-economic benefits:** Several ecosystems are often governed by local communities who benefit from NbS in ways which are difficult to quantify (Viti, et al., 2022). Not only the benefits experienced by communities but benefits such as climate change mitigation in terms of carbon capture are also difficult to quantify, especially in countries which are yet to establish carbon trade markets. A review of the literature shows that several studies acknowledge this difficulty but only a few attempts to incorporate them in the economic analysis of NbS (Wesenbeeck, Kok, Avila, Gwee, & Penning, 2021). This makes non-economic benefits incomparable which often leads to stakeholders, such as government agencies and investors, overlooking such benefits (Dumitru, Frantzeskaki, & Collier, 2020).

There are several more gaps identified in the literature revolving around NbS which need to be studied more thoroughly so that immediate action can be taken to address them. These gaps are interlinked and often appear together for users of NbS. For example, an inadequate socio-economic analysis along with a lack of market analysis would often lead to unstable or poor investments. Hence, the study of the gaps in NbS must also consider the interlinkages between different gaps. Creating common frameworks is a complex task given the importance of different geographies and ecosystems. In order to mainstreaming NbS, any framework must consider both economic and non-economic benefits to the highest possible extent.

The identification of gaps and potential of NbS can prevent grey solutions from causing irreversible damage to the entire ecosystem of a place. One such example is the timely intervention by Asian Development Bank (ADB) in the infrastructure projects in Nepal and Bangladesh (Matthews & Cruz, 2022). Transport projects in both of the countries would have affected several biodiversity hotspots. Interventions by ADB in the form of proposing NbS and providing context specific training with the collaboration of engineers, ecologists, wildlife experts and local communities led to alternative solutions which upheld the symbiotic relationship between human and nature.

4. NbS for DRR: Hazard-specific interventions to build resilience

Extreme weather events and natural disasters are deemed as the top two greatest risks to human wellbeing and the global economy (World Economic Forum, 2020). A report by the UN states that India suffered annual losses worth USD 87 billion due to extreme weather and climate events (WMO, 2020). Further, four out of ten world's costliest events took place in Asia, with cyclones and floods causing damages worth USD24 billion in 2021 alone (WMO, 2021). However, the impact of extreme weather and climate events is felt all over the world. Hurricane Ida, which struck the United States cost USD 65 billion in damages and led to 95 casualties (Christian Aid, 2021). The floods in Western Europe, cost USD 43 billion and claimed more than 200 lives, while floods in China cost destruction worth USD 17.5 killing 320 people and displaced over a million (Paul, 2021). As climate change and its impacts wreak havoc globally, the approaches for addressing the same still rely on hard-engineered interventions (Jones, Hole, & Zavaleta, 2012).

While several efforts have been put to collating evidence on the efficiency and effectiveness of NbS, most of the discourse is yet to be streamlined and mainstreamed. One of the key barriers to mainstreaming NbS can be attributed to the limited focus and skewed lens of looking at NbS only as region-specific or narrow ecosystem-based approaches. We do acknowledge that there is growing recognition on the flexibility and scalability of NbS (Hobbie & Grimm, 2020; Kapos, Wicander, Salvaterra, Dawkins, & Hicks, 2019), but the efforts and reviews are not systematic yet (Bonnesoeur, Locatelli, Guariguata, & Ochoa-Tocachi, 2019; Dadson, et al., 2017; Filoso, Bezerra, Weiss, & Palmer, 2017; Morris, Konlechner, Ghisalberti, & Swearer, 2018; Rowinski, Vastila, Aberle, & Jarvela, 2018). Most of the global practices are targeted at large-scale implementable solutions and oftentimes overlook the short-term interventions. This paper attempts to identify NbS that can be implemented at scale to adapt and mitigate to hydro-met disasters such as floods, cyclones, droughts and their associated events.

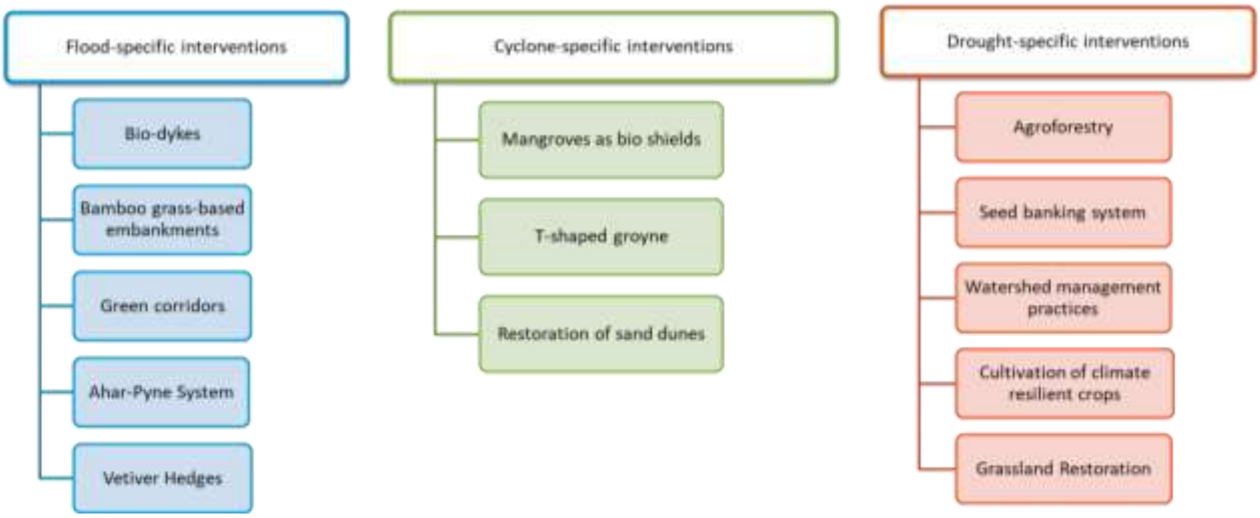

Figure 4: Hazard-specific NbS (*Authors' compilation*)

4.1 Flood-specific interventions

Floods are one of the most disastrous climate events leading to widescale and mass destruction. The immediate impacts include loss of lives and damage to communities, livelihoods, infrastructures, and economies. Further, damage to infrastructures can have long-term impacts disrupting critical services and supply chains bringing the economy to a standstill. Floods are also a leading cause of the spread of vector-borne diseases, loss of crop lands and the death of livestock. An analysis by CEEW suggests that more than 97.5 million people are exposed to extreme flood events as per Census 2011 (Mohanty, 2020). Furthermore, 8 million hectares of land are impacted by floods annually, while 40 million hectares of land are exposed to floods (Ray, et al., 2019). Warming oceans add to a surge in atmospheric moisture, causing extreme rainfall events and hence increasing the frequency and intensity of floods in recent decades. CEEW's analysis also finds that there has been a surge in extreme flood events in recent decades, leading to the loss of lives and livelihoods (Mohanty & Wadhawan, 2021).

NbS can play a fundamental role in flood management and flood risk reduction. However, flood mitigation measures are biased towards grey infrastructures as the benefits and costs are easy to quantify, and their protective capacity can be easily measured. This represents a missed opportunity as grey infrastructures are costlier, highly energy intensive and lack the ability to provide multiple co-benefits, unlike NbS or natural infrastructures that are cost effective, conserve energy and offer a myriad of adaptation and mitigation co-benefits (e.g., biodiversity protection, carbon sequestration, and recreational opportunities) (Lallemant, et al., 2021). Additionally, insufficient knowledge and lack of empirical evidence further derails the agenda of mainstreaming NbS for risk management. This paper, attempts to highlight and quantify these benefits and the ability of several NbS to reduce the impacts of extreme flood events while saving ecosystems, biodiversity, lives and livelihoods. Table 1 below represents numerous such interventions and highlights the multitude of benefits targeted at flood risk management in India and South-Asia region.

S.No.	Name of intervention	Place/Geography of implementation	Co-Benefits	Literature/Case Study
1	Bio-dykes	Bangalipur, Nepal	Control of flood water movement Reduce soil erosion Cheaper alternative to existing grey infrastructure	(Khadka, 2018) (Practical Action, 2018) (Ward, et al., 2017)

			Creation of new habitats, thus improving biodiversity	
2	Bamboo-grass based embankment	Bangladesh and Nepal	Control river bank erosion Livelihood generation	(Sinha & Bimson, 2021)
3	Green Corridors	Bangkok	Reduction in the risk of urban floods	(Jongman, Tiffer, & Wang, 2022)
4	Living root bridges	Meghalaya, India	Reduce the risks of stormwaters and river flooding Unique ecosystems which act as a habitat for several species	(Chaudhari, Bhattacharyya, & Samal, 2016)
5	Vetiver Hedges	Several countries in South and South-East Asia	Increase crop production Protection against soil erosion	(Gilon, 2021)
6	Ahar-Pyne System	Bihar, India (flood prone area)	Flood-water management systems; Maintain groundwater levels in off-seasons	(Vyas, 2020)
7	Dong Bandh System	Assam, India (flood prone area)	Management of river water; Prevents flooding of crop fields	(Murti & Buyck, 2014)

Table 1: Flood-specific nature-based interventions (*Authors' compilation)*

The interventions summarised in table 1 describe targeted solutions that can be implemented and scaled geographically to adapt to and mitigate the impacts of floods including fluvial, riverine, urban flooding and their compounding flood impacts like surface run-off and soil erosion (Forfang, 2021). Such solutions not only help mitigate the impacts of floods but also support in building resilience, restoring soil quality and reducing the loss of crop lands. Further, a study finds that over USD 50 billion worth damages against extreme flood events could have been saved in the past 20 years by investing in NbS. The study also states that every USD 1 invested in wetland and ridge restoration have been found to save USD 7 in avoided damages and more than 45 per cent of the climate risk (Leudke, 2019). Thus, making it imperative to invest in such solutions and scaling them across boundaries and geographies.

4.2 Cyclone-specific interventions

Each year the impacts of tropical cyclones around the globe lead to multiple casualties and cause significant damage to infrastructures and economies, with adverse outcomes for communities and societies. Cyclones are generally an hourly affair however, the scale of devastation is aggravated by the associated events such as heavy rainfall, storm surges, hailstorms, floods, and cold waves (Mohanty & Wadhawan, 2022). An analysis by CEEW states that a four-fold increase in extreme cyclone events is witnessed across the Indian states (Mohanty, 2020). WHO states that storms have affected over 726 million people from 1998-2017 (World Health Organization (WHO), n.d.). Further, another study finds that between 1980-2009 there have been more than 4 million deaths due to cyclones in the LDCs of Southeast Asia and the Western Pacific (Doocy, Dick, Amy Daniels, & Kirsch, 2013). Cyclones have adversely impacted the world population the past quarter of a century, however a greater cause of concern is the escalating future vulnerability to cyclones due to factors such as urbanisation, population growth, increasing coastal settlement, and global warming.

