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# Nature-Based Solutions to Sea Level Rise and Other Climate Change Impacts on : A Law and Policy Perspective

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This article is a contribution to the Special issue "*Nature-based solutions for coastal protection*". The present paper discusses law and policy perspectives on the protection of mangrove ecosystems, and is a good example of the topic "Plants in The Anthropocene" in Nordic Journal of Botany. Nordic Journal of Botany welcomes research covering how plants and vegetation contribute to building with nature, as well as governance for a sustainable future linked to the aims of the UN's Sustainable Developmental Goals. With the upcoming Special issue, we propose to cover a comprehensive view of nature-based solutions from a number of research disciplines in order to provide an inclusive understanding of coastal management issues and a way forward.

## *Research*

# Nature-based solutions to sea level rise and other climate change impacts on oceanic and coastal environments: a law and policy perspective

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There are several nature-based adaptation options available to coastal nations. In this paper, we offer a brief overview of these options and then focus on mangroves to consider how laws and policies can support nature-based solutions and thereby contribute to more effective overall adaptation efforts. We first outline the concept of adaptation and its variants, thereby setting the context for this study. We then briefly explore the science relating to nature-based adaptation. We analyze the international legal regime in place to protect mangrove ecosystems. Finally, we discuss the merits, the challenges, and strategies developed to surmount some of the challenges that coastal countries can face while implementing nature-based adaptation options by utilizing Bangladesh's experience on mangrove conservation as a case study. Ultimately, we conclude that it may be necessary to implement both hard and nature-based adaptation options and that an effective law and policy framework will be critical. It will also be important to look beyond physical coastal protection to augment coastal livelihoods and build resilient coastal communities with greater adaptive capacities.

Keywords: Adaptation, climate change, coral reefs, integration, law and policy, mangroves, nature-based solutions

## Introduction

The climate crisis is a reality that is upon us. Even if countries adhere to their nationally determined contributions and are ultimately successful in capping emissions in



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line with the Paris Agreement's collective goals, the cumulative effect of the past, along with locked-in future emissions, will challenge us for many decades to come. Among the ecosystem theatres where climate change impacts will be particularly severe are coastal regions, home to nearly 40% of the Earth's population. Sea levels are rising and will continue to do so indefinitely (IPCC 2019). The main uncertainty is the extent of the rise – will it be around a foot or a meter by the end of the century, and how fast will it continue to rise? The first and most obvious impacts of sea-level rise (SLR) are coastal erosion, inundation, and storm-related floods. SLR will also lead to tidal waters' encroachment into estuaries and river systems and the adulteration of freshwater reserves and food crops. It will damage nesting beaches and displace coastal lowlands, wetlands, and human populations. It will adversely impact mangroves, seagrasses and intertidal areas and the species that rely on them, many of which are ecologically sensitive and commercially valued. It will distress endemic and habitat-forming benthic species, which are highly susceptible to water level changes and coastal erosion (Kaplanis et al. 2020). SLR will amplify the adverse effects of existing anthropogenic or natural forms of pressure that affect coastal areas, including urban sprawl, overfishing, aquaculture, tourism, damming, extraction of materials, marine biological invasions, coastal subsidence, and tectonic movement (U.N.G.A 2017). In short, with each passing day that action is delayed, SLR will create increasing governance and management challenges for coastal areas throughout the world.

As far as responding to these severe consequences, climate change adaptation emerges as a critical governance and management tool. Adaptation refers to initiatives and measures that seek to decrease the vulnerability or moderate harm to natural and human systems from current and anticipated climate change impacts. It also includes initiatives that aim to take advantage of opportunities if and where they present themselves (IPCC 2007). There are various adaptation measures and classifications to consider. This paper examines both benefits and challenges and how these can be overcome when nature-based adaption (NBA) techniques or ecosystem-based adaptation approaches are implemented in coastal areas to react to SLR and other climate change impacts. NBA techniques are fundamental, particularly for developing countries. This is partly because, for these countries, due to the limited availability of capital and other resources to meet the monetary and technological demands of adaptation, they tend to have less capacity for engineering based adaptation (Ruhl 2010). Adaptation may also not be their priority, as they may have more immediate and pressing problems to deal with, such as poverty reduction and efforts to meet their populations' basic needs. Of course, in some situations, leaving aside issues of capacity and priority, NBA will offer better results than hard engineering-based solutions.

As will be explored below, there are several nature-based adaptation options available to coastal nations. In this paper, the focus is on mangroves, though other options will be identified. We will explore how nurturing these options can positively contribute to ongoing adaptation efforts. This paper employs a doctrinal methodology to underscore the importance of law and policy in implementing NBA solutions to SLR and other climate change impacts on oceanic and coastal environments. Climate change adaptation is sometimes considered the domain of coastal managers and scientists. However, it is our proposition that law and legal frameworks have an essential role to play in facilitating adaptation generally and nature-based adaptation specifically.

Existing international law on adaptation is scanty and diffuse. International law treaties, soft-law instruments, and the obligations they espouse do compel State parties in broad and general terms to conserve the oceanic and coastal environment and its resources. International law requires State parties to enact national-level laws and policies to put the relevant international law into practice. Since healthy oceanic and coastal ecosystems are *sine qua non* and key in an adaptation strategy, the obligations in international law become pertinent as they provide a legal springboard to spur the adoption and implementation of NBA at the domestic level. However, most countries' domestic law and policy environments do not adequately support adaptation and particularly NBA. It is this aspect that the paper seeks to highlight, and this is its core contribution.

To accomplish this objective, the remainder of this paper is divided into four parts. Part 2 will outline the concept of adaptation and its variants. It will explore the science relating to the NBA and its comparative advantages over hard engineering adaptation options, thereby setting the context for this study. However, a caveat is in order. While NBA may have certain socio-ecological advantages over hard armouring, an inference that hard armouring is necessarily inferior should not be drawn. There are serpentine stretches of coastlines all over the world, where hard armouring may be the only option available to keep a rising sea and other climate change impacts at bay. Part 3 will analyze the international legal regime supportive of the protection of these ecosystems. Part 4 discusses the merits, challenges, and strategies developed by coastal countries to surmount the difficulties that emanate while implementing nature-based adaptation options, using nature-based adaptation projects relating to mangroves in Bangladesh to illustrate these issues. The paper concludes in Part 5 by drawing on the discussion in the preceding parts and highlighting the criticality of effective laws, policies and integrated approaches. Ultimately, of course, it will be necessary to consider both hard and NBA options, and to look beyond physical coastal protection to augment coastal livelihoods and build resilient coastal communities with greater adaptive capacities.

## Understanding climate change adaptation: hard engineering versus nature-based adaptation

Adaptation to climate change primarily describes the initiatives and measures that can help decrease vulnerability or moderate the degree of harm that can befall natural and

human systems because of real or anticipated climate change effects (IPCC 2018). Adaptation is not all about responding to negative consequences. Climate change can also lead to opportunities, and therefore adaptation may seek to utilize these if and where present (IPCC 2007). There are different kinds of adaptation measures and related classifications. However, it must be pointed out since adaptation is a dynamic process, it is difficult to compartmentalize it to fit strictly into this primary taxonomy. There can be considerable overlap. An adaptation strategy may exhibit features that may require it to be placed in more than one column.

Adaptation is anticipatory or proactive in cases where measures are designed and put in place before the event's occurrence and its impact becomes apparent (IPCC Annex 1: Glossary). They are reactive when they are designed and put into operation after the event unfolds (Warren et al. 2004). Adaptation can also be classified as planned and autonomous. It is planned or proactive if it is a product of deliberate policy decisions. However, if the response is unplanned and spontaneous, then adaptation is autonomous (Pittock and Jones 2009). In managed systems, adaptation tends to be anticipatory and planned, and in unmanaged natural systems, it is more reactive and autonomous (Pittock and Jones 2009). Anticipatory adaptations are more result-oriented and cost-efficient (Warren et al. 2004).

An important aspect that warrants mentioning is that successful adaptation depends in no small measure on the availability of adaptive capacity within the impacted group or society. In most developing economies, the subaltern (indigenous peoples, artisanal fishers, women, children, the elderly, and natural-resource-dependent communities) stand politically, socially, and economically marginalized and have the least adaptive capacity (Kuriakose et al. 2009). Climate change impacts, therefore, hit these groups the hardest. Underdevelopment, unemployment, environmental pollution, natural resource degradation, extreme poverty, gender bias, illiteracy, institutional weaknesses, and widespread corruption impair the development of adaptive capabilities (Smith et al. 2001). There is an increasing tendency towards a systematic alienation of traditional communities from accessing natural resources upon which their existence, their identity, and survival depend, further hindering adaptive capacities (IPCC 2001). As the experience in some of the African and South Asian coastal countries reveals, often, the symbiotic relationship which traditional communities share with their natural resources is disrupted in the name of economic development. A new set of players, namely, the bureaucracy and the industrialists, replaces these communities. As they have more social, economic, and political power, they often utilize the formal legal systems to exploit coastal resources to further their economic interests (EPW 2012). Such barriers and misguided efforts can destabilize an adaptation process's success and contribute to negative consequences, including maladaptation (IPCC 2007). Undoubtedly, adaptation is an extension of good development policies and practices (Stern 2006). The overall success of an economic development program is considerably enhanced when development accommodates climate change-related adaptation. Such an approach operates both ways – along with economic and social development, adaptive capacity is enhanced, which contributes to more significant economic and social development. Mainstreaming adaptation into existing developmental efforts aimed at, for instance, poverty alleviation, biodiversity conservation, and combating land degradation can potentially yield more sustainable outcomes – it can help increase the adaptive capacities of vulnerable populations and fortify economic and social development (Huq and Reid 2004). Conversely, where development patterns do not mainstream adaptation, populations are subjected to higher risk levels, undercutting their ability to adapt. Based on this foundational understanding of adaptation, we now examine the significance and dynamics of climate change adaptation when applied to coastal zones.