A study claims that nature-based solutions are most effective against small storms, however, because of their frequency these are the largest contributors to overall flood impacts. There are multiple widely accepted solutions under consideration for cyclone risk mitigation, however, mangroves are the most used cyclone mitigating NbS and are implemented and scaled widely across various landscapes especially in the South-Eastern countries. A study finds that mangroves have the capacity to mitigate over 90 per cent of risks by restricting tidal flows (Sandilyan & Kandasamy, 2015). Table 2 further enumerates on the various applications and benefits mangroves and other interventions targeted at cyclone risk management in India and South-Asia region.

S.No.	Name of intervention	Place/Geography of implementation	Co-Benefits	Literature/Case Study
1	Mangrove Plantation	Several countries of South and South-East Asia (Inter-tidal zones; coastal areas)	Livelihood generation; Unique ecosystems	(Kusmana & Sukristijiono, 2016) (Menendez,

			which act as habitats for several species; Protection against damage from high tides High capacity for carbon sequestration	2020) (Spalding, McIvor, Tonneijck, & van Eijk, 2014) (Alongi, 2012)
2	T-shaped groyne	Bangkok	Protection against high tidal waves; Reduction of soil erosion	(Wancharoen, 2014)

Table 2: Cyclone-specific nature-based interventions (*Authors' compilation)*

As highlighted in Table 2, NbS not only have targeted mitigation and adaptation benefits but provide a plethora of additional services that help build resilience at scale. Granular cyclonic risk assessment comprising of inundation levels and targeted implementation of NbS can help in strategising and deriving hyper-local developmental action plans for preparedness and mitigation (Mohanty, Adapting to a Changing Climate Through Nature-Based Solutions, 2022). Further, USD 8.1 trillion investment in nature is required over the next three decades to successfully tackle the climate, biodiversity, and land degradation crises (UNEP & WEF, 2021). Making it crucial to scale investments across multiple solutions to reap sustainable benefits in the long-term.

4.3 Drought-specific interventions

Droughts are defined as "an extended period of unusually low precipitation that produces a shortage of water, and operationally, it is defined as the degree of precipitation reduction that constitutes a drought, that varies by locality, climate and environmental sector" (Below, Grover-Kopec, & Dilley, 2007). There are primarily three kinds of droughts i) meteorological drought ii) hydrological drought iii) agricultural droughts. Drought has been identified as the single greatest culprit of agricultural production loss causing over 34 percent of production loss in LDCs and LMICs leading to a whopping cost of USD 37 billion to the overall sector (FAO, 2020). The land-surface changes have triggered extreme droughts in recent decades (Mohanty & Wadhawan, 2022). The recent spurt in drought events is triggered by changes in precipitation levels, land-use land cover changes, and further intensified by urban heat island effect.

Investing in NbS especially in water conservation and watershed management practices are documented to majorly reduce the impacts of extreme drought events. A case study from Ethiopia states that through local investments in NbS "average crop production tripled, and the number of households relying on aid during droughts fell from 90% in 2002 to 10% in 2012" (Chatterton, Denier, Scherr, & Stam, 2015). Table 3 further sheds light on such solutions targeted at drought risk management in India and South-Asia region.

S.No.	Name of intervention	Place/Geography of implementation	Co-Benefits	Literature/Case Study
1	Agro-forestry	Several countries in South and South-East Asia	Reduction of soil erosion; Preservation of groundwater; Improving nutrient in soil	(Kumar & Singh, 2020)
2	Cultivation of Millets	South Asian countries like India and Pakistan	Climate-resilient crops, hence ensure food security; Improve soil quality and production	(Bandyopadhyay, Muthamilarasan, & Prasad, 2017)
3	Grassland Restoration	Several countries in South Asia	Reduce soil erosion; Tackle desertification	(Perinchery, 2021)
4	Integrated Watershed Management	Several countries in South Asia	Preserve groundwater in rainfed areas; Improve soil quality	(Wani, Sreedevi, Reddy, Venkateshvarlu, & Prasad, 2008) (Sharma, Samra, Scott, & Wani, 2005) (Jain, Sewak, & McGahey)

5	Seed Banking	Andhra Pradesh, India	Preserve seed variety lost to extreme events; Climate resilient crops, hence ensure food security; Improve soil quality and production	(Pisupati, 2010)
6	Karez Irrigation System	Pakistan and China	Preserve groundwater during dry seasons	(UNESCO, n.d.)

Table 3: Drought-specific nature-based interventions (*Authors' compilation)*

NbS including watershed management practices and catchment restoration call for harmony between ecosystems and landscapes to address the societal and communal challenges due to droughts (Holden, et al., 2022). Drought is a a weather and climate extreme that cannot be ignored but requires targeted interventions for better preparedness to: (i) be cope with the impacts of drought; (ii) developing resilient ecosystems; and (iii) improving resilience for faster and enhanced recovery (Solh & van Ginkel, 2014). The interventions mentioned in table 3 will enable the administrative systems and communities to better prepare for the onset of a drought and not only surviving but adapting to the severe impacts of droughts.

5. Comparison of benefits vis-à-vis costs – cost-benefit analysis (CBA)

The push for NBS in both international and national policies has seen growth in recent years (Subramanian, 2020), but as identified in the last section, funding from the relevant stakeholders has been a big challenge (Wood, 2022). One of the primary challenges behind this is the lack of understanding of measuring the effectiveness of an NbS with respect to the different kinds of environmental and socio-economic impacts (Kopsieker, et al., 2021). The Adaptation Gap report released by UNEP identified the lack of data collection on NbS as the potential reason behind the absence of any defined framework for calculating the effectiveness of NbS (United Nations Environmental Programme, 2021).

The effectiveness of NbS is calculated based on the positive economic and non-economic impacts which are experienced during the lifetime of the specific solution. Since both of these impacts are measured in different units, hence it becomes difficult to compare the two kinds of impacts. For example, two of the multiple benefits of millet farming is the resilient nature of crop to droughts and rising temperatures and the increase in livelihoods of a farmer (Bandyopadhyay, Muthamilarasan, & Prasad, 2017). Both of these outcomes, even though co-related, are measured in different terms and may have separate weights of influence based on the context of the ecosystem and the farmer. In such a scenario, without the presence of a defined framework for comparing benefits and conversion guidelines, it is not possible to understand the differentiated impacts and benefits of the NbS. The economic and non-economic impacts can be converted into monetary terms through either direct or indirect methods (Horvathova, Duchkova, & Vackarova, 2019). The various kinds of analyses within these methods could be categorized as follows:

Methods	Revealed Preference Methods	Stated Preference Methods
Direct Methods	Market Price Method	Contingent Valuation
Indirect Methods	• Cost Based Method (which further includes damage cost avoidance, replacement cost, and substitute cost methods) • Production function • Travel cost method	Choice Modelling

Table 4: Benefit valuation methods (as provided by (Horvathova, Duchkova, & Vackarova, 2019))

There are a few other methods as well such as benefit transfer methods which include value-transfer, transfer by function, met-analysis, etc. which can also be used to derive monetary value of non-economic benefits but the evidence of these methods being used in literature remains less. These methods not only support in deriving the precise economic values of a particular solution but also assist in converting non-economic impacts to monetary terms for easy comparison. Once the impacts are converted into comparable terms, several analysis tools can be used to derive the effectiveness of NbS. These tools include Cost Benefit Analysis (CBA), Cost-Effectiveness, Multi-Criteria Analysis and Participatory CBA. Upon a thorough review of multiple pieces of literature concerned with the economic analysis of NbS, it was found that the most commonly used tool is CBA (Vicarelli, Kamal, & Fernandez, 2016). Although CBA is the most applied tool, several studies limit the scope of the analysis due to two key reasons - the absence of data and lack of preliminary understanding of the NbS. Another common observation was the use of different lists of indicators to conduct the CBA. This was observed even in the cases where ecosystems and socio-economic profiles were similar. No common or unified pattern has been noted in the process of identifying the indicators. This indicates that neither a unified framework nor guidelines exist for identifying indicators in practice for conducting a CBA for NbS.

However, there have been several proposals for a framework which can be used to identify and measure multiple benefits produced by a NbS. A report by EKLIPSE identifies different categories of impacts and then further proposes indicators and actions which could be considered for an effective CBA (Raymond, 2017). Similarly, a handbook prepared by the European Commission also proposed an elaborate framework to compare the different benefits of NbS by listing out a series of indicators, categorized into different branches. Similarly, UNDP and other research institutes also propose or consider frameworks but as mentioned above (Kuhl & Boyle, 2021), there is no defined or accepted methodology to which countries or organizations could refer which makes it difficult to conduct a fair CBA. Organizations often refer to only a few indicators which prevents investors from analysing the impacts of the NbS, thus making it harder to build financial decisions.

The aim of this study is to propose a distinct list of indicators for NbS, based on an in-depth review of literature, which can be used for a cost-benefit analysis. In other words, the list of indicators can be used to achieve a conclusive result by conducting CBA, which would not only remain consistent but will also provide the overall understanding of the different impacts of an NbS. The indicators and their categorisation provided in this chapter could further be used to develop a framework which can bridge the gap between data on NbS and investment for NbS. The next section focuses on and summarises the methodology followed for selecting the indicators to be considered for conducting a CBA for NbS.

5.1 Methodology

The benefits produced by each NbS can be measured differently based on factors such as geography, scale of implementation, type of stakeholders involved, etc. In such a scenario, it is not advisable to propose one defined list of indicators to measure each NbS. Moreover, based on the party implementing the solution, the objective of using a NbS may be different. For example, the main purpose of mangrove plantation could be to increase livelihood opportunities in one region and to respond to storm damage due to cyclones in another region. Hence, the focus has been shifted to the categorisation of benefits which can further contain different indicators based on 'local factors of influence'[2]. Some of these factors include social dynamics, political will, geography of the region, scale of implementation, etc.

The first step taken towards identifying an extensive list of indicators was to understand the wide range of benefits produced by the NbS. The benefits were further categorised into specific categories for simpler classification and understanding of investors, local communities and other relevant stakeholders. Through an in-depth review of literature, different indicators were identified within each benefit. The list of indicators provided within

[2] Local factors of influence refer to the set of factors which define the context of the region where the NbS is being implemented. These factors could be socio-economic, political and even geographical in nature.

each benefit represent only a small fraction of the large pool of indicators which could be considered based on the local factors of influence.