The Intergovernmental Panel on Climate Change (IPCC) in 1988 established the Response Strategies Working Group, which created four subgroups. The most relevant was the Coastal Zone Management Subgroup (CZMS), which New Zealand and the Netherlands chaired. The CZMS identified several adaptation responses (Dronkers et al. 1990), which the IPCC subsequently adopted in 1990 as part of its First Assessment Report (Dronkers et al. 1990). The Report of the Coastal Management Subgroup articulated three primary objectives of coastal management: 1) avoiding development in areas vulnerable to inundation; 2) ensuring the continual functioning of critical natural systems and; 3) protecting human lives, essential properties, and economic activities against the ravages of the seas (Dronkers et al. 1990). The report also made known several climate change adaptation measures categorized under the three broad headings: retreat, accommodate, and protect (Dronkers et al. 1990). However, as it is challenging to have a strict classification of adaptation, it is also hard to categorize the different adaptation measures under these headings. There is considerable overlap.

A planned retreat is an example of proactive adaptation. It seeks to prevent harm by removing people and investment from coastal properties susceptible to severe erosion, flooding, weather events, all of which stand to be aggravated by SLR, and situating them further inland. To do so, there must be alternative land available for resettlement. Hence, retreat may not be a practical solution for small island states and areas experiencing intense coastal squeeze, such as mega-coastal cities (Abel et al. 2011). Retreat may also be challenging to implement along coastlines where populations and infrastructure are already concentrated (Printz V. Gleneig 2010). Increasing taxes on properties in vulnerable zones (Grannis 2011), high insurance premiums (Lloyd 2008), and establishing setback lines, zoning, and buffer zones are methods used to implement planned retreat.

Accommodation is based on the premise that some coastal zone values will be laid waste to a rising sea and that people may have to flee their homes and move to higher ground (Dronkers et al. 1990). Accommodation takes various forms – from 'building codes and resilient designs' (Grannis 2011) to rebuilding restrictions and redesigning structures

to minimize impacts (e.g. elevating residential and commercial buildings on pilings to protect them from floods) (ICE 2009). Generally, retreat and accommodation assume that some land loss and some coastal flooding will occur and that some dynamic coastal functions and values will be forever lost or altered. The focus is to help coastal ecosystems preserve their dynamic character by adapting naturally to SLR and other climatic processes (Ehler et al. 1996).

The last in the triad is protection. It seeks to shield coastal residents from harmful impacts and is attained by constructing defensive coastal armouring. Measures in this category can take the form of either hard or soft coastline protection (utilizing structural and non-structural devices). Since this paper aims to explore the relative utility of NBA options, we will look at the nature and scope of hard and soft coastline protection measures in greater detail.

Coastal instability, coupled with high population density and high-value coastal infrastructure, has led to the proliferation of civil engineering works in several stretches of urbanized coastlines worldwide to combat erosion and preserve shoreline integrity. Hard shoreline armouring has emerged as a popular adaptation method to respond to SLR. It involves civil engineering to build stable structures like bulkheads, seawalls, tetrapod seawalls, revetments, dykes, groins, tide gates, storm surge barriers, and artificial islands, floating cities and floating homes to protect the coast against flooding and erosion (Grannis 2011). However, in several cases, the introduction of hard-engineering structures has had undesired effects; it has upset the natural equilibrium of shorelines to exacerbate coastal erosion and has significantly impacted coastal processes. Several reasons can be proffered to explain the negative environmental consequences, including inept planning, improper structure placement, and even corruption. More pertinent, particularly in developing countries, are the reasons relating to the high costs of these structures, often leading to design compromises and a lack of coordination among government departments. The result may be that materials used contravene standard protocols relating to shore-hardening engineering. These challenges can be compounded by a lack of adequate information about coastal processes, such as biodiversity interactions in the area and even beyond, the precise nature of climate change impacts, and local societal and economic considerations. Accordingly, their long-term resilience to hold back the enormity of a rising sea on a large scale may be restricted. In some instances, particularly from an ecological perspective, these measures may also have counterproductive consequences on neighbouring properties. For instance, storm walls may prevent the natural inland migration of wetlands and mangroves, ultimately leading to their destruction (Gilman et al. 2006). Groins can entrap sediments that move along the shore. Protection in one area is often attained at the expense of increased erosion in another (UNFCCC 2003). By interfering with the process of littoral drift, hard armouring can exacerbate erosion and flooding (Byron Shire Council v. Vaughan 2009). Hard adaptation has reduced the human death toll from disasters; however, it is often found not to protect coastal ecosystems and biodiversity. But if designed appropriately, there are reports that seawalls have increased local ecosystems and biodiversity's resiliency. For instance, seawalls in Singapore have been found to assist in the recolonization of corals and reef communities, where they function as cost-effective artificial reefs (Lionel et al. 2012).

Hard armouring can have other negative consequences. They can restrict public access. In developing economies with a significant presence of artisanal fishing, they can prevent the launching and landing of traditional catamarans used for fishing operations in coastal areas (Rodriguez et al. 2008). Concretizing the coastline may also affect visual aesthetics, compromising 'beach, sun, and sand' tourism opportunities. Hard structures may also require continual maintenance. In many coastal stretches in the developing world, lack of maintenance because of high costs has led to these structures being uncared for. Over time, they lose their strength, age early, and ultimately, the seawall fails. Perhaps the most alarming downside of hard shoreline armouring is that it may lull government authorities, developers, and (more importantly) coastal communities into a false sense of safety and complacency that they can persist with a casual approach to coastal development and that engineering can provide a quick-fix (Grannis 2011).

A critical civil engineering-based adaptation technique particularly significant for Small Island Developing States with minimal land for relocation is creating artificial islands. A key project is currently underway in The Maldives, a country that comprises almost 1300 islands, that average a measly 1.5 m a.s.l. The Maldives is acutely vulnerable to SLR. It runs a real risk of physical obliteration and losing its statehood status from a one-meter rise in sea level. The country is essentially made up of 'reef islands' formed by the build-up of reef rubble in the lagoons, with additional sediments layered on top of the core by wave action. The individual islands are arranged in a 750-km long chain of atolls (the term atolls come from the Dhivehi (the language of the Maldives) word atholhu). The atoll-reef structure affords substantial natural protection from tidal waves and storm surges. However, urbanization, destructive practices, and pollution have diminished their strength and effectiveness. Due to land paucity, one of the primary adaptation techniques adopted by this island state to the impending catastrophe is constructing artificial islands and their augmentation. Initiated in the wake of the 2004 Indian Ocean tsunami to house those rendered homeless, the Hulhumal*é* artificial island construction project envisages extensive reclamation by pumping tons of dredged coral, rocks and sand from surrounding atolls and depositing it on shallow reefs. The intention is to fortify the artificial island to situate it at least three metres a.s.l. (Dauenhauer 2017).

Ultimately, artificial islands may be the only hope for several countries. However, this option is constrained by a legal handicap. Under the Law of the Sea Convention (UNCLOS) terrestrial features in the ocean are categorized into islands, rocks, low-tide elevations, and artificial islands. In line with the fundamental idea that the land commands the sea, the UNCLOS states that an island can, like the

mainland, generate the territorial sea, the contiguous zone, the exclusive economic zone (EEZ), and the continental shelf (UNCLOS 1982). However, due to the incessant hammering of these islands by intense wave action, rising seas, and changing precipitation patterns, it may become increasingly difficult for islands to continue to support human habitation. Therefore, legally under the UNCLOS, they may degenerate into rocks. Rocks are features that cannot sustain human habitation or economic life on their own (UNCLOS 1982). Under the UNCLOS, they are entitled to a territorial sea and a contiguous zone, but they cannot generate an EEZ or a continental shelf (UNCLOS 1982). A low-tide elevation (LTE) is a naturally formed land area surrounded by and above water at low tide, but it is submerged during high tide (UNCLOS 1982). If the LTE is within the limits of an existing territorial sea, then the low-water line on that elevation can be used as a basepoint to determine the breadth of the territorial sea. However, this does not convert the LTE into an island.

As far as artificial islands are concerned, the UNCLOS empowers a coastal State with an exclusive right to construct, operate and use artificial islands within the EEZ (UNCLOS 1982). In some instances, this right can be exercised on the continental shelf way beyond the EEZ (UNCLOS 1982). Artificial islands do not possess a territorial sea or the other maritime zones; but, they can engender a 'safety zone' of a 500-meter radius in which the concerned State can exert exclusive sovereign control. Another critical legal implication of artificial island construction is the notice requirement. UNCLOS requires 'due notice' to be provided regarding the construction of such 'artificial islands, installations or structures' and requires the adoption of permanent means to warn others of their presence (UNCLOS 1982). This provision is designed to protect unsuspecting foreign vessels from running aground when sailing within the EEZ of another state (Kohl 2018).

Generally, the artificial islands that SIDS like the Maldives are constructing are built over rocks or LTEs. Since artificial islands are incapable of generating territorial seas or EEZs, these structures will still be incapable of generating the entire gamut of maritime zones even if engineered to support human habitation. This may prove detrimental to the SIDS, many of whom place their hope on artificial islands to sustain their statehood status and ensure long-term economic well-being and sustenance.