The list of indicators selected was further classified into a separate category based on their ability to be converted into monetary terms for the purpose of conducting a cost-benefit analysis. It is important to note that local factors of influence play a crucial role here as well. For example, carbon sequestration could be economic in regions such as EU which have established a carbon market and subsequently a price on the amount of carbon stored. On the other hand, other regions which do not possess such a mechanism currently, might prefer considering the same in the category of non-economic indicator. Table 5 below presents a robust list of indicators that should be considered while conducting a thorough cost-benefit analysis before application of a certain NbS intervention.

Category	Benefit	Indicator(s)
Climate Change	Mitigation efforts	Total carbon removed or stored in vegetation and soil (Davies, Edmondson, Heinemeyer, Leake, & Gaston, 2011); (Demuzere, et al., 2014); (Baro, et al., 2014)
		Soil carbon content (Keenor, et al., 2021)
		Surface area of restored/created wetlands (Ramachandra & Rajinikanth, 2004)
		Allometric forest models of carbon sequestration (Giannico, et al., 2016)
		Comparison with calculations of carbon consumption of equivalent non-NbS actions (Faber, Margin, & Sick, 2021)
	Disaster resilience	Mean annual direct and indirect losses due to natural and climate hazards
		Agricultural and industrial buildings potentially exposed to risks
		Transportation infrastructure and lifelines vulnerable to risks
		Flood hazard (Akter, Brouwer, Luke Brander, & Haque, 2009); (Hu, Wang, Liu, Gong, & Kantz, 2021)
		Shoreline characteristics and erosion protection
	Temperature regulation	Decrease in mean or peak daytime local temperatures (Lee, Villaruel, & Gaspar, 2016)
		Monthly mean maximum and minimum temperature (Burke, Hsiang, & Miguel, 2015)
		Urban Heat Island (Miner, Taylor, Jones, & Phelan, 2016); (Johnson, See, Oswald, Prokop, & Krisztin, 2020)
		Thermal comfort score (Raimundo & Oliveira, 2021); (Lingua, et al., 2020)
	Benefits to the public	Energy and carbon savings (Jin & Kim, 2019); (IEA, 2019)
		Number of students benefiting from education and research about coastal resilience/amenity (Piwowarczyk, Kronenberg, & Dereniowska, 2013); (Shuster & Doerr, 2015)
		Avoided damage costs (Gedan, Kirwan, Wolanski, Barbier, & Silliman, 2011); (Narayan, et al., 2016); (IPCC, 2007)
	Benefits to the biodiversity	Estimates of species, individuals and habitat distribution (Bell, 1997); (Yepsen, Moody, & Schuster, 2016); (Diagne, et al., 2021); (Lewis, Kling, Dundas, & Lew, 2022)

		Algal bloom (Smith, Bass, Sawyer, Depew, & Watson, 2019)
Water Management	Quality of drinking water	Metal concentration or load (He, et al., 2014)
		Water quality: total faecal coliform bacteria content of NbS effluents
		Calculated drinking water provision (WHO, 2012); (UN, 2021)
	Improved disaster resilience	Rate of evapotranspiration
		Flood excess volume (Akter, Brouwer, Luke Brander, & Haque, 2009); (Hu, Wang, Liu, Gong, & Kantz, 2021)
		Flood peak reduction (Akter, Brouwer, Luke Brander, & Haque, 2009); (Hu, Wang, Liu, Gong, & Kantz, 2021)
	Quality of Groundwater	Chemical status of groundwater (Tiwari, Singh, Singh, & Maio, 2016)
		Quantitative status of groundwater (Feyen & Gorelick, 2004)
		Aquifer surface ratio with excessive metallic content (arsenic, nitrate, lead, etc.) (Raymond, et al., 2017)
	Water for Agriculture	Water dependency for food production (D'Odorico, et al., 2020)
		Rainwater or greywater use for irrigation purposes (Al-Karablieh, et al., 2012)
Green Space Management	Infrastructure	Effective green infrastructure at urban-rural interface (Victoria Institute of Strategic Economic Studies (VISES), 2015)
		Percentage of green infrastructure integrated into existing structures (Green-Gray Community of Practice, 2020)
		Frequency of use of green and blue spaces (Kabisch & Haase, 2014)
	Green cover	Distribution of public green space – total surface or per capita (Dumenu, 2013)
		Total vegetation cover (Cohen, Baudoin, Palibrk, Persyn, & Rhein, 2012)
		Annual trend in vegetation cover in urban green infrastructure (Krasny, Lundholm, & Kobori, 2013)
		Green space accessibility (Tamosiunas, et al., 2014)
		Diversity of green space (D'Amato, et al., 2017); (Johnson, et al., 2021)
	Benefits to climate and environment	Soil organic matter content (Keenor, et al., 2021)
		Tree biomass stock change (Ramachandra & Rajinikanth, 2004)
		Land use change and green space configuration (Hertel, 2018)
		Percentage of waste averted from going into landfills (European Comission, 2000); (DEFRA, 2011)
	Benefits to the public	Recreational opportunities provided by green infrastructure (Kabisch & Haase, 2014)
		Food production in urban allotments and NbS (Grafius, et al., 2020)
		Sustainable transportation modes allowed (Badassa, Sun, & Qiao, 2020)
		Community garden area (Kabisch & Haase, 2014)
Biodiversity Enhancement	Population of species of flora and fauna	Number of native species(Bell, 1997); (Yepsen, Moody, & Schuster, 2016); (Diagne, et al., 2021); (Lewis, Kling, Dundas, & Lew, 2022)
		Number of invasive alien species
		Animal species potentially at risk
		Number of conservation priority species

	Habitat restoration	Proportion of protected areas (Task Force on Economic Benefits of Protected Areas of the World Commission on Protected Areas (WCPA) of IUCN, 1998)
		Derelict land reclaimed for NbS (Mathey, Banse, Lehmann, & Brauer, 2015)
		Percentage of contaminated area reclaimed (Goddard, Dougill, & Benton, 2010)
		Percentage reclaimed from existing buildings (Setiawan, Zhang, Corder, & Matsubae, 2021)
	Quality of Natural Resources	Soil and Water Quality within habitats (He, et al., 2014)
		Food web stability (European Commission, 2021)
		Quantity of blue-green space (Kabisch & Haase, 2014)
		Ecosystem disservices (increase in number of mosquitoes, plants emitting allergic pollen) (European Commission, 2021)
	Functional richness	Diversity of functional groups (European Commission, 2021)
		Pollinator species presence (Gallai, et al., 2016); (Hanley, Breeze, Ellis, & Goulson, 2014)
		Abundance of ecotones
Air Quality	Reduction in pollutants	Total particulate matter removed by NbS vegetation (Baro, et al., 2014); (Bealey, et al., 2007); (Bottalico, et al., 2016); (World Bank, 2022)
		Trends in emissions of NOx and SOx
		Concentration of particulate matter and other gases in ambient air (Grote, et al., 2017); (Tallis, Taylor, Sinnett, & Freer-Smith, 2011); (Dechezleprêtre, Rivers, & Stadler, 2020)
		Number of days during which ambient air pollution concentrations in the proximity of the NbS exceeded threshold values during the preceding 12 months (Raymond, et al., 2017)
	Reduction in emission	Total carbon removed or stored in vegetation and soil (Davies, Edmondson, Heinemeyer, Leake, & Gaston, 2011); (Demuzere, et al., 2014); (Baro, et al., 2014)
		Amount of carbon produced through NbS in comparison to other solutions
	Benefits to the public	Premature deaths and hospital admissions averted per year (Tiwary, et al., 2009)
		Mortality due to poor air quality (WHO, n.d.)
		Avoided costs for air pollution control measures (Manes, et al., 2016)
		Reduction in the number of people with respiratory diseases
Public Health and Wellbeing	Positive health impacts	Self-reported mental health and wellbeing (Roe, et al., 2013); (Knapp & Wong, 2020); (Layard, 2016)
		Observed physical activity within NbS (Anokye, Pokhrel, & Fox-Rushby, 2014)
		General wellbeing and happiness (Boadu, 2018)
		Connectedness to nature and social interaction (Manski, 2000)
		Improvement in nutritional content of products obtained from NbS measures (Fattore, et al., 2021); (Wun, Levin, Kemp, & Bushnell, 2020)
	Detrimental effects of not applying NbS	Mortality due to poor air quality (WHO, n.d.)
		Exposure to noise pollution (Swinburn, Hammer, & Neitzel, 2015)
		Hospital admissions due to high temperature during extreme heat events (Garcia-Leon, et al., 2021)

		Level of chronic stress (Roe, et al., 2013); (Knapp & Wong, 2020); (Layard, 2016)
	Improvement in the immunity of children	Cognitive and social development in children (Amoly, et al., 2014); (Grosse & Zhou, 2021)
		Exploratory behaviour in children (Amoly, et al., 2014)
		Reduced percentage of obese people and children (Tremmel, Gerdtham, Nilsson, & Saha, 2017)
		Infant mortality rate
	Reduction in diseases	Reduction in the number of people with respiratory diseases (WHO, n.d.)
		Reduced number of cardiovascular morbidity and mortality events (Tamosiunas, et al., 2014)
		Reduced autoimmune diseases and allergies (Kuo, 2015)
Potential Economic Opportunities and Green Jobs	Employment	Number of new jobs created (Saraev, 2012)
		Number of new jobs related to NbS construction and maintenance (Rizvi, Baig, & Verdone, 2015)
		New businesses attracted and additional business rates (Eftec, 2013)
		Net additional jobs in the green sector enabled by NBS projects (Saraev, 2012); (Tyler, Warnock, Provins, & Lanz, 2013)
	Improvement in economy	Mean land and/or property value in proximity to green space (Eftec, 2013)
		Retail and commercial activity in proximity to green space
		GVA to local economy from new business creation (Rizvi, Baig, & Verdone, 2015)
		Private finance attracted to the NbS site / private investment in the bio-economy
	Individual economic growth	Average land productivity and profitability (Rizvi, Baig, & Verdone, 2015)
		Increase in income (Rizvi, Baig, & Verdone, 2015)
		Individual earnings uplift arising from skills enhancement in the design and implementation of NBS (Falxa-Raymond, Svednsen, & Campbell, 2013)
		Gross value added per employees based on full-time equivalent jobs in the green sector (Tyler, Warnock, Provins, & Lanz, 2013)
Key: Green – Economic/Quantifiable; Orange – Non-economic/Non-quantifiable		

Table 5: Category-wise list of indicators for conducting a CBA (*Authors' analysis)*

After collecting a list of benefits produced by NbS, it was realized that these benefits could be further categorized into distinctive categories. These categories do not only resemble a larger global issue but are also considered major areas where action is required. Consequently, they also resemble broader heads which attract attention from various stakeholders such as investors and governments. Thus, the categories identified fit into the broader targeted actions and benefits provided by NbS.