Soft armouring ('natural infrastructure' or 'living shorelines'), or the creation of bio-shields are not subject to such legal handicaps. They offer significant shelter against inundation, tidal flooding, wave impact, shore erosion, and salinity intrusion and are considered a superior option than hard shoreline armouring (Verchick and Scheraga 2012). Soft armouring or NBA or ecosystem-based adaptation employs biodiversity, natural resources, and ecosystem services to facilitate climate change adaptation. It relies on biodiversity and ecosystem services to help people adapt to the harmful effects of climate change, particularly in coastal regions. The approach is more inclusive, participatory and offers a wide assortment of social benefits and community interests at varying scales based on the ecosystem interactions. Currently, several NBA options are being implemented around the world, focusing on local ecosystems. These measures assume several forms, like artificial beach nourishing, dune creation (Grannis 2011), protection of existing and creation of new bio-shields (such as mangrove replanting (Wong 2009), wetland restoration (Alongi 2008), and coastal forestry promotion (Forbes and Broadhead 2007)). This has practically spotlighted the importance of coastal and near-shore marine ecosystems, mainly on mangroves, tidal salt marshes, peatlands, and seagrass meadows and coral reefs.

Another important fact that makes these coastal ecosystems attractive is their ability to capture and sequester carbon (Crooks et al. 2011). It is estimated that each square mile of these ecosystems can sequester carbon at rates higher than what a square mile of mature tropical forests can accomplish (IUCN 2017). Furthermore, coastal ecosystems can store carbon in organic-rich sediments of up to five times more than temperate and tropical forests. These ecosystems are collectively referred to as 'blue carbon'. While soft armouring may be less expensive than hard armouring, it may require constant upkeep and monitoring. Like hard armouring, it can be challenging to implement on a large scale (Neumann et al. 2000). Below, we discuss some major coastal ecosystems' tangible and intangible benefits that can play a significant role in facilitating NBA.

## Mangroves

Mangroves straddle between the land and the sea, and they are present in the tidal waters of nearly 123 tropical or subtropical countries (UNESCO 2018). Mangroves or *mangals* are a unique coastal and marine habitat that is essentially a combination of forest and wetland. They render multiple ecosystem services:

1. Provisioning - a source for food, fibre, fuel, timber and non-timber forest products, habitat for aquatic and terrestrial species, and supply for biochemical and genetic materials
2. Regulating - pollution control, erosion protection, a buffer against natural hazards, hydrological services, and climate control, including carbon sequestration
3. Cultural – educational, aesthetic, spiritual and inspirational and recreational and, finally,
4. Supporting – biodiversity, nutrient cycling, pollination, and soil formation.

Ultimately, mangroves' value as natural defences against storm waves and as carbon sinks renders them more critical than ever before. Mangroves are at the forefront of the battle against climate change. Increasingly, mangrove forest protection is seen as an essential solution to coastal erosion. There is overwhelming scientific evidence that mangrove forests can play a decisive role in protecting coastal areas from rising sea levels. Areas with considerable mangrove vegetation are more likely to withstand erosion and inward water encroachment.

This is due to the soil building up around their complex web-like roots, their husks, and leaves, all of which serve to dissipate wave energy and tidal currents and obstruct water flow. Accordingly, areas where mangroves are cleared, are more susceptible to SLR and other climate change impacts.

Mangroves have the additional benefit of storing carbon. They are some of the most carbon-rich forests on the planet, and the average annual carbon sequestration potential for mangroves ranges from six to eight Mg $CO_2e$ $ha^{-1}$ (tons of $CO_2$ equivalent per hectare) (The Blue Carbon Initiative). For these reasons, their management attracts a wide range of international environmental law instruments that impose hard and soft law obligations on party states to ensure their upkeep.

Mangroves were long treated as unproductive wastelands. Even now, despite considerable knowledge regarding the ecosystem services that they provide, they continue to be cleared to make room for more coastal development, such as for shrimp aquaculture. Some studies indicate that nearly one-third of the world's mangrove forests have been lost (Alongi 2002). The rate at which they vanish is three to four times the rate of deforestation on land (UNEP 2014). The destruction of these coastal shields leaves coastlines more vulnerable and unleashes the carbon stored in these ecosystems, emitting it back into the atmosphere, further contributing to anthropogenic climate change.

## Coral reefs

Corals are colonial organisms made up of individual polyps, that live symbiotically with the single-celled microalgae (zooxanthellae) in their body tissue (National Oceanic and Atmospheric Administration 2019). The polyps secrete a calcium carbonate skeleton, which becomes the foundation of coral reef ecosystems. Coral reefs are formed by hundreds of thousands of these polyps and are found in warm, shallow, clear, low-nutrient tropical and sub-tropical waters, the optimum temperatures ranging between 25-29°C (Grimsditch and Salm 2005).

Even though tropical coral reefs cover only 0.1 percent of the ocean, they are amongst the most biodiverse ecosystems on the planet, supporting one-quarter of all marine species, earning them the sobriquet the 'rainforests of the sea.' Found in the waters of more than 100 countries, including more than 80 developing countries, they provide a wide array of ecosystem services that sustain livelihoods, improve food security, and support income generation. Importantly, for purposes of climate adaptation, coral reefs and related structures, by rising from considerable depths of the ocean floor to the surface, often running parallel to coastlines for tens or hundreds of kilometres, offer an important buffer against erosion and protection from extreme weather events. Coral reefs enable the mass transfer of wave energy and lessen inundation and damage during storms. They provide significant wave attenuation benefits comparable to artificial defences such as breakwaters. Reef crests alone can dampen and dissipate wave energy considerably (Ferrario et al. 2014). More than 100 million people globally receive risk reduction benefit from reefs, and if these ecosystems are degraded, then these communities will have to bear hazard mitigation and adaptation costs.

Much depends on the health of the reefs. Their resilience, overall reef health, and the toughness of the structure enable the continuance of protective services. Coral reef degradation is commonplace in developing countries. In several coastal stretches, in place of former vibrant coral reef systems, we have fragmented patches that may, in certain circumstances, prove counterproductive as these degraded systems may accelerate or focus the wave energy with potentially devastating consequences. The IUCN identifies unsustainable fishing, pollution, waste disposal, coastal development, sedimentation, SCUBA diving, anchoring, predator outbreaks, invasive species, and epidemic diseases as prime causes of coral degradation.

Furthermore, they estimate that twenty percent of coral reefs worldwide have been destroyed. Twenty-four percent are in imminent danger, and a further twenty-six percent are under long-term danger of collapse (Grimsditch and Salm 2005). Among the most significant threats coral reefs face is the prospect of bleaching due to high temperatures or due to ocean acidification. Coral bleaching generally happens when the ocean becomes too warm or due to changes in the oceanic waters' pH level, inducing the corals to expel the algae (zooxanthellae) living in their tissues, causing it to turn white. A bleached coral is not dead; corals can survive a bleaching event. However, they remain highly stressed, and if there are other stressors at work, it may become challenging for them to recuperate, and they can eventually die. Thus, while coral reefs can play an essential part in adaptation and mitigating climate change, these ecosystems ironically stand threatened by climate change and from other impacts due to anthropogenic development.

## Seagrass beds

Seagrasses are essentially flowering plants found submersed in shallow oceanic and estuarine waters worldwide, except for Antarctic waters. Their global coverage exceeds 177 000 $km^2$ (Bjork et al. 2008). Descendants of terrestrial plants that re-entered the ocean, there are nearly sixty species globally. An IUCN study points out that seagrass meadows provide ecosystem services that rank among the highest of all ecosystems in the world (Bjork et al. 2008). They stabilize sediments, serve as nursery grounds for commercially important fish and other species, prevent coastal erosion by attenuating waves, and filter suspended sediments and nutrients from the water column. They are an essential source of food for megaherbivores like dugongs and green sea turtles. Seagrass also serves as a carbon sink. As is the case with mangroves and coral reefs, seagrasses are experiencing declines due to anthropogenic stressors like eutrophication, landfill activities, destructive fishing practices, and pollution (Orth et al. 2006). They require some of the highest light levels among plants and are acutely responsive to environmental changes, particularly

those that affect water clarity (Orth et al. 2006). Climate change impacts like temperature stress, increased ultra-violet radiation, storms and related sediment disturbances, sea-level rise and increasing water depths, changes in pH can affect the vitality of seagrass ecosystems (Bjork et al. 2008).

In conclusion, coastal ecosystems such as mangroves, coral reefs, and seagrass beds are central in facilitating NBA. Their general ability to hold ground even in the face of intense storms and other extreme weather events renders them attractive as 'green walls'. They also serve to sustain and nurture the livelihoods of coastal communities dependent on these resources for their survival. Through this process, they augment the adaptive capacities of coastal communities. As well, their intense carbon sequestration potential renders these ecosystems extremely important in furthering climate change mitigation. In sum, similar to mangroves and corals, seagrass beds facilitate climate mitigation, climate adaptation and sustainable coastal development. These aspects can be discerned from an examination of Fig. 1.

## International law in the service of nature-based adaptation

This section examines the relevance of key multilateral environmental regimes, including the agreements and soft law instruments that they encompass: the UNCLOS, the CBD, the Ramsar Convention, the UN climate change regime, the World Heritage Convention and the international forestry regime. It explores how each of these instruments requires or encourages coastal state parties to further the NBA's cause by requiring and encouraging them to conserve and develop coastal ecosystems through their normative prescriptions and ensuing obligations.