Both the benefits and indicators can increase, decrease, or further categorised based on the objectives and benefits desired from the NbS. Further, the indicators mentioned could have multiple metrics of measurement. Therefore, the economic category only considers the potential of the indicator to be converted into economic terms (for the purpose of comparison) and not the potential of the metric for the indicator. Indicator must have the potential to be economically measured/compared but the metric may or may not be economic. However, as mentioned earlier as well, the economic category might change based on region and other socio-economic and technological factors. Moreover, it is essential to note that this study is strictly not promoting the use of specific indicators only because they can be converted into economic terms. Considering and understanding non-economic indicators while selecting NbS is as important as analysing economic indicators.

This study focuses only on identification of indicators necessary for conducting a CBA. Due to lack of availability of data, no common framework on CBA and ambiguity amongst the various approaches one could adopt for a CBA, conducting a thorough CBA is beyond the scope of this study. Since, selection of appropriate indicators is crucial for carrying out an accurate CBA, it is helpful to analyse the lessons learnt from the available literature, including gaps and challenges, and topics untouched to provide context for any future discussions and negotiations on establishing a common framework to evaluate the benefits from NbS.

6. Conclusion and way forward: Pathways to unlock the potential of nature-based solutions

The manuscript explicitly enumerates on the effectiveness, efficacy and benefits of NbS primarily through the premise of EbA and Eco-DRR. There is no denying that the climate is changing-changing fast, any further delay will etch all developmental trajectories. As the chapter pans out, the thrust of mainstreaming NbS through piloting and scaling some of the NbS can climate-proof communities, economic sectors and infrastructures. Enumerated are some recommendations that can help in implementing NbS and bring it from the margins to the mainstream.

6.1 Implementing NbS-at-scale through system innovation: System innovation entails policy coherence on NbS that recognised and integrated NbS in climate and disaster policies, plans and schemes like NDMA acts, NAPCCs, SAPCCs, so on and so forth. System innovation can bring policy coherence and integrate socio-economic, developmental environmental governance unification. Furthermore, such innovations can address the sustainable development indices and can enhance regional cooperation at an implementation level. However, it is significant to comprehend that cost of inaction due to lack of system innovation can limit resilience agenda by inequitable natural resource allocation and halting the adaptation modules as committed in NDCs. System innovations will lead to harmonising fiscal allocations for financing NbS.

6.2 Financing NbS: Countries need to include nature-based infrastructure like wetlands, mangroves, forest ecosystems, and some highlighted and targeted bioengineering interventions like bio-dykes, anti-sand dunes, among others, under the ambit of critical risk-mitigating infrastructure. Built-in infrastructure like buildings, roadways network systems, electric systems, dams, and bridges are currently considered under critical infrastructure's standard definition and practice. Broadening the definition of infrastructure to include natural ecosystems and nature-based solutions offers an opportunity to deploy and enhance nature-based solutions (NbS) to produce sustainable and climate-resilient responses. Restoring, rebuilding and investing in nature-based solutions can make our cities and villages more climate-resilient and alter the adverse impacts of climate change.

6.3 Establishing a NbS task force: Mainstreaming and promoting climate responsive NbS through a constitutionally mandated body can create means and ways to mainstream and implement NbS-at-scale. Through NbS we can adopt a proactive risk mitigation strategy empowered to analyse and identify the cost and benefits of environmental and socio-economic benefits of NbS interlinked with granular risk assessments. Currently, climate action plans do not consider NbS during the design or implementation phase and hence an NbS task force can be pivotal in bridging these gaps.

6.4 Developing a unified framework for evaluating NbS: A common assessment framework to evaluate the economic and non-economic benefits of NbS is the need-of-the-hour. It is necessary to develop a detailed and comprehensive assessment and evaluation framework to shed light on the many benefits provided by NbS. This will further enhance interest in their mainstreaming and also help nudge financial flows to its implementation. There is a need for consistent economic evaluation in the national and global databases to understand progress made and to identify the most implementable and scalable solutions. The common measurement will help us not only quantify progress towards SDGs, but also monitor the larger environmental changes that govern the capacities of nations to reduce risk.

As policymakers fund improvements to the nation's infrastructure, natural systems and solutions, referred to as nature-based solutions, should also be considered critical infrastructure. These recommendations will help formulate strategies to climate-proof population, economies, and infrastructure by integrating, implementing and scaling NbS. If the impacts of a 1.5°C warmer future are irreversible adequate adaptation led actions through NbS can halt the scale and impact of climate extremities shaping the resilience trajectory for many vulnerable countries.

References

Ahmed, N., Howlader, N., Hoque, M. A.-A., & Pradhan, B. (2021). Coastal erosion vulnerability assessment along the eastern coast of Bangladesh using geospatial techniques. *Ocean and Coastal Management*.

Akter, S., Brouwer, R., Luke Brander, & Haque, E. (2009). Economic valuation of flood risk exposure and reduction in a severely flood prone developing country. *Environment and Development Economics*, 397-417.

Al-Karablieh, E., Salman, A., Al-Omari, A. S., Wolff, H. P., Al-Assa'd, T. A., Hunaiti, D. A., & Subah, A. (2012). Estimation of the Economic Value of Irrigation Water in Jordan. *Journal of Agricultural Science and Technology*, 487-497.

Alongi, D. (2012). Carbon sequestration in mangrove forests. *Carbon Management*, 313-322.

Amoly, E., Dadvand, P., Forns, J., Lopez-Vicente, M., Basagana, X., Julvez, J., . . . Sunyer, J. (2014). Green and blue spaces and behavioral development in Barcelona schoolchildren: The BREATHE project. *Environmental Health Perspectives*, 1351-1358. doi:10.1289/ehp.1408215

Anokye, N. K., Pokhrel, S., & Fox-Rushby, J. (2014). Economic analysis of participation in physical activity in England: implications for health policy. *International Journal of Behavioral Nutrition and Physical Activity*. doi:10.1186/s12966-014-0117-9

Badassa, B. B., Sun, B., & Qiao, L. (2020). Sustainable Transport Infrastructure and Economic Returns: A Bibliometric and Visualization Analysis. *Sustainability*. doi:10.3390/su12052033

Bandyopadhyay, T., Muthamilarasan, M., & Prasad, M. (2017). Millets for Next Generation Climate-Smart Agriculture. *Frontiers Plant Science*.

Baro, F., Chapparo, L., Gomez-Baggethun, E., Langemeyer, J., Nowak, D., & Terradas, J. (2014). Contribution of ecosystem services to air quality and climate change mitigation policies: The case of urban forests in Barcelona, Spain. *AMBIO: A Journal of Environment and Society*, 466-479. doi:10.1007/s13280-014-0507-x

Barot, S., Lata, J., & Lacroix, G. (2012). Meeting the relational challenge of ecological engineering within ecological sciences. *Ecological Engineering*, 13-23.

Batmanian, G. (2022, May 19). *What You Need to Know About Nature-Based Solutions to Climate Change*. Retrieved from World Bank: https://www.worldbank.org/en/news/feature/2022/05/19/what-you-need-to-know-about-nature-based-solutions-to-climate-change#:~:text=Nature%2Dbased%20solutions%20are%20actions,well%2Dbeing%20and%20biodiversity%20benefits.

Bealey, W., McDonald, G., Nemitz, E., Donovan, R., Dragosits, U., Duffy, T., & Fowler, D. (2007). Estimating the reduction of urban PM10 concentrations by trees within an environmental information system for planners. *Journal of Environmental Management*, 44-58. doi:10.1016/j.jenvman.2006.07.007

Beatty, C., Cox, N., & Kuzee, M. (2018). *Biodiversity guidelines for forest landscape restoration opportunities assessments. First edition.* Gland, Switzerland: IUCN.

Bell, F. (1997). The economic valuation of saltwater marsh supporting marine recreational fishing in the southeastern United States. *Ecological Economics*, 243-254. doi:10.1016/S0921-8009(96)00105-X

Below, R., Grover-Kopec, E., & Dilley, M. (2007). Drought related disasters: A global assessment. *Journal of Environment and Development*, 328-344.

Benedict, M., & McMahon, E. (2002). *Green Infrastructure: Smart Conservation for the 21st century. Sprawl Watch Clearinghouse Monograph Series.* Washington DC: Sprawlwatch Clearinghouse.

Bhagirath. (2021, March 19). *Parched no more: MGNREGA enables multi-cropping in Bundelkhand’s Himmatpura*. Retrieved from Down to Earth: https://www.downtoearth.org.in/news/water/parched-no-more-mgnrega-enables-multi-cropping-in-bundelkhand-s-himmatpura-75970

Bhogal, S., Green, A., Petrie, C. A., & Dixit, S. (2022, May 16). *Here's how one ancient crop is helping to fight India's water and food crisis*. Retrieved from World Economic Forum: https://www.weforum.org/agenda/2022/05/ancient-crop-india-water-food-crisis/

Boadu, K. (2018). *Don’t worry be Happy: Analysis of Happiness as an Economic measurement.* University of San Francisco.

Bonnesoeur, V., Locatelli, B., Guariguata, M., & Ochoa-Tocachi, B. (2019). Impacts of forests and forestation on hydrological services in the Andes: A systematic review. *Forest Ecology and Management*, 569-584.

Bottalico, F., Chirici, G., Giannetti, F., De Marco, A., Nocentini, S., Paoletti, E., . . . Travaglini, D. (2016). Air pollution removal by green infrastructures and urban forests in the city of Florence. *Agriculture and Agricultural Science Procedia*, 243-251. doi:10.1016/j.aaspro.2016.02.099

Burke, M., Hsiang, S. M., & Miguel, E. (2015). Global non-linear effect of temperature on economic production. *Nature*, 235-239. doi:10.1038/nature15725

Campari, J. (2021, June 16). *Soils: our most valuable environmental asset*. Retrieved from Crossroads: Blog-IUCN: https://www.iucn.org/crossroads-blog/202106/soils-our-most-valuable-environmental-asset

Chatterton, P., Denier, L., Scherr, S., & Stam, N. (2015). *Little Sustainable Landscapes Book.* Global Canopy Program.

Chaudhari, P., Bhattacharyya, S., & Samal, A. C. (2016). Living Root Bridge: A potential no cost eco-technology for mitigating rural communication problems. *International Journal of Experimental Research and Review*, 33-36.

Christian Aid. (2021). *Counting the cost 2021: A year of climate breakdown.* Christian Aid.

Cohen, M., Baudoin, R., Palibrk, M., Persyn, N., & Rhein, C. (2012). Urban biodiversity and social inequalities in built-up cities: New evidences, next questions. The example of Paris, France. *Lanscape and Urban Planning*, 277-287. doi:10.1016/j.landurbplan.2012.03.007

Cohen-Shacham, E., Walters, G., Janzen, C., & Maginnis, S. (2016). *Nature-based Solutions to address global societal challenges.* Gland, Switzerland: IUCN.

Conservation in Sri Lanka. (n.d.). *Coral Reefs*. Retrieved from Conservation in Sri Lanka: http://iucnsrilanka.org/conservation-sri-lanka/coastal-and-marine-ecosystems/coral-reefs/

Convention on Biological Diversity (CBD). (2010). 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.* Nagoya: CBD.

Dadson, S., Hall, J., Murgatroyd, A., Acreman, M., Bates, P., Beven, K., . . . Wilby, R. (2017). A restatement of the natural science evidence concerning catchment-based 'natural' flood management in the UK. *Proceedings of the Royal Society: Mathematical, Physical and Engineering Sciences*.

D'Amato, D., Droste, N., Allen, B., Kettunen, M., Lahtinen, K., Korhonen, J., . . . Toppinen, A. (2017). Green, circular, bio economy: A comparative analysis of sustainability avenues. *Journal of Cleaner Production*, 716-734. doi:10.1016/j.jclepro.2017.09.053

Davidson, N. (2016). Wetland Losses and the Status of Wetland-Dependent Species. In C. Finlayson, G. Milton, R. Prentice, & N. Davidson, *The Wetland Book* (pp. 1-14). Dordrecht: Springer. doi:https://doi.org/10.1007/978-94-007-6173-5_197-1

Davies, Z., Edmondson, J., Heinemeyer, A., Leake, J., & Gaston, K. (2011). Mapping an urban ecosystem service: quantifying above-ground carbon storage at a city-wide scale. *Journal of Applied Ecology*, 1125-1134. doi:10.1111/j.1365-2664.2011.02021.x

Dechezleprêtre, A., Rivers, N., & Stadler, B. (2020). *The Economic Cost of Air Pollution: Evidence from Europe.* OECD.

DEFRA. (2011). *The Economics of Waste and Waste Policy.* London: Department for Environment, Food and Rural Affairs (DEFRA).

Demuzere, M., Orru, K., Heidrich, O., Olazabal, E., Geneletti, D., Orru, H., . . . Faehnle, M. (2014). Mitigating and adapting to climate change: Multi-functional and multi-scale assessment of green urban infrastructure. *Journal of Environmental Management*, 107-115. doi:10.1016/j.jenvman.2014.07.025

Dhakal, S. (2013). Flood Hazard in Nepal and New Approach of Risk Reduction. *MDGA 11: Community based flood and GLOF risk reduction Project, Nepal.*

Diagne, C., Leroy, B., Vaissiere, A.-C., Gozlan, R. E., Roiz, D., Jaric, I., . . . Courchamp, F. (2021). High and rising economic costs of biological invasions worldwide. *Nature*, 571-576. doi:10.1038/s41586-021-03405-6

Dicks, J., Dellaccio, O., & Stenning, J. (2020). *Economic costs and benefits of nature-based solutions to mitigate climate change.* Cambridge Econometrics.

D'Odorico, P., Chiarelli, D. D., Rosa, L., Bini, A., Zilberman, D., & Rulli, M. C. (2020). The global value of water in agriculture. *Economic Sciences*. doi:10.1073/pnas.2005835117

Doocy, S., Dick, A., Amy Daniels, & Kirsch, T. (2013). The Human Impact of Tropical Cyclones: a Historical Review of Events 1980-2009 and Systematic Literature Review. *PLoS Curr*.

Down to Earth. (2021, March 22). *Greater water security, more jobs, lesser outmigration: what villages in Odisha and West Bengal have got from MGNREGA, finds Down To Earth survey*. Retrieved from Centre for Science and Environment (CSE), Media Resource Centre: https://www.cseindia.org/greater-water-security-more-jobs-lesser-outmigration-what-villages-in-odisha-and-west-bengal-have-got-from-mgnrega-finds-down-to-earth-survey-10750

Dumenu, W. K. (2013). What are we missing? Economic value of an urban forest in Ghana. *Ecosystem Services*. doi:10.1016/j.ecoser.2013.07.001

Dumitru, A., Frantzeskaki, N., & Collier, M. (2020). *Identifying principles for the design of robust impact evaluation frameworks for nature-based solutions in cities.* 107-116: Environmental Science and Policy.

Eftec. (2013). *Green Infrastructure's contribution to economic growth: a review. A final report for DEFRA and Natural England.* London: DEFRA.

Eggermont, H., Balian, E., Azevedo, J. M., Beumer, V., Brodin, T., Claudet, J., . . . Le Roux, X. (2015). Nature-based Solutions: New Influence for Environmental Management and Research in Europe. *GAIA*, 243-248.

Eggermont, H., Le Roux, X., Tannerfeldt, M., Enfedaque, J., & Zaunberger, K. (2021). *Strategic Research & Innnovation Agenda .* Horizon Europe Partnership on Biodiversity.

European Comission. (2000). *A Study on the Economic Valuation of Environmental Externalities from Landfill Disposal and Incineration of Waste.* European Comission, DG Environment.

European Commission. (2013). *Green Infrastructure (GI) — Enhancing Europe's Natural Capital. .* Brussels: Commission to the European Parliament/The European Economic and Social Committee/Committee of the Regions.

European Commission. (2021). *Evaluating the Impact of Nature-Based Solutions.* Brussels: European Commission.

European Commission, Directorate-General for Research and Innovation. (2021). *Evaluating the impact of nature-based solutions: a handbook for practitioners.*
European Commission. Directorate General for Research and Innovation. (2020). *Nature-based solutions: state of the art in EU funded projects.* Publications Office, LU.
European Environment Agency. (2015, September 11). *Green infrastructure: better living through nature-based solutions*. Retrieved from European Environment Agency: https://www.eea.europa.eu/articles/green-infrastructure-better-living-through
Faber, G., Margin, C., & Sick, V. (2021). Life Cycle and Techno-Economic Assessment Templates for Emerging Carbon Management Technologies. *Frontiers: Sustainability*. doi:10.3389/frsus.2021.764057
Falxa-Raymond, N., Svednsen, E., & Campbell, L. (2013). From job training to green jobs: A case study of a young adult employment program centered on environmental
FAO. (2020). *Damage and Loss: Agriculture on the Proving Grounds.* FAO.
FAO. (2020). *Global Forest Resources Assessment 2020: Main report.* Rome: FAO.
FAO. (2021). *Principles for Ecosystem Restoration to Guide the United Nations Decade 2021-2030.* FAO.
Fattore, G., Federici, C., Drummond, M., Mazzocchi, M., Detzel, P., Hutton, Z. V., & Shankar, B. (2021). Economic evaluation of nutrition interventions: Does one size fit all? *Health Policy*, 1238-1246. doi:10.1016/j.healthpol.2021.06.009
Feyen, L., & Gorelick, S. (2004). Reliable groundwater management in hydroecologically sensitive areas. *Water Resources Research*. doi:10.1029/2003WR003003
Filoso, S., Bezerra, M. O., Weiss, K. C., & Palmer, M. (2017). Impacts of forest restoration on water yield: A systematic review. *PLoS One*.
Fisher, R., Maginnis, S., Jackson, W., Barrow, Jeanrenaud, S., Ingles, A., . . . Oviedo, G. (2008). *Linking Conservation and Poverty Reduction: Landscapes, People and Power.* Gland, Switzerland: IUCN.
Forfang, S. (2021, August 12). *Study finds nature-based solutions add flood resilience across large areas*. Retrieved from North Sea Region Blog: https://northseablog.eu/study-finds-nature-based-solutions-add-resilience-against-floods/#:~:text=Building%20with%20Nature%20explores%20the,flood%20risk%20in%20local%20areas
Gann, G., McDonald, T., Walder, B., Aronson, J., Nelson, C., Jonson, J., . . . Dixon, K. (2019). Special Issue: International principles and standards for the practice of ecological restoration. Second Edition. *Restoration Ecology*, S1-S46.
Gallai, N., Garibaldi, L., Li, X., Breeze, T. D., Santo, M. E., Rodriguez, J., . . . Veldtman, R. (2016). Economic valuation of pollinator gains and losses. In S. G. Potts, & V. Imperatriz-Fonse, *Thematic assessment on pollinators, pollination and food production* (pp. 340-463). IPBES.
Garcia, S., Zerbi, A., Aliaume, C., Do Chi, T., & Lasserre, G. (2003). *The Ecosystem Approach to Fisheries: Issues, Terminology, Principles, Institutional Foundation, Implementation and Outlook-FAO Fisheries Technical Paper No. 443.* Rome: FAO.
Garcia-Leon, D., Casanueva, A., Standardi, G., Burgstall, A., Flouris, A. D., & Nybo, L. (2021). Current and projected regional economic impacts of heatwaves in Europe. *Nature*. doi:10.1038/s41467-021-26050-z.

Gedan, K., Kirwan, M., Wolanski, E., Barbier, E., & Silliman, B. (2011). The present and future role of coastal wetland vegetation in protecting shorelines: Answering recent challenges to the paradigm. *Climate Change*, 7-29. doi:10.1007/s10584-010-

Giannico, V., Lafortezza, R., John, R., Sanesi, G., Pesola, L., & Chen, J. (2016). Estimating stand volume and above-ground biomass of urban forests using LiDAR. *Remote Sensing*, 10.3390/rs8040339.

Gilon, C. (2021, May 31). *Women from Kerala weave a solution to the region's climate woes*. Retrieved from Mongabay India: https://india.mongabay.com/2021/05/women-from-kerala-weave-a-solution-to-the-regions-climate-woes/

Giri, C., Long, J., Abbas, S., Murali, R., Qamer, F., Pengra, B., & Thau, D. (2015). Distribution and dynamics of mangrove forests of South Asia. *Journal of Environmental Management*, 101-111.

Girot, P., Ehrhart, C., & Oglethorpe, J. (2011). *Integrating Community and Ecosystem-Based Approaches in Climate Change Adaptation.* Ecosystem & Livelihoods Adaptation Networks.