### United Nations Convention on the Law of the Sea, 1982

The obvious starting point for exploring the applicable international legal regime is the United Nations Convention on the Law of the Sea, 1982 (UNCLOS) (Convention on the Law of the Sea 1982a). The UNCLOS heralded a new legal regime for the sustainable development of the oceans (U.N. General Assembly 2010). Being a treaty that germinated in the aftermath of the Stockholm Conference, it was natural for environmental and conservation-oriented matters to find a place in its text. These elements of UNCLOS, in turn, are relevant to the protection of mangrove, coral and seagrass bed ecosystems. The importance of marine environmental protection is evident right from the preamble to the UNCLOS, which states, 'a legal order for the seas and the oceans … will facilitate … the conservation of their living resources, and the study, protection and preservation of the marine environment.' It also requires state parties to protect and maintain their marine species, including those within its internal waters. Under the UNCLOS, states have the right to establish the breadth of their territorial sea up to a limit not exceeding twelve nautical miles, measured from baselines. The waters on the baseline's landward side constitute its internal waters where coastal states have sovereignty (Convention on the Law of the Sea 1982b). Since most coastal ecosystems formations, including mangroves, coral reefs and seagrass beds, are generally concentrated in waters that extend up to 50 meters in depth, this leaves most of these ecosystems within the scope of states' internal waters or in their territorial sea, and therefore under their exclusive sovereign jurisdiction. Even with respect to cold-water coral reefs, states can exercise jurisdiction over these living resources up to 200 nautical miles from their coastlines and even further in case of an extended continental shelf (Convention on the Law of the Sea 1982c).

Among the other specific interest provisions are part XII of the UNCLOS entitled 'Protection and Preservation of the Marine Environment' and its core articles (Convention on the Law of the Sea 1982d, General Assembly Resolution 2010). The starting point here is the unqualified obligation (Goodwin 2011) that the UNCLOS imposes on states an 'to protect and preserve the marine environment (Convention on the Law of the Sea 1982e).' While the Convention recognizes states' sovereign right to exploit their natural resources according to their environmental policies, it has to conform with their duty to protect and preserve the marine environment (Convention on the Law of the Sea 1982f). A strong presumption can thus be drawn that the duty to protect and preserve the marine environment takes precedence over the principle of national sovereignty.

One of the biggest threats that coastal and marine ecosystems face is from land-based sources of pollution. As a result of eutrophication fuelled by riverine run-off of fertilizers, sewage outfall and reactive nitrogen from the burning of fossil fuels, the number of hypoxic dead zones in oceans has increased severe threats to the stability and functioning of coastal and marine ecosystems (General Assembly Resolution

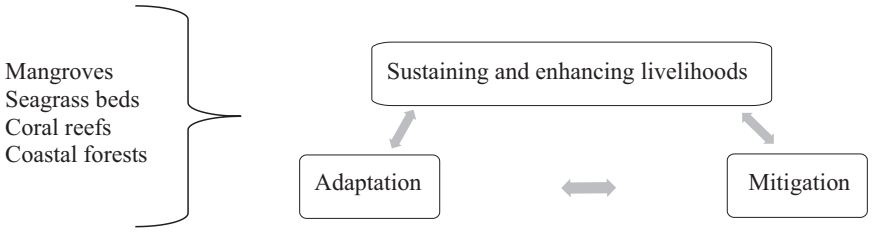


Figure 1. Nature-based adaptation for sustainable coastal development.

2010). Right from the time of the Stockholm Conference and its Declaration of 1972, and even before, states were called upon to take measures 'to prevent pollution of the seas, by substances … liable to create hazards to human health, to harm living resources and marine life, to damage amenities or to interfere with other legitimate uses of the sea.' (Stockholm Declaration 1972, Hassan 2004, London Convention 1972). This obligation was further developed in the UNCLOS. Parties are to adopt all measures either individually or jointly to 'prevent, reduce or control' marine environmental pollution from any source, using the best practicable means at their disposal and in accordance with their capabilities (Convention on the Law of the Sea 1982g). The obligation to control marine pollution is taken a step further by requiring parties to enact laws and regulations, taking into account internationally accepted rules, standards and recommended practices and procedures (Convention on the Law of the Sea 1982h). Such laws and regulations are to minimize the release of toxic, harmful or noxious substances, especially those that are persistent, into the marine environment to the fullest extent possible (Convention on the Law of the Sea 1982i).

Realizing that if legal regulation is left entirely in the hands of the more than 140 odd coastal states, this will result in a fragmented array of national laws prescribing different and even conflicting obligations, the UNCLOS calls upon states to endeavour to establish global and regional rules, standards and recommended practices and procedures considering characteristic regional features, the economic capacity of developing States and their need for economic development (Convention on the Law of the Sea 1982j). UNCLOS also emphasizes the need for States to enforce their laws and regulations relating to pollution from land-based sources (Convention on the Law of the Sea 1982k). Apart from legal tools to manage the problem, the Convention provides a sort of carte blanche power to States to take non-legal measures that may be necessary to prevent, reduce and control such pollution. Thus, states have considerable discretion to craft appropriate responses.

The Convention embodies the principle of no-harm, and parties are to take measures to deal with all sources of pollution to the marine environment, including the release of harmful, toxic or noxious substances (particularly, persistent) from land-based sources; pollution from vessels; and contamination from other installations used to explore the seabed and subsoil. Again, article 194(5) emphasizes the need to develop measures 'taken in accordance with this Part' and these 'include those necessary to protect and preserve rare or fragile ecosystems as well as the habitat of depleted, threatened or endangered species and other forms of marine life.' Even though this article's remit is to be guided by the heading of 'Measures to prevent, reduce and control pollution of the marine environment,' since it refers to measures to be 'taken in accordance with this Part,' the scope is broadened considerably. It is not restricted solely to pollution control. Viewed in this perspective, then, the reference to 'rare or fragile ecosystems' in the article practically enlarges the scope to include measures to protect ecosystems such as mangroves, seagrass beds, and corals (Goodwin 2011). States are also called upon to take measures to deal with the pollution that emanates from the use of technologies, and the introduction of alien species, which can, at times, turn invasive to decimate local fisheries (Convention on the Law of the Sea 1982l). The repercussions of such changes can prove catastrophic for coastal ecosystems. For instance, the mangroves share an intricate relationship with the fish that inhabit them. They act as nurseries to sustain the fish with food and provide the habitat. But, if certain invasives were to decimate the herbivorous fish, the reef algae could overrun the habitat.

### *Convention on Wetlands of International Importance especially as Waterfowl Habitat, 1971 (Ramsar)*

An essential international convention that can support coastal ecosystems' conservation is the Convention on Wetlands of International Importance, especially as Waterfowl Habitat (Ramsar Convention) (Ramsar Convention 1971a). In 1971, a year before the trail-blazing Stockholm Conference, the Ramsar Convention was concluded. It emerged as the first global multilateral environmental law agreement to deal with managing a particular habitat type (Goodwin 2011). The Convention defines wetlands are 'areas of marsh, fen, peatland, or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six meters' (Ramsar Convention 1971b) Even though the Ramsar Convention is often criticized for its narrow scope, evident from the definition of wetlands, the Convention is based on three primary pillars – firstly, the wise use of all wetlands; second, the designation of suitable wetlands in the List of Wetlands of International Importance (Ramsar List); and third, international cooperation (Tehran Declaration 2011). The obligations envisaged by its text can be grouped at two levels – the first deals with obligations regarding all wetlands, and the second is about obligations concerning listed wetlands.

As far as obligations in the first instance are concerned, they are the following: irrespective of whether the wetlands finds a place in the List or not, contracting parties establish nature reserves and provide for their adequate 'wardening' (Ramsar Convention 1971c). They are also to encourage research, exchange data and publications on this subject ((Ramsar Convention 1971d), promote personnel training (Ramsar Convention 1971e), and consult with each other regarding how the convention obligations are to be implemented, mainly when the subject matter is a transboundary wetland (Ramsar Convention 1971f, Ramsar 1999). Regarding wetlands that are included in the List, contracting parties are to formulate and implement 'planning to promote the conservation' and 'as far as possible the wise use of wetlands in their territory' (Ramsar Convention 1971g). Even though there was some early confusion regarding the use of

the terms 'conservation' in the case of listed wetlands and 'wise use' for non-listed wetlands, and whether they imply the same level of protection, it is now generally accepted that both refer to the same standard (Ramsar 2005, Goodwin 2011).

Contracting parties should select suitable wetlands found in their territories based on their international significance taking into consideration their ecological, botanical, zoological, limnological, or hydrological factors, for inclusion in a List of Wetlands of International Importance (List) (Ramsar Convention 1971h) maintained by the Bureau (International Union for Conservation of Nature and Natural Resources) (Ramsar Convention 1971i). Once wetlands are included in the List, the contracting party should devise and implement plans for wetland conservation (Ramsar Convention 1971j). Parties should also establish mechanisms to identify changes (actual or perceived) in any wetland's ecological character in the List. These changes can be due to technological developments, pollution or other human interference, and in such cases, the Bureau must be informed of the matter (Ramsar Convention 1971k). Where 'urgent national interests' warrant, contracting parties can delete or restrict a wetland's boundaries on the List. In such cases, the parties are to compensate for the loss by creating additional nature reserves for waterfowl, either in the same area or elsewhere.

The Ramsar Convention requires parties to periodically report how the commitments they have assumed under the Convention are being implemented, including those relating to mangroves. Every three years at the Conference of the Parties (COP), these commitments are reviewed, and additional measures are adopted to address wetland loss. These COPs have adopted several resolutions that directly pertain to mangrove conservation. The Ramsar Convention recognizes the relevance of wetlands in climate change mitigation and adaptation. The Tehran Declaration on Wetlands and Sustainable Development highlights that the 'wise use of wetlands plays a major role in climate change mitigation and adaptation including through the storage and sequestration of carbon and the regulation of the water cycle…' (Ramsar 2012). The contracting parties to Ramsar have also adopted resolutions that emphasize the need to protect and conserve wetlands to combat the impacts of climate change (Ramsar 2002). Presently, there are 290 mangrove sites on the List of Wetlands of International Importance globally, covering a total of 29 751 181 ha. As of 2016, more than 10% of total Ramsar sites include mangroves (Slobodian et al. 2018).

### The World Heritage Convention, 1972

Certain marine and coastal ecosystems like mangroves and coral reefs can be part of world heritage, subjecting these ecosystems to yet another layer of management and regulation at the international level. The United Nations Convention Concerning the Protection of the World Cultural and Natural Heritage (World Heritage Convention 1972a) negotiated and adopted under the auspices of the United Nations Educational, Scientific, and Cultural Organization at its seventeenth session in 1972, immediately in the wake of the Stockholm Conference, is yet another instrument that can be harnessed to protect coral reefs, mangrove forests and other coastal resources depending on their uniqueness. Coming at a time when the world's cultural and natural heritage was facing increasing threats of destruction, the World Heritage Convention furthers the principle of inter-generational equity by protecting cultural or natural heritage for future generations for 'the loss, through deterioration or disappearance, of any of these most prized assets constitutes an impoverishment of the heritage of all the peoples of the world' (UNESCO 2019). The Operational Guidelines for the Implementation of the World Heritage Convention (Operational Guidelines), even though not legally binding, facilitates the application of this Convention by providing parties with important guidance (UNESCO 2019).

The remit of the World Heritage Convention is to prevent the 'deterioration or disappearance' of 'cultural or natural heritage,' which leads to a 'harmful impoverishment' of the 'world heritage of mankind.' (World Heritage Convention 1972b) Natural heritage is defined to include physical and biological formations of 'outstanding universal value from the aesthetic or scientific point of view.' (World Heritage Convention 1972c, UNESCO 2019). It also includes 'geological and physiographical formations and precisely delineated areas which constitute the habitat of threatened species of animals and plants of outstanding universal value from the point of view of science or conservation.' (World Heritage Convention 1972c).

The World Heritage Convention calls upon parties to the utmost of their resources and, where appropriate, with international assistance and cooperation, to identify, protect, and transmit to future generations cultural and natural heritage (World Heritage Convention 1972d). This obligation is enhanced by requiring state parties to integrate heritage protection into comprehensive planning programmes. Parties must adopt appropriate legal, scientific, technical, administrative and financial measures to identify, protect, and rehabilitate heritage (World Heritage Convention 1972e). While state parties are to extend help to other state parties, they must not intentionally take any measures that might directly or indirectly harm other state parties' cultural and natural heritage (World Heritage Convention 1972f). An essential feature of this Convention is that it sets up an Intergovernmental Committee for the Protection of the Cultural and Natural Heritage of Outstanding Universal Value (the World Heritage Committee) (World Heritage Convention 1972g). This body maintains a 'World Heritage List' of properties of cultural and natural heritage. These properties are of 'outstanding universal value.' (World Heritage Convention 1972h). The term 'outstanding universal value' is crucial and the touchstone that helps delineate this treaty's jurisdictional boundaries (Goodwin 2011, UNESCO 2019).

'Outstanding universal value' is defined as 'cultural and/or natural significance which is so exceptional as to transcend national boundaries and be of common importance for present and future generations of all humanity.' (UNESCO

2019) In other words, for habitat or area to be included, it has to be of an exceptional standard, of the highest order, and that its protection is of the most profound concern to the international community as a whole (UNESCO 2019). Accordingly, the contracting State within whose territory the property situates has to identify and create an inventory that it finds suitable for inclusion in the List (World Heritage Convention 1972i). These tentative lists are submitted to the World Heritage Committee (UNESCO 2019), who then decides by a majority of two-thirds of its members present and voting (World Heritage convention 1972j) whether to inscribe the nominated property on to the List or to reject or refer the matter back to the nominating State.

The practical implications that ensue when a property is inscribed into the List are that a series of technical and financial assistance is made available for its maintenance and upkeep (World Heritage Convention 1972k). Another essential feature of the World Heritage Convention is that it provides for creating a List of World Heritage in Danger (Danger List). Properties on the World Heritage List, threatened by grave and specific dangers, such as accelerated deterioration, urban or tourist development projects; armed conflict; calamities and cataclysms; and natural disasters are included in the Danger list. Once in the Danger List, the property is given priority in securing international assistance (UNESCO 2019).

Even though several coral reefs, mangroves, and other coastal wetlands are on the World Heritage List (UNEP 2020), many of these fall under its protective ambit as part of a broader ecosystem of natural sites. The requirement of outstanding universal value implies that only very few systems may ultimately find a place in the List. Of course, the World Heritage Convention imposes obligations on all its state parties irrespective of whether a given site is on the List or not. These obligations can trigger action at the national level. There are important conditions laid down in the Operational Guidelines, regarding criteria for natural properties to be included on the World Heritage List. The conditions include that the property should be under a system of protection and management (UNESCO 2019) have its boundaries delineated, and the property identified (UNESCO 2019), and that such boundaries can coincide with existing or proposed nationally protected areas (UNESCO 2019), and can support protected areas (Goodwin 2011). In sum, while seeking to promote the protection of sites of outstanding universal value by amalgamating nature conservation with the preservation of cultural properties, the World Heritage Convention plays a more tangential role. It is not pivotal to protecting the coastal and marine environment.

### The Convention on Biological Diversity, 1992 (CBD)

Based on the principle that 'conservation of biological diversity is a common concern of humankind,' (Convention on Biological Diversity 1992a) the Convention on Biological Diversity (CBD) focuses on three core areas, namely: 'conservation of biological diversity', 'sustainable use of its components', and 'fair and equitable sharing of the benefits of genetic resources' (Convention on Biological Diversity 1992b). The CBD is the principal international instrument on biodiversity conservation and related matters. The CBD does not per se refer to mangroves, coral reefs, seagrass beds or to any other specific ecosystem; instead, biological diversity is defined in rather broad terms to include 'marine and other aquatic ecosystems and the ecological complexes of which they are part.' (Convention on Biological Diversity 1992c) The definition is comprehensive in its ambit to include coastal ecosystems (Convention on Biological Diversity 2011-2020).

The CBD calls upon contracting parties to develop novel or alter existing national strategies, plans or programmes for biological diversity conservation and its utilization in a sustainable manner (Convention on Biological Diversity 1992d), identify and monitor biological diversity components important for conservation and sustainable use (Convention on Biological Diversity 1992e), and identify and monitor activities that can adversely affect them (Convention on Biological Diversity 1992f). The CBD contemplates both in situ (Convention on Biological Diversity 1992g) and ex situ conservation with preference to in situ as 'the fundamental requirement for biological diversity conservation'. Furthermore, it is provided that contracting parties are (as far as possible and as appropriate) to establish a system of protected areas or areas where special measures are needed to conserve biodiversity. Besides, they should develop guidelines on selecting, establishing, and managing such sites (Convention on Biological Diversity 1992h, 2004a). This is perhaps the most crucial provision central to marine environmental protection, including coastal ecosystem conservation and management. Area-based conservation measures, mainly marine protected areas, are helpful and have universal recognition for being an essential tool for biological diversity conservation and the sustainable use of its components.

Equally important is the ecosystem-based approach advocated by the CBD regime, which is a strategy that targets the 'integrated management of land, water and living resources' to promote their conservation and sustainable use in an equitable manner (Convention on Biological Diversity 2020). The ecosystem-based approach emerges as the loadstar, providing a pathway to attaining the three core objectives that the CBD stands for (Convention on Biological Diversity 2000). Representing a learning process by doing, it is a useful normative framework that brings together social, economic, cultural and environmental values, producing 'positive outcomes for both biodiversity and human well-being' (Convention on Biological Diversity 2008). Even though the convention text does not expressly deal with the ecosystem-based approach, the concept draws sustenance from the definition to the term ecosystem in the Convention, namely that it is 'a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.' (Convention on Biological Diversity 1992i)

Subsequently, the different COPs to the CBD have supplied flesh and bones to this concept and have encouraged its more comprehensive application (Convention on Biological Diversity 2002, 2004b).

The CBD has been criticized for its predisposition towards terrestrial environments and its biodiversity. To offset such criticism, the Jakarta Mandate was adopted at the second COP of the CBD in 1995 (Convention on Biological Diversity 1995). It outlines the programme of action for implementing the Convention for protecting marine and coastal biodiversity. Since then, the COP has consistently adopted decisions specifically relevant to marine and coastal biodiversity conservation (Convention on Biological Diversity 2004c). In short, the CBD, being an almost universally subscribed treaty with a clear mandate to create protected areas, emerges as the centrepiece instrument in an otherwise diffused regime on marine environmental protection. The ecosystem approach that it espouses can play an essential part in conserving coastal wetlands and mangroves.

### The UN Climate Regime

The UN Framework Convention on Climate Change was adopted in 1992 and entered into force in 1994. It's aim is to protect the climate system for present and future generations. The initial focus of the UN climate regime was on mitigation, though even the UNFCCC does call on state parties to adopt measures to facilitate adequate adaptation to climate change (UNFCCC 1992). The most relevant provisions of the UNFCCC concerning NBA are articles 4(1) (d) and (e). Article 4(1) (d) calls upon parties to promote and cooperate with conservation and enhance sinks and reservoirs of all greenhouse gases, including biomass, forests and oceans, and other terrestrial, coastal and marine ecosystems. Article 4(1) (e) calls on parties to develop appropriate and integrated plans for coastal zone management. Adaptation has gradually become more of a focus of the UN climate regime, particularly following the adoption and eventual entry into force of the Kyoto Protocol (Kyoto Protocol 1997, Suarez and Kallhauge 2017).

Among the initiatives under the UNFCCC that have relevance for NBA is an effort on Reducing Emissions from Deforestation and forest Degradation (REDD+), a mechanism developed to protect natural carbon sinks in forests in developing countries. It seeks to create financial value for the carbon stored in such forests and offer incentives for developing countries to protect their forest ecosystems. The basic idea is for developing countries to receive results-based payments for results-based actions. REDD+ goes beyond simply deforestation and forest degradation and includes the role of conservation, sustainable management of forests and enhancement of forest carbon stocks (UNFCCC Decision 9/CP.19; Abidin 2015).