Goddard, M., Dougill, A., & Benton, T. (2010). Scaling up from gardens: biodiversity conservation in urban environments. *Trends in Ecology and Evolution*, 90-98. doi:10.1016/j.tree.2009.07.016

Gokhale, Y. (2021, July 5). *Nature-based solutions: Convenient ignorance of the inconvenient truth*. Retrieved from Down to Earth: https://www.downtoearth.org.in/blog/environment/nature-based-solutions-convenient-ignorance-of-the-inconvenient-truth-77783

Grafius, D. R., Edmondson, J. L., Norton, B. A., Clark, R., Mears, M., Leake, J. R., . . . Warren, P. H. (2020). Estimating food production in an urban landscape. *Nature*. doi:10.1038/s41598-020-62126-4

Green-Gray Community of Practice. (2020). *Practical Guide to Implementing Green-Gray Infrastructure.*

Grosse, S. D., & Zhou, Y. (2021). Monetary Valuation of Children's Cognitive Outcomes in Economic Evaluations from a Societal Perspective: A Review. *Children (Basel)*. doi:10.3390/children8050352

Grote, R., Samson, R., Alonso, R., Amorim, J., Carinanos, P., Churkina, G., . . . Calfapietra, C. (2017). *Functional traits of urban trees in relation to their air pollution mitigation potential: A holistic discussion.* Frontiers in Ecology and the Environment.

Hagedoorn, L., Koetse, M., & Beukering, P. J. (2021). *Estimating Benefits of Nature-based Solutions: Diverging Values From Choice Experiments With Time or Money Payments.* Frontiers in Environmental Science: Sec. Environmental Economics and Management

Hagedoorn, L., Koetse, M., van Beukering, P., & Brander, L. (2020). Time Equals Money? Valuing Ecosystem-Based Adaptation in a Developing Country Context. *Environmental Development Economics*, 482-508.

Hanley, N., Breeze, T. D., Ellis, C., & Goulson, D. (2014). Measuring the economic value of pollination services: Principles, evidence and knowledge gaps. *Ecosystem Services*. doi:10.1016/j.ecoser.2014.09.013

He, J., Zhang, H., Zhang, H., Guo, X., Song, M., Zhang, J., & Li, X. (2014). Ecological Risk and Economic Loss Estimation of Heavy Metals Pollution in The Beijiang River. *Ecological Chemistry and Engineering*, 189-199. doi:10.2478/eces-2014-0015

Hertel, T. W. (2018). Economic perspectives on land use change and leakage. *Environmental Research Letters*. doi:10.1088/1748-9326/aad2a4
Hobbie, S., & Grimm, N. (2020). Nature-based approaches to managing climate change impacts in cities. *Philosophical Transactions of the Royal Society*.
Holden, P., Rebelo, A., Wolski, P., Odoulami, R., Lawal, K., Kimutai, J., . . . New, M. (2022). Nature-based solutions in mountain catchments reduce impact of anthropogenic climate change on drought streamflow. *Communications: Earth and Environment*.
Horvathova, E., Duchkova, H., & Vackarova, D. (2019). *An assessment of costs and benefits of nature-based solutions in cities.* Global Change Research Institute of the Czech Academy of Sciences.
Hu, X., Wang, M., Liu, K., Gong, D., & Kantz, H. (2021). Using Climate Factors to Estimate Flood Economic Loss Risk. *International Journal of Disaster Risk Science*, 731-744. doi:10.1007/s13753-021-00371-5
IEA. (2019). *Multiple Benefits of Energy Efficiency.* Paris: IEA.
Internal Displacement Monitoring Centre (IDMC). (2022). *Global Report on Internal Displacement 2022.* IDMC.
IPCC. (2007). *Cost-benefit analysis, damage cost estimates and social costs of carbon*. Retrieved from IPCC Fourth Assessment Report: Climate Change 2007: https://archive.ipcc.ch/publications_and_data/ar4/wg3/en/ch3s3-5-3-3.html
Islam, M. S., Shahriar, B., & Nayar, F. (2014). Bio-technical solution for dyke protection in saline zone of Bangladesh. *Proceedings of The 2014 World Congress on Advances in Civil, Environmental and Materials Research (ACEM'14).*
IUCN. (2018, May 2). *Restoring from experience in Myanmar*. Retrieved from IUCN: https://www.iucn.org/news/forests/201805/restoring-experience-myanmar
IUCN. (2020). *Guidance for using the IUCN Global Standard for Nature-based Solutions. A user-friendly ramework for the verification, design and scaling up of Nature-based Solutions.* Gland, Switzerland: IUCN.
Jain, S., Sewak, R., & McGahey, C. (n.d.). *Solving for Water Security in a Micro-Watershed.* UNICEF.
Jin, T., & Kim, J. (2019). A comparative study of energy and carbon efficiency for emerging countries using panel stochastic frontier analysis. *Nature*. doi:10.1038/s41598-019-43178-7
Johnson, D., See, L., Oswald, S. M., Prokop, G., & Krisztin, T. (2020). A cost–benefit analysis of implementing urban heat island adaptation measures in small- and medium-sized cities in Austria. *Environment and Planning B: Urban Analytics and City Science*. doi:10.1177/2399808320974689
Johnson, J. A., Ruta, G., Baldos, U., Cervigni, R., Chonabayashi, S., Corong, E., . . . Polasky, S. (2021). *The Economic Case for Nature : A Global Earth-Economy Model to Assess Development Policy Pathways.* Washington DC: World Bank.
Jones, H., Hole, D., & Zavaleta, E. (2012). Harnessing nature to help people adapt to climate change. *Nature Climate Change*, 504-509.
Jongman, B., Tiffer, R., & Wang, X. (2022, May 19). *Nature-based solutions for resilient cities and restoring local biodiversity*. Retrieved from World Bank Blogs: https://blogs.worldbank.org/sustainablecities/nature-based-solutions-resilient-cities-and-restoring-local-biodiversity

Jui, U. M. (2021, October 31). *How coastal erosion is 'code red' for Bangladesh*. Retrieved from The Business Standard: https://www.tbsnews.net/bangladesh/environment/how-coastal-erosion-code-red-bangladesh-323158

Kabisch, N., & Haase, D. (2014). Green justice or just green? Provision of urban green spaces in Berlin, Germany. *Landscape and Urban Planning*, 129-139. doi:10.1016/j.landurbplan.2013.11.016

Kabisch, N., Frantzeskaki, N., Pauleit, S., & Naumann, S. (2016). Nature-based solutions to climate change mitigation and adaptation in urban areas: Perspectives on indicators, knowledge gaps, barriers, and opportunities for action. *Ecology and Society*.

Kapos, V., De Mel, M., Rosenzweig, C., Kolenda, M., Emerton, L., & Neufeldt, H. (2021). Chapter 6: Nature-based solutions for adaptation. In UNEP, *Adaptation Gap Report 2020* (pp. 43-76). Nairobi: UNEP.

Kapos, V., Wicander, S., Salvaterra, T., Dawkins, K., & Hicks, C. (2019). *The role of the natural environment in adaptation, background paper for the global commission on adaptation.* Rotterdam and Washington DC: Global Commission on Adaptation.

Keenor, S. G., Rodrigues, A. F., Mao, L., Latawiec, A. E., Harwood, A. R., & Reid, B. J. (2021). Capturing a soil carbon economy. *Royal Society Open Science*, 10.1098/rsos.202305.

Khadka, R. (2018). *Bio-dyke, an environment friendly solution to protect river banks.* Practical Action: Technology challenging poverty.

Knapp, M., & Wong, G. (2020). Economics and mental health: the current scenario. *World Psychiatry*. doi:10.1002/wps.20692

Kopsieker, L., Gerritsen, E., Stainforth, T., Lucic, A., Costa Domingo, G., Naumann, S., . . . Davis Mc. (2021). *Nature-based solutions and their socio-economic benefits for Europe's recovery: Enhancing the uptake of nature-based solutions across EU policies.* Institute for European Environmental Policy.

Krasny, M., Lundholm, C., & Kobori, H. (2013). Urban landscapes as learning arenas for biodiversity and ecosystem services management. *Springer Netherlands*, 629-664. doi:10.1007/978-94-007-7088-1_30

Kuhl, L., & Boyle, A. (2021). *Nature-based Solutions Valuation Report: Incorporating climate informed cost-benefit analysis into assessment of Nature-based Solutions in Latin America and the Caribbean.* School of Public Policy and Urban Affairs, Northeastern University and UNDP.

Kumar, M., & Singh, H. (2020). Agroforestry as a Nature-Based Solution for Reducing Community Dependence on Forests to Safeguard Forests in Rainfed Areas of India. In S. Dhyani, A. Gupta, & M. Karki, *Nature-based Solutions for Resilient Ecosystems and Societies. Disaster Resilience and Green Growth.* Singapore: Springer.

Kuo, M. (2015). How might contact with nature promote human health? Promising mechanisms and a possible central pathway. *Frontiers Psychology*. doi:10.3389/fpsyg.2015.01093

Kusmana, C., & Sukristijiono, S. (2016). Mangrove Resource Uses by Local Community in Indonesia. *Journal of Natural Resources and Environmental Management*, 217-224.

Lallemant, D., Hamel, P., Balbi, M., Lim, T., Schmitt, R., & Win, S. (2021). Nature-based solutions for flood risk reduction: A probabilistic modeling framework. *One Earth*, 1310-1321.

Lavorel, S., Colloff, M., McIntyre, S., Doherty, M., Murphy, H., Metcalfe, D., . . . Williams, K. (2015). Ecological mechanisms underpinning climate adaptation services. *Global Change Biology*, 12-31.

Layard, R. (2016). The Economics of Mental Health. *IZA World of Labor*. doi:10.15185/izawol.321

Lee, M., Villaruel, M. L., & Gaspar, R. (2016). *Effects of Temperature Shocks on Economic Growth and Welfare in Asia.* Manila: Asian Development Bank.

Leudke, H. (2019, October 16). *Nature as Resilient Infrastructure – An Overview of Nature-Based Solutions*. Retrieved from Environmental and Energy Study Institute: https://www.eesi.org/papers/view/fact-sheet-nature-as-resilient-infrastructure-an-overview-of-nature-based-solutions

Lewis, D. J., Kling, D. M., Dundas, S. J., & Lew, D. K. (2022). Estimating the value of threatened species abundance dynamics. *Journal of Environmental Economics and Management*. doi:10.1016/j.jeem.2022.102639

Lingua, C., Becchio, C., Bottero, M., Corgnati, S. P., Dell'Anna, F., & Fabi, V. (2020). Energy and Economic Evaluation of Thermal Comfort. The Case Study of the Hotel Residence L'Orologio. *International Building Performance Simulation Association.* Rome.

Litvak, E., & Pataki, D. (2016). Evapotranspiration of urban lawns in a semi-arid environment: An in situ evaluation of microclimatic conditions and watering recommendations. *Journal of Arid Environments*, 87-96. doi: 10.1016/j.jaridenv.2016.06.016

Locatelli, B., Evans, V., Wardell, A., Andrade, A., & Vignola, R. (2011). Forests and climate change in Latin America: Linking adaptation and mitigation. *Forests*, 431-450.