Since 2015, the Paris Agreement (Paris Agreement 2015a) has become the heart and focus of the UN Climate Regime. The Paris Agreement (PA) is the product of a decade-long negotiating process to develop a post-2020 climate regime to replace the Kyoto Protocol (Kyoto Protocol 1997). The PA covers all key elements of the new climate regime, including mitigation, adaptation, loss and damage, finance, technology, capacity-building, education, transparency, stocktaking, compliance, procedural issues, and institutional arrangements.

The key elements of the PA include the nationally determined contributions (NDCs) made by all parties to the Agreement, the commitment to significant funding for developing countries, five-year stocktaking and review cycles, enhanced transparency, and a facilitative approach to compliance. These individual elements are collectively expected to contribute to a robust long-term ambitious goal of keeping the global average temperature increases to well below 2 degrees Celsius. The PA confirms the need for all countries to contribute to this collective goal in light of their capacity, responsibility, and other national circumstances. Preambular language in the Paris Agreement includes substantial references to gender equity, human rights, and intergenerational equity.

The UN Climate Regime has long struggled with the relationship and relative priority of the three key elements of an effective global response to human-induced climate change, mitigation, adaptation and loss and damage. The challenge is further complicated by the many cross-cutting issues, such as finance, technology, capacity building, transparency, accountability and compliance, that have to be addressed for an effective global response to climate change. The PA marks an important milestone in moving forward on these interrelated issues, particularly on adaptation in the regime. It does so through several breakthroughs that enhance the profile and role of adaptation and, to a lesser extent, loss and damage, in the regime.

Adaptation and the related issue of loss and damage have long been priorities for developing countries, while developed countries have tended to focus on mitigation. Developing countries initially struggled to make adaptation or loss and damage a priority, in part because they were exempt from mitigation obligations under the UNFCCC (UNFCCC 1992) and its Kyoto Protocol. This all changed when developing countries agreed to take on mitigation commitments in the PA, even though they collectively have much less capacity and responsibility to address climate mitigation. The resulting leverage enabled developing countries to push for a higher priority for both adaptation and loss and damage in the PA than the UNFCCC and the Kyoto Protocol. As a result, the PA has significantly advanced the adaptation agenda.

With respect to adaptation, the PA offers the following key advancements:

- It includes a stand-alone article on adaptation alongside articles on mitigation, finance, technology and loss and damage.
- It includes a global goal on adaptation as a key way to highlight the importance of adaptation along with the global mitigation goal represented as the temperature goal of well below 2 degrees.

- Adaptation efforts are to be included in parties' nationally determined contributions (NDCs). These NDCs are required to be filed by all parties and have to be updated regularly.
- Adaptation is recognized as a priority for the $US100 billion finance to be mobilized annually starting in 2020.
- Adaptation is included in the global stocktake to take place every five years, ensuring that both national progress and the adequacy of international support for adaptation will remain on the agenda of the parties to the PA.
- There is a clear recognition in the PA about the links between mitigation and adaptation, particularly the reality that the more effective the mitigation efforts, the more manageable the adaptation challenge will be (Perez and Kallhauge 2017).

With respect to loss and damage, the issue is now formally recognized along with mitigation and adaptation as a key stand along with the element of the PA. However, loss and damage is not recognized in the finance provisions, it is not a required element of NDCs, and it is not clear whether loss and damage will be included in the global stocktake (Paris Agreement 2015b). As a result, the future of loss and damage is uncertain for the time being, further highlighting the importance of effective mitigation and adaptation under the PA (Siegele 2017).

Ultimately, the PA leaves much to be resolved on both adaptation and loss and damage, including the NBA's role in protecting coastal ecosystems and communities that depend on them. In particular, there is a need for more clarity on the priority given to nature-based solutions in the PA's collective effort to support adaptation in developing countries. The benefits of nature-based adaptation through the protection and enhancement of coral, seagrass bed and mangrove ecosystems are clear and multiple. The mechanisms to give appropriate priority to efforts to protect and enhance these ecosystems are in place. Ultimately, the global stocktake offers perhaps the most promising opportunity to ensure that national adaptation plans and global finance for adaptation give appropriate priority to these important nature-based solutions to coastal adaptation needs.

### Other instruments

Apart from the above regimes, there are other multilateral environmental agreements pertinent to nature-based adaptation. The Convention on International Trade in Endangered Species of Wild Flora and Fauna can play a role by regulating the trade in coral reef specimens and products (CITES 1973). The International Maritime Organization also plays a part in conserving these ecosystems through designations such as special areas under the MARPOL and particularly sensitive sea areas (International Maritime Organization 2006). Among the most important of the other regimes is the international law on forest conservation and management. Mangrove forests, tropical peat-swamp forests, and other coastal forests can be subjected to an additional layer of regulation and management at the international level qua the forest conservation instruments.

Despite this importance, we are yet to see a binding international instrument that tackles forests' sustainable management at the international level. In this direction, attempts were effectively stonewalled by states unwilling to take on binding commitments that diminish their sovereign rights to manage and utilize forest resources (Maguire 2012). Accordingly, a patchwork of international instruments exists, administered by several institutions. Many of these are relevant from the perspective of coastal forest protection.

The primary international institution that deals with forest management is the United Nations Forum on Forests (UNFF). Established as a subsidiary body under the Economic and Social Council of the United Nations via Resolution 2000/35, its chief objective is to promote '… the management, conservation and sustainable development of all types of forests and to strengthen long-term political commitment to this end…' (ECOSOC 2000). This brings to focus the Non-binding Authoritative Statement of Principles for a Global Consensus on the Management, Conservation and Sustainable Development of All Types of Forests, 1992 (Rio Forest Principles) and the Non-legally binding Instrument on all Types of Forests 2007 (United Nations 1993).

International negotiations for a globally binding forest convention was initiated in 1990, by the G-7, to be finalized and adopted in 1992, at the Rio United Nations Conference on Environment and Development (UNCED). However, during the negotiations, it became apparent that the international community was sharply divided, and consensus regarding a binding forest convention was elusive. There was even disagreement on whether such a convention should be negotiated at all. Finally, as a compromise between the developed and developing countries, the juridically non-binding Rio Forest Principles were adopted. They make several recommendations for forest conservation and sustainable forestry. In this regard, Chapter 11 of Agenda 21 on Combating Deforestation is also relevant.

The efforts spearheaded by the UNFF finally led to the UN General Assembly's adoption of the Non-Legally Binding Instrument on All Types of Forests (renamed as the UN Forest Instrument in 2015). The UN Forest Instrument in 2015 is a more comprehensive document than its predecessor, and it applies to all types of forests (U.N. General assembly 2016, ECOSOC 2016) It defines sustainable forest management' as a dynamic and evolving concept,' that 'aims to maintain and enhance the economic, social and environmental values of all types of forests, for the benefit of present and future generations.' (ECOSOC 2016).

The UN Forest Instrument in 2015 is based on four global objectives, which include reversing the loss of forest cover and increase efforts to prevent forest degradation; improve the livelihoods of forest-dependent people; significantly increase the area of protected forests and increased, new and additional financial resources from all sources for the implementation of sustainable forest management (ECOSOC 2016). Since the primary responsibility for the sustainable

management of its forests and the enforcement of its forest-related laws falls on the concerned State, the UN Forest Instrument in 2015 casts obligations on States relating to national policies and measures (ECOSOC 2016) and set out measures on international cooperation and means of implementation (ECOSOC 2016). In sum, even though both the instruments are non-binding in their scope, they still provide comprehensive direction useful to the conservation of these ecosystems.

## Summary of international law context

To summarize, analysis of the most relevant international law sources reveals that the international law instruments identified are general and that most only indirectly touch upon the issue of coastal and marine ecosystem management, let alone address nature-based climate change adaptation issues. This is because most of these instruments were adopted when climate change adaptation and the importance of NBA were not issues of global concern. Nevertheless, they offer essential context as the prescriptions contained therein impel the conservation and preservation of ecosystems and resources, including coastal areas. Moreover, of course, a healthy coastal ecosystem enables effective adaptation to climate change.

The discussion reveals that many international treaties deal with protecting coastal and marine ecosystems directly or indirectly. This exercise's objective was to identify critical linkages between the goal of conservation, the NBA, and these instruments. Despite areas of congruence in the applicable law, overall, the relevant linkages are not always well interwoven to provide a comprehensive basis to support the development of actions at the national level. This is a cause for concern, particularly for developing countries that continue to be hamstrung by capacity constraints, technological inability, lack of resources (despite calls on developed country parties by the above-identified treaties to provide financial aid and technology transfer), and competing interests. The MEA's identified do not add up to provide a wholesome legal response to this issue, now made more intricate and complicated given increasing sea surface temperatures, sea-level rise and the downward swings in the pH level of the oceans. Nevertheless, however diffused the existing international legal framework may be, it does guide national governments. Therefore, the focus now must shift from law and policy formulation to implementation of existing obligations at the national level.

A major stumbling block that has prevented comprehensive approaches towards conserving the coastal and marine environment is that most of these valuable resources fall within the coastal State's jurisdictional ambit, subject, of course, to the no harm principle. The practical implications of national sovereignty fly in the face of the conservation efforts, as envisaged in the different international law instruments, considerably denting their potency. Even though countries profess loyalty to sustainable development, a significant factor that has proved detrimental to environmental protection efforts is prioritizing short-term economic gains that involve their retrogression and decimation by irresponsible development.

Interestingly, all these instruments support the designation of marine protected areas as a primary tool to protect and conserve degraded ecosystems. Constituting such enclaves has merits. Unfortunately, many marine protected areas are 'paper parks' (MPA News 2001) that are increasingly under threat (Monbiot 2012). It is also doubtful whether MPA designation and ensuing protective measures can protect these sensitive ecosystems from the over-arching threat of climate change. This reflects an insufficient commitment by the states regarding their international commitments, which majorly contribute to the degradation of coastal and marine ecosystems, rendering them non-resilient to climate change impacts. Therefore, it is incumbent upon respective coastal states to implement international environmental law mandates by adopting measures to put these principles into practice.

## Facilitating nature-based adaptation through mangrove conservation: lessons from Bangladesh

Bangladesh is one of the world's most vulnerable countries to natural disasters. Its coastline is about 600 km long and is primarily situated just one meter a.s.l. The coastal areas are replete in biodiversity, blessed with various flora, fauna, their supportive habitats, and ecosystems. However, they are highly fragile and are exposed to various kinds of hydro-meteorological disasters, including floods, cyclones, tidal surges, and salinity intrusion. These coastal ecosystems are further threatened by non-climatic stressors, such as land-use change, sedimentation, water pollution, and overfishing.

Administratively, Bangladesh's coastal zone is organized into nineteen districts that fall under three distinct regions. The coastal zones accommodate nearly 28 percent of the total population, and most of them live below the poverty line and are highly dependent on natural resources. There is an overwhelming consensus among the climate change epistemic communities that Bangladesh is one of the most negatively impacted countries by climate change including SLR. For Bangladesh, these negative impacts are 'life-threatening,' rather than 'lifestyle threatening', (Jolly et al. 2014) and they will magnify existing adverse trends. It is believed that climate change has already led to significant anomalies in rainfall patterns, which has affected the stability of the water regime. As a country that is more than 80% floodplain, such changes to the water sector have increased coastal erosion, the recurrence of drought, and salinity intrusion from the Bay of Bengal, reducing the overall potable water availability, hindering water access to worsen rural poverty.

Coastal Bangladesh accommodates around 35 million people who live in the nineteen coastal districts. These are the populations most vulnerable to climate risks. Global warming is expected to inundate 10-15% of Bangladesh's land by 2050, resulting in the displacement of over 35 million peoples from the coastal districts (Hasan et al. 2013).

Bangladesh is home to some of the world's largest agglomerations of mangroves, including two-third of the Sundarban, with the remaining one-third within India's national border. The Sunderbans is a unique hydrological interface where the freshwater flows of the tributaries and distributaries of the Ganges–Brahmaputra riverine system mix with saline waters of the Bay of Bengal to create a mangrove forest that covers nearly 10 000 km$^2$. This mangrove ecosystem is home to astonishing biodiversity and iconic wildlife, including the highly endangered Asia's last two remaining species of freshwater dolphin and the only population of tigers (royal Bengal tiger, *Panthera tigris*) that live entirely in mangroves.

These mangrove ecosystems perform a range of essential services. Apart from filtering pollutants from upstream runoff, the Sundarbans provide an abundant supply of natural resources, including fish, crustaceans, firewood, nipa palm and honey, to sustains the ever-increasing human population that lives along its fringes. The mangroves also provide coastal hazard protection and erosion control, acting as a buffer against natural disasters and the rising seas. The Sundarbans was declared a Ramsar site in 1992 and is also a World Heritage Site. The health of these mangrove ecosystems is deteriorating fast due to a combination of factors, including extensive saltwater shrimp aquaculture, pollution, high dependency of locals on mangrove resources leading to overexploitation, inadequate understanding of ecosystem dynamics, and sea-level rise (Government of Bangladesh 2015).

For long, in Bangladesh, coastal greenbelts have been viewed as an essential strategy to reduce the vulnerability of exposed coastal coastlines and populations. Bangladesh has placed faith in mangroves to provide a protective barrier for the coastal communities and their villages situated on the shoreline and create coastal environments that also provide biodiversity benefits. Since the 1960s, Bangladesh has resorted to massive afforestation with nearly 200 000 ha of mangroves planted along the coast. However, these efforts have not been entirely successful due to several institutional, technical, policy, and socioeconomic factors discussed below. Simply put, the long-term sustainability of coastal greenbelts has so far not been ensured.

Nevertheless, 'coastal afforestation as means of coastal protection has a long tradition in Bangladesh, which has created a virtual green wall along with many areas of the active Ganges–Brahmaputra–Meghna delta.'(Bujan and Hussainy 2016) Bangladesh is also one of the few countries in the developing world that has recognized the importance of NBA options and have developed appropriate legal and policy frameworks to support its implementation. Given its unique geographical features, mangrove plantations have emerged as one of the key NBA measures. With assistance from international donors, Bangladesh has implemented large-scale mangrove afforestation projects. Several small-scale community-based projects are also underway.

To help ensure coastal greenbelts' are managed sustainably, the UNDP initiated a four-year project called the 'Community Based Adaptation to Climate Change through Coastal Afforestation in Bangladesh' (CBACC). This project was implemented between 2009 and 2015 with UNDP-GEF (Least Developed Countries Fund LDCF). The CBACC project aimed to reduce coastal communities' vulnerability to climate change impacts through coastal afforestation and livelihood diversification. It sought to promote climate-resilient development in the coastal areas of Bangladesh. It was implemented in four upazilas (sub-district) in the coastal districts of Barguna and Patuakhali (western region), Bhola (central region), Noakhali (central region), and Chittagong (eastern region) (Ferguson and Das 2012). The project included two key components: afforestation and livelihood development. One of the most important afforestation measures identified was to create mangrove plantations on newly accredited land. Several Government Ministries and Departments, such as the Ministry of Fisheries and Livestock, and the Department of Lands, were involved (Ferguson and Das 2012). The project was successfully implemented, and virtually all targets were achieved or exceeded. The original target was only 6000 ha. This was subsequently revised, and nearly 9000 ha of mangrove forests were created, resulting in 241 metric tons (Mt) of annual carbon storage (Bujan and Hussainy 2016). The primary mangrove species employed were *Sonneratia apetala*, and *Avecinnia Officinalis*, even though other species that occur naturally in Bangladesh were also used (Bujan and Hussainy 2016). The mangrove afforestation component involved 1032 households, which also enhanced their livelihood (Bujan and Hussainy 2016).

Subsequently, in 2016, UNDP Bangladesh, with GEF/LDCF funding, took up the 'Integrating Community-based Adaptation into Afforestation and Reforestation (ICBA-AR) Programmes in Bangladesh'. The prime objective of this project, executed by the Ministry of Environment and Forests (MoEF) was to reduce vulnerabilities of communities 'to the adverse impacts of climate change through participative design, community-based management and diversification of afforestation and reforestation programmes.'(Government of Bangladesh 2017b) Its striking feature is that it links the livelihood aspirations of coastal communities with the country's coastal greenbelt management system. In other words, it integrates livelihood with coastal afforestation and reforestation, thereby reducing climate change vulnerabilities and enhancing livelihood opportunities. The project concluded recently, and the total budgetary allocation was the US $ 5 650 000. Eight climate-vulnerable coastal sub-districts were chosen for implementation. The following are the three project outcomes. Outcome-1 addressed existing barriers in terms of livelihood opportunities and the need for coastal forest diversification, impacting coastal forest sustainability. The emphasis on Outcome-II was to strengthen community engagement and ownership of forestry-based adaptation and climate risk reduction programs. Outcome – 3 focused on protecting communal livelihood assets in afforestation and reforestation sites from extreme climate events through sufficient early warning and preparedness planning (Government of Bangladesh 2017a). The project involved the planting

of climate-resilient mangrove and non-mangrove species. Overall, the project has made significant strides in reducing the vulnerability of communities through afforestation and reforestation. Several activities towards diversifying livelihood options, making effective greenbelts, and diversifying mangroves plantations were undertaken, and, as per the Mid-term Review Report, the achievements are 'satisfactory.'

All the same, it must be pointed out that Bangladesh has not excluded hard engineering. With financial support from the World Bank, the country is implementing the Coastal Embankment Improvement Project - phase I (Rijai and Choudhury 2019). These embankment programs have been relatively successful in mitigating saltwater intrusion. The project aims to cover a net area of about 100 817 ha covering six districts (World Bank 2019). However, due to poor construction and lack of maintenance, there have been reports of pluvial flooding and excessive waterlogging in several places (Adnan et al. 2019).

In most coastal countries, climate change-related risks, mitigation, and, more importantly, adaptation concerns are seldom reflected in laws and policies that contribute to coastal development governance. This failure to incorporate climate concerns into existing coastal development strategies, programmes, laws and policies is a primary constraint that hampers sustainable coastal development. Fragmentation between different government agencies and departments, turf protection, and very little policy integration across sectors, let alone incorporating climate change concerns, continue. However, Bangladesh has managed to create a supportive legal and policy environment. Notably, it is a party to all the major environmental law conventions identified earlier relevant to coastal and marine environmental protection and NBA.

Even though there is no direct legislation on mangrove conservation in Bangladesh, the overall environmental legal and policy framework is supportive of the central idea that enhancing the resiliency of ecosystems and biodiversity through protection and conservation enables effective adaptation to climate change impacts. As well, by protecting and conserving biodiversity and related ecosystems, subsistence economies that depend on these resources will be able to thrive, and their adaptive capacities will be considerably enhanced. The salience of some of these legislations supportive of mangrove conservation is provided below.

The Bangladesh Environment Conservation Act, 1995 empowers the Ministry of Environment and Forests to declare 'ecologically critical areas' to prevent ecosystems' degradation. Utilizing this power, in 1999, Bangladesh declared a 10-km landward periphery from the Sundarbans boundary as an ecologically critical area (ECA) covering about 292 926 ha. This declaration has enhanced the conservation efforts of this globally unique mangrove ecosystem.

Bangladesh is rich in biodiversity. The Sunderbans itself supports a rich fish fauna of 400 species, 270 species of birds and over 300 species of plants. The economy, the life and livelihoods of the people are intertwined with the various goods and services provided by these ecosystems. For instance, the Sunderbans annually contributes somewhere between USD273 million to USD714 million to the Bangladesh economy (Government of Bangladesh 2016). Recognizing the importance of biodiversity to the country's overall development and economic progress, the Constitution of Bangladesh calls for the protection and improvement of the environment and biodiversity, including the wetlands and forests for the present and future generations of citizens (Government of Bangladesh 1972). Perhaps the most critical legislation from the perspective of biodiversity conservation is the Bangladesh Biological Diversity Act, 2017. This legislation regulates biodiversity conservation and seeks to secure the sustainable use of resources and biota and to provide a fair and equitable share of the benefits derived from their use. The comprehensive National Bioversity Strategy and Action Plan of Bangladesh 2016-2021, which identifies fifty activities under twenty headline targets for biodiversity conservation, supplements the legal framework.

The lives of the people of Bangladesh, its environment, and the ability to adapt to the salinity intrusion from the Bay of Bengal are primarily dependent upon freshwater availability. The water ecosystem of this country is mostly dependent on three major rivers: the Ganges-Padma, the Brahmaputra, and the Meghna, which drain through Bangladesh to merge with the Bay of Bengal. However, since more than ninety percent of the annual run-off enters this country from outside its borders, there is a great degree of uncertainty as any water diversion by the upper riparians can lead to deleterious consequences (Government of Bangladesh 2005). India used to withdraw large quantities of water at the Farakka barrage to ensure navigability in the Kolkata port to Bangladesh's detriment. Eventhough the Ganges treaty has brought about a semblance of balance, the Farakka and India's plans to interlink the various rivers that flow through its territories, even if some are international watercourses, to the detriment of other riparian states continues to be an irritant. Since the water that flows through its rivers is the lifeblood of Bangladesh, and water is the primary medium through which climate change impacts will be felt, Bangladesh must develop its water resources sustainably. In this context, it is worthy to note that due to increased salinity, the Sunderbans mangrove forests' density has decreased. In 1959, the total growing stock of plants per hectare was 296. By 1996, it had fallen to 144, less than half (Government of Bangladesh 2016-2021). The Bangladesh Water Act, 2013 (Government of Bangladesh 2013) established the normative framework for the integrated development, protection, and conservation of water resources. A provision significant for mangrove conservation is S.20. It prohibits persons or organizations from stopping or creating obstacles to the natural flow of any watercourse. As part of the fortification of flood control embankments and to ensure the tree plantation programs' success, the law also provides for planting suitable trees alongside an embankment in an organized and planned manner (Government of Bangladesh 2013).

The Wildlife (Conservation and Security) Act, 2012 (Government of Bangladesh 2012) is a comprehensive law aimed at conserving and protecting biodiversity, forest, and wildlife. It mirrors the underlying philosophy of article 18A of the Constitution. This law has several provisions relevant to mangrove conservation. For instance, it prohibits willful picking, uprooting, destroying, or collecting any plant mentioned in Schedule IV (Government of Bangladesh 2012). The Government can declare any government forests or any government land or wetland as a sanctuary (known by nomenclatures like a wildlife sanctuary, wetland-dependent animal sanctuary or marine protected area) for conserving forest and wildlife habitats (Government of Bangladesh 2012). Once a wetland is declared as a sanctuary, measures to protect the occupational, traditional or the right of livelihood of local communities like fishers and boatmen should be taken (Government of Bangladesh 2012). In a sanctuary, activities such as harvesting, destroying or collecting any plant, setting a fire, introducing alien and invasive plant species, diverting or polluting watercourses are prohibited.

Even though one-third of Bangladesh is coastal, it is yet to enact a coastal law. Nevertheless, it has a Coastal Zone Policy of 2005, which identifies integrated coastal zone management (ICZM) as key to coastal development and implementing nature-based adaptation management options. The Coastal Zone Policy commits different ministries, departments, and agencies to coordinate their activities across sectors. Among the various measures that the Policy highlights as part of the strategy to reduce vulnerabilities, it identifies sea-dykes as the first line of defence against storm surges and afforestation on it as significant (Ministry of Water Resources 2005). It also talks about the importance of social forestry and the need for afforestation (Ministry of Water Resources 2005), meaningful conservation of critical ecosystems through marine reserves, heritage sites, etc. (Ministry of Water Resources 2005) To ensure the effective implementation of the Coastal Zone Policy, 2005, through governance and concrete interventions, the Government has brought out the Coastal Development Strategy, 2006. This policy identifies nine strategic priorities, including safety from natural hazards and improving livelihood conditions (Ministry of Water Resource 2006).

As far as climate change adaptation is concerned, the Climate Change Strategy and Action Plan, 2009 emphasizes the need for climate-proofing. As part of the adaptation strategy, it specifically identifies the need to implement coastal greenbelt projects that involve mangrove planting along the shoreline. The National Adaptation Programme of Action (NAPA) prepared by the Ministry of Environment and Forest, clearly specifies coastal afforestation with community participation as a critical adaptation strategy (Government of Bangladesh 2005). The document identifies fifteen projects to address the adverse effects of climate change. Among these projects, critical to our discussion is 'reduction of climate change hazards through coastal afforestation with community participation'. This project, among others, envisages enhancing the vegetative cover along the Bangladesh coast (Ministry of Water Resources 2005).

## Discussion

Given its unique geography and vulnerabilities, NBA options to climate change impacts and sea-level rise offer the best prospects for countries like Bangladesh. As one of the few countries in the developing world that has recognized that climate change adaptation has to be mainstreamed within the existing development processes, Bangladesh has ensured an efficient use of scarce resources and that the planners and the Government are equipped better to handle the ensuing challenges. This country has also shown a significant affinity towards developing a coherent policy and legal framework supportive of NBA. This is reflected by a growing recognition and integration of climate change adaptation concerns in their environment and resource-conservation laws, national-level policy-making processes, and local-level development practices. Another important lesson that emerges from Bangladesh is that NBA is community-centric. NBA is based on the community's needs, their livelihood requirements, and their developmental aspirations. NBA processes are result-oriented when funnelled by the community.

In sum, Bangladesh has a superior legal and policy framework that recognizes the importance of mangrove restoration and rehabilitation to address natural disasters and adapt to climate change. These have emerged as the hallmark of Bangladesh's approach to climate change adaptation. Bangladesh has also made remarkable strides in attaining consistent economic growth and reducing poverty. It has been climbing up the rugs, and presently it finds itself situated as a lower-middle-income country. However, as elsewhere, it is in the implementation where limited capacity and resources and long-standing biases favouring short-term economic development pose the primary problems. The Sundarbans and their related environs run the risk of accelerated industrialization. Despite overwhelming evidence that healthy mangrove ecosystems are critical to Bangladesh, the country has embarked on an ambitious project with support from neighbouring India to construct a mega coal-fired power plant in the close vicinity of the Sunderbans. Many believe that the harmful pollution that the Rampal power plant could generate would endanger these mangrove ecosystems and jeopardize the lives of those who depend on the mangroves for their basic sustenance (Islam and Al-Amin 2019). Of course, coal-fired power plants have contributed significantly to the greenhouse gas emissions that fuel global warming. At the same time, it is the mangroves that have the potential to decelerate climate change by soaking up carbon.

## Conclusion

At least in the immediate future, the rush to the shoreline continues to show no signs of abatement. However, coastal communities that live and depend on coastal lands, ecosystems, and resources are hard-pressed to continue to benefit from unsustainable coastal development and marine pollution. Without realizing coastal ecosystems' potential as a

plausible solution to the adaptation-mitigation conundrum, human hands continue to degrade them, drain them, or fill them up. All this suggests that coastal ecosystems are in greater need of protection now than at any time in the past.

Compounding matters, the intractable warming climate and rising sea levels have already raised the spectre of large-scale inundation and permanent shoreline changes. In other words, there is a high threat that some of these ecosystems and the services they provide will be permanently lost. Despite the possibility of this scenario playing out, the irony is that these very coastal ecosystems that stand to be engulfed by climate change and a rising sea, particularly mangroves and reefs, offer a reasonable prospect of reducing coastal vulnerability to the rising seas and other hazards. Nature-based adaptation options provide a protective barrier to coastal communities and their homes, often situated close to the shoreline. These coastal ecosystems can also help sustain the livelihood opportunities and enhance the adaptive capabilities of vulnerable coastal communities' through the continued provision of essential services, including food, fibre, and fuel. Therefore, it is extremely critical that the health of these coastal ecosystems is maintained and that they are nourished. This in turn highlights the importance of law and legal systems, as they play a supportive role in creating an enabling environment that provides for the protection of these ecosystems and facilitates the implementation of NBA.

While one of the core objectives of this paper was to highlight the benefits of NBA, it does not seek to devalue the importance and utility of hard engineering options in appropriate circumstances. Given current coastal realities, it will likely not be possible to do without hard engineering adaptation options. In some highly urbanized coastal stretches, hard engineering may be the only feasible choice. But in others, particularly those with less infrastructure and alternative land for relocation, policymakers would well be advised to prioritize nature-based adaptation over hard engineering. NBA may also be preferable for coastal communities with limited resources and those suffering from the ill-effects of improperly placed and constructed civil engineering structures. There will likely also be coastlines that will demand a judicious blend of hard-engineering and NBA solutions.

Conserving and augmenting coastal and marine ecosystems is perhaps the most economical and sustainable way to implement NBA actions, more so, since we are now increasingly cognizant of the potential of these ecosystems as sinks. Therefore, one of the most critical pre-requisites in successfully implementing adaptation is that it must be based on an integrated approach. This is particularly so in the case of NBA actions that require recognizing the interconnections spread over a range of sectors, involving various actors