Loma, M., Quispe, J., & Studer, E. (2017). *Comprehensive Agrarian Risk Management.* FAO.

Manes, F., Marando, F., Capotorti, G., Blasi, C., Salvatori, E., Fusaro, L., . . . Munafo, M. (2016). Regulating Ecosystem Services of forests in ten Italian Metropolitan Cities: Air quality improvement by PM10 and O3 removal. *Ecological Indicators*, 425-440. doi:10.1016/j.ecolind.2016.03.009

Manski, C. F. (2000). Economic Analysis of Social Interactions. *Journal of Economic Perspectives*. doi:10.1257/jep.14.3.115

Mathey, J., Banse, J., Lehmann, I., & Brauer, A. (2015). Brownfields as an element of green infrastructure for implementing ecosystem services into urban areas. *Journal of Urban Planning and Development*. doi:10.1061/(ASCE)UP.1943-5444.0000275

Matthews, J., & Cruz, E. O. (2022). *Integrating Nature-Based Solutions for Climate Change Adaptation and Disaster Risk Management: A Practitioner's Guide.* Asian Development Bank.

McQuistan, C., Rana, B., Shreshta, K., Uprety, D., & Acharya, S. (2021). *Bio-dykes: Working with nature to reduce flood losses.* Practical Action.

Menendez, P. (2020, June 23). *Protecting mangroves, to deal with cyclones*. Retrieved from India Water Portal: https://www.indiawaterportal.org/articles/protecting-mangroves-deal-cyclones

Miner, M. J., Taylor, R. A., Jones, C., & Phelan, P. E. (2016). Efficiency, economics, and the urban heat island. *Environment and Urbanization*. doi:10.1177/0956247816655676

Ministry of Information and Broadcasting, Government of India. (2021, December 1). *National Action Plan on Climate Change (NAPCC)*. Retrieved from Press Information Bureau:

https://static.pib.gov.in/WriteReadData/specificdocs/documents/2021/dec/doc202112101.pdf

Mitsch, W. (2012). What is ecological engineering? *Ecological Engineering*, 5-12.

Mitsch, W., & Jørgensen, S. (2004). *Ecological Engineering and Ecosystem Restoration.* John Wiley & Sons.

Mohanty, A. (2020). *Preparing India for Extreme Climate Events: Mapping Hotspots and Response Mechanisms.* New Delhi: CEEW.

Mohanty, A. (2022). Adapting to a Changing Climate Through Nature-Based Solutions. In R. Brears, *The Palgrave Encyclopedia of Urban and Regional Futures.* Springer Nature.

Mohanty, A., & Wadhawan, S. (2021). *Mapping India's Climate Vulnerability: A District-Level Assessment.* New Delhi: Council on Energy, Environment and Water (CEEW).

Mohanty, A., & Wadhawan, S. (2022). The State of Extreme Events in India. In R. Brears, *The Palgrave Encyclopedia of Urban and Regional Futures.* Springer Nature.

Morita, K., & Matsumoto, K. (2021). Governance Challenges for Implementing Nature-Based Solutions in the Asian Region. *Climate Change and Security*.

Morris, R., Konlechner, T., Ghisalberti, M., & Swearer, S. (2018). From grey to green: Efficacy of eco-engineering solutions for nature-based coastal defence. *Global Change Biology*, 1827-1842.

Mulongoy, K., & Gidda, S. (2008). *The Value of Nature: Ecological, Economic, Cultural and Social Benefits of Protected Areas.* CBD.

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

Narayan, S., Beck, M., Reguero, B., Losada, I., van Wesenbeeck, B., Pontee, N., . . . Burks-Copes, K. (2016). The effectiveness, costs and coastal protection benefits of natural and nature-based defences. *Plos One*. doi:10.1371/journal.pone.0154735

Odum, H. (1996). Scales of ecological engineering. *Ecological Engineering*, 7-19.

OECD. (2015). *Climate Change Risks and Adaptation: Linking Policy and Economics.* Paris: OECD Publishing. doi:https://doi.org/10.1787/9789264234611-en

Pandey, K. (2015, August 31). *Green roofs can help cities adapt to climate change*. Retrieved from Down to Earth: https://www.downtoearth.org.in/interviews/urbanisation/-green-roofs-can-help-cities-adapt-to-climate-change--50850

Paul, M. (2021, December 29). *Disaster damage: 2021 sixth year with insured loss bill over $100 billion*. Retrieved from Down to Earth: https://www.downtoearth.org.in/news/climate-change/disaster-damage-2021-sixth-year-with-insured-loss-bill-over-100-billion-80894

Pedrr. (2010). *Demonstrating the Role of Ecosystems-based Management for Disaster Risk Reduction.* Partnership for Environment and Risk Reduction.

Perinchery, A. (2021, June 29). *Are we overlooking the role of grasslands in mitigating climate change?* Retrieved from Mongabay India: https://india.mongabay.com/2021/06/are-we-overlooking-the-role-of-grasslands-in-mitigating-climate-change/

Pisupati, B. (2010). *Connecting the Dots: Biodiversity, Adaptation, Food Security and Livelihoods.* Nairobi: UNEP.

Piwowarczyk, J., Kronenberg, J., & Dereniowska, M. (2013). Marine ecosystem services in urban areas: Do the strategic documents of Polish coastal municipalities reflect their importance? *Landscape and Urban Planning*. doi:10.1016/j.landurbplan.2012.10.009

Practical Action. (2018, February 14). *Bio-dykes: saving communities and instilling confidence in them*. Retrieved from Flood Resilience Portal: https://floodresilience.net/blogs/bio-dykes-saving-communities-and-instilling-confidence-in-them/

Raimundo, A. M., & Oliveira, A. V. (2021). Energy Needs and Economic Cost of Thermal Comfort in Buildings under a Temperate Climate. *SSRN*. doi:10.2139/ssrn.3921695

Ramachandra, T., & Rajinikanth, R. (2004). *Economic Valuation of Wetlands.* Bangalore: Center for Ecological Sciences, Indian Institute of Science.

Ray, D., West, P., Clark, M., Gerber, J., Prishchepov, A., & Chatterjee, S. (2019). Climate change has likely already affected global food production. *PLoS ONE*.

Raymond, C. (2017). *An impact evaluation framework to support planning and evaluation of nature-based solutions projects: prepared by the EKLIPSE Expert Working Group on nature-based solutions to promote climate resilience in urban areas.* Centre for Ecology and Hydrology.

Raymond, C., Berry, P., Breil, M., Nita, M., Kabisch, N., de Bel, M., . . . Calfapietra, C. (2017). *An Impact Evaluation Framework to Support Planning and Evaluation of Nature-based Solutions Projects.* Wallingford, United Kingdom: Centre for Ecology & Hydrology.

Reddy, K., & Jawitz, J. (2009). Soil and Water Quality: Integral Components of Watershed Management. *Journal of Crop Improvement*, 60-69.

Reddy, V., Saharawat, Y., & George, B. (2017). Watershed Management in South Asia: A Synoptic Review. *Journal of Hydrology*.

Rizvi, A., Baig, S., & Verdone, M. (2015). *Ecosystems Based Adaptation: Knowledge Gaps in Making an Economic Case for Investing in Nature Based Solutions for Climate Change.* Gland, Switzerland: IUCN.

Roe, J., Thompson, C. W., Aspinall, P., Brewer, M., Duff, E., Miller, D., . . . Clow, A. (2013). Green space and stress: Evidence from cortisol measures in deprived urban communities. *International Journal of Environmental Research and Public Health*. doi:10.3390/ijerph10094086

Romnee, A., & De Herde, A. (2015). Hydrological efficiency evaluation tool of urban stormwater best management practices. *International Journal of Sustainable Development and Planning*, 435-452.

Rowinski, P., Vastila, K., Aberle, J., & Jarvela, J. (2018). How vegetation can aid in coping with river management challenges: A brief review. *Ecohyrdology and Hydrobiology*.

Ruangpan, L., Vojinovic, Z., Di Sabatino, S., Leo, L., Capobianco, V., Oen, A., . . . Lopez-Gunn, E. (2020). Nature-based solutions for hydro-meteorological risk reduction: a state-of-the-art review of the research area. *Nat. Hazards Earth Syst. Sci.*, 243-270.

Russo, A., & Cirella, G. (2021). Urban Ecosystem Services: Current Knowledge, Gaps, and Future Research. *Land*.

Sadgir, P., Patil, G., & Takalkar, V. (2006). Sustainable Watershed Development by Refilled Continuous Contour Trenching Technology. *Rainwater Harvesting and Water Management*.

Sandilyan, S., & Kandasamy, K. (2015). Mangroves as bioshield: An undisputable fact. *Ocean and Coastal Management*, 94-96.

Saraev, V. (2012). *Economic benefits of greenspace: a critical assessment of evidence of net economic benefits. Forestry Commission Research Report.* Edinburgh: Forestry Commission.

Sarkar, S. (2021, November 11). *Climate negotiators must wake up to loss and damage as disasters multiply*. Retrieved from Mongabay: India: https://india.mongabay.com/2021/11/climate-negotiators-must-wake-up-to-loss-and-damage-as-disasters-multiply/

Seddon, N., Smith, A., Smith, P., Key, I., Chausson, A., Girardin, C., . . . Turner, B. (2021). Getting the message right on nature-based solutions to climate change. *Global Change Biology*, 1518-1546.

Setiawan, I. E., Zhang, Z., Corder, G., & Matsubae, K. (2021). Evaluation of Environmental and Economic Benefits of Land Reclamation in the Indonesian Coal Mining Industry. *Resources*. doi:10.3390/resources10060060

Sharda, V. (2011). Watershed Management and Water Harvesting as Strategic Tools for Groundwater Augmentation. *Strategic Tools for Groundwater Augmentation*.

Sharma, B., Samra, J., Scott, C., & Wani, S. (2005). *Watershed Management Challenges Improving Productivity, Resources and Livelihoods.* Colombo: International Water Management Institute.

Shaw, R., Luo, Y., Cheong, T., Halim, S., Chaturvedi, S., Hashizume, M., . . . Zhang, Z. (2022). Asia. In H. Portner, D. Roberts, M. Tignor, E. Poloczanska, K. Mintenback, A. Alegria, . . . B. Rama, *Climate Change 2022: Impacts, Adaptation, and Vulnerability.Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge: Cambridge University Press.

Shuster, E., & Doerr, P. (2015). *A guide for incorporating ecosystem service valuation into coastal restoration projects.* Delmont: The Nature Conservancy: New Jersey Chapter.

Sinha, V., & Bimson, K. (2021). *Nature-based Solutions in the Ganges Brahmaputra Meghna (GBM) river basin: Case Studies and lessons learned.* Bangkok: IUCN ARO.

Smith, R., Bass, B., Sawyer, D., Depew, D., & Watson, S. B. (2019). Estimating the economic costs of algal blooms in the Canadian Lake Erie Basin. *Harmful Algae*. doi:10.1016/j.hal.2019.101624

Solh, M., & van Ginkel, M. (2014). Drought preparedness and drought mitigation in the developing world’s drylands. *Weather and Climate Extremes*.

Spalding, M., McIvor, A., Tonneijck, F., & van Eijk, P. (2014). *Mangroves for coastal defence. Guidelines for coastal managers & policy makers.* Wetlands International and The Nature Conservancy.

Subramanian, K. (2020, February 17). *WWF Global Futures pushes ‘nature-based solutions’ agenda*. Retrieved from Down to Earth: https://www.downtoearth.org.in/blog/climate-change/wwf-global-futures-pushes-nature-based-solutions-agenda-69320

Suding, K. (2011). Toward an Era of Restoration in Ecology: Successes, Failures, and Opportunities Ahead. *Annual Review of Ecology, Evolution, and Systematics*, 465-487.

Swinburn, T. K., Hammer, M. S., & Neitzel, R. L. (2015). Valuing Quiet: An economic assessment of US environmental noise as a cardiovascular health hazard. *American Journal of Preventive Medicine*, 345-353. doi:10.1016/j.amepre.2015.02.016

Tallis, M., Taylor, G., Sinnett, D., & Freer-Smith, P. (2011). Estimating the removal of atmospheric particulate pollution by the urban tree canopy of London under current and future environments. *Landscape and Urban Planning*, 129-138. doi:10.1016/j.landurbplan.2011.07.003

Tamosiunas, A., Grazuleviciene, R., Lucksiene, D., Dedele, A., Reklaitiene, R., Baceviciene, M., . . . Nieuwenhuijsen, M. (2014). Accessibility and use of urban green spaces, and cardiovascular health: Findings from a Kaunas cohort study. *Environmental Health*. doi:10.1186/1476-069X-13-20

Task Force on Economic Benefits of Protected Areas of the World Commission on Protected Areas (WCPA) of IUCN. (1998). *Economic Values of Protected Areas: Guidelines for Protected Area Managers.* Gland, Switzerland: IUCN.

Throp, H., Yang, A., & Sherman, S. (2021, November 29). *Building Investor Confidence in Nature-based Solutions*. Retrieved from Chatham House: https://accelerator.chathamhouse.org/article/building-investor-confidence-in-nature-based-solutions

Tiwary, A., Sinnett, D., Peachey, C., Chalabi, Z., Vardoulakis, S., Fletcher, T., . . . Hutchings, T. (2009). An integrated tool to assess the role of new planting in PM10 capture and the human health benefits: A case study in London. *Environmental Pollution*, 2645-2653. doi:10.1016/j.envpol.2009.05.005

Tremmel, M., Gerdtham, U.-G., Nilsson, P. M., & Saha, S. (2017). Economic Burden of Obesity: A Systematic Literature Review. *International Journal of Environmental Health and Public Research*. doi:10.3390/ijerph14040435

Tyler, P., Warnock, C., Provins, A., & Lanz, B. (2013). Valuing the benefits of urban regeneration. *Urban Studies*, 169-190. doi:10.1177/0042098012452321

UN. (2021). *The United Nations World Water Development Report 2021: Valuing Water. .* Paris: UNESCO.

UNDP: Climate and Forests Programme. (2021). *Considerations for integrating Nature-based Solutions into Nationally Determined Contributions: Illustrating the potential through REDD+.* New York: UNDP.

UNDRR. (2021). *Words into Action: Engaging for resilience in support of the Sendai Framework.* UNDRR.

UNEP & WEF. (2021). *State of Finance for Nature.* UNEP, WEF, ELD and Vivid Economics.

UNEP. (2019, August 8). *Nature can still heal itself, if we give it the urgent attention it needs*. Retrieved from UNEP: https://www.unep.org/news-and-stories/story/nature-can-still-heal-itself-if-we-give-it-urgent-attention-it-needs

UNEP. (2021). *Becoming #GenerationRestoration: Ecosystem restoration for people, nature and climate.* Nairobi: UNEP.

UNEP. (2021). *Nature-based solutions for climate change mitigation.* Nairobi: UNEP.

UNESCO. (n.d.). *Karez System Cultural Landscape*. Retrieved from UNESCO: World Heritage Convention: https://whc.unesco.org/en/tentativelists/6110/

UNISDR/UNDP. (2012). *A Toolkit for Integrating Disaster Risk Reduction and Climate Change Adaptation into Ecosystem Management of Coastal and Marine Areas in South Asia.* New Delhi: UNDP.

United Nations Environmental Programme. (2021). *Adaptation Gap Report 2021: The gathering storm – Adapting to climate change in a post-pandemic world.* Nairobi: UNEP and World Adaptation Science Programme (WASP).

Veerkamp, C., Ramieri, E., Romanovska, L., Zandersen, M., Forster, J., Rogger, M., & Martinsen, L. (2021). *Assessment Frameworks of Nature-based Solutions for Climate Change Adaptation and Disaster Risk Reduction.* European Topic Centre Climate Change Impacts, Vulnerability and Adaptation.

Vicarelli, M., Kamal, R., & Fernandez, M. (2016). Cost Benefit Analysis for Ecosystem-Based Disaster Risk Reduction Interventions: A Review of Best Practices and Existing Studies. In F. Renaud, *Ecosystem-Based Disaster Risk Reduction and Adaptation Practice, Advances in Natural and Technological Hazards Research.* Springer International Publishing Switzerland.

Victoria Institute of Strategic Economic Studies (VISES). (2015). *Green Infrastructure Economic Framework.* Melbourne: Victoria University.

Viti, M., Lowe, R., Sorup, H. J., Rasmussen, M., Arnbjerg-Nielsen, K., & McKnight, U. S. (2022). Knowledge gaps and future research needs for assessing the non-market benefits of Nature-Based Solutions and Nature-Based Solution-like strategies. *Science of the Total Environment*.

Vyas, K. (2020, November 18). *Ahar pynes: Traditional flood harvesting systems of South Bihar*. Retrieved from India Water Portal: https://www.indiawaterportal.org/articles/ahar-pynes-traditional-flood-harvesting-systems-south-bihar

Wancharoen, S. (2014, April 5). *Saving the Bang Khunthian coast will cost B1.5bn*. Retrieved from Bangkok Post: https://www.bangkokpost.com/thailand/politics/403518/saving-the-bang-khunthian-coast-will-cost-b1-5bn

Wani, S., Sreedevi, T., Reddy, T., Venkateshvarlu, B., & Prasad, C. (2008). Community watersheds for Improved Livelihoods through Consortium Approach in Drought Prone Rainfed Areas. *Journal of Hydrological Research and Development*.

Ward, P., Jongman, B., Aerts, J., Bates, P., Botzen, W., Loaiza, A. D., . . . Winsemius, H. (2017). *A global framework for future costs and benefits of river-flood protection in urban areas.* nature climate change.

Watkiss, P., Downing, T., & Dyszynski, J. (2010). *AdaptCost Project: Analysis ofthe Economic Costs of Climate Change Adaptation in Africa.* Nairobi: UNEP.

Wesenbeeck, B. v., Kok, S., Avila, C. B., Gwee, R., & Penning, E. (2021). *Economic rationale of NBS in freshwater ecosystems.* Deltares.

White, C., Collier, M., & Stout, J. (2021). Using ecosystem services to measure the degree to which a solution is nature-based. *Ecosystem Services*.

WHO. (2012). *Global costs and benefits of drinking-water supply and sanitation interventions to reach the MDG target and universal coverage.* WHO.

WHO. (n.d.). *Estimating the morbidity from air pollution and its economic costs*. Retrieved from World Health Organization: https://www.who.int/activities/estimating-the-morbidity-from-air-pollution-and-its-economic-costs

Wild, R., & Mutebi, J. (1996). *Conservation through community use of plant resources. Establishing collaborative management at Bwindi Impenetrable and Mgahinga Gorilla National Parks, Uganda.* Paris: UNESCO.

WMO. (2020). *State of Climate in Asia 2020.* WMO.

WMO. (2021, August 31). *Weather-related disasters increase over past 50 years, causing more damage but fewer deaths*. Retrieved from WMO:

https://public.wmo.int/en/media/press-release/weather-related-disasters-increase-over-past-50-years-causing-more-damage-fewer

Wood, J. (2022, March 7). *What are nature-based solutions and how can we finance them?* Retrieved from Race to Resilience: UNFCCC: https://climatechampions.unfccc.int/what-are-nature-based-solutions-and-how-can-we-finance-them/

World Bank. (2021, April 6). *Building Coastal Resilience to Protect Lives and Livelihoods in Bangladesh*. Retrieved from World Bank: https://www.worldbank.org/en/results/2021/04/26/building-coastal-resilience-to-protect-lives-and-livelihoods-in-bangladesh

World Bank. (2022). *The Global Health Cost of PM2.5 Air Pollution : A Case for Action Beyond 2021. International Development in Focus.* Washington DC: World Bank.

World Economic Forum. (2020). *The Global Risks Report 2020.* World Economic Forum.

World Health Organization (WHO). (n.d.). *Tropical Cyclones*. Retrieved from WMO: https://www.who.int/health-topics/tropical-cyclones#tab=tab_1

World Meteorological Organization (WMO). (2022, January 19). *2021 one of the seven warmest years on record, WMO consolidated data shows*. Retrieved from World Meteorological Organization: https://public.wmo.int/en/media/press-release/2021-one-of-seven-warmest-years-record-wmo-consolidated-data-shows

Wun, J., Levin, C., Kemp, C., & Bushnell, D. (2020). Measurement of Benefits in Economic Analyses of Nutrition-Specific and -Sensitive Programs: A Systematic Review. *Current Developments in Nutrition*. doi:10.1093/cdn/nzaa053_132

WWAP. (2018). *The United Nations World Water Development Report 2018: Nature-Based Solutions for Water.* Paris: UNESCO.

WWF. (2022). *Nature Based Solutions – a review of current financing barriers and how to overcome these.* WWF.

Yepsen, M., Moody, J., & Schuster, E. (2016). *A framework for developing monitoring plans for coastal wetland restoration and living shoreline projects in New Jersey.* New Jersey: New Jersey Measures and Monitoring Workgroup of the NJ Resilient Coastlines Initiative.

Zhang, K., & Chui, T. F. (2018). Interactions between shallow groundwater and low-impact development underdrain flow at different temporal scales. *Hydrological Processes*, 3495-3512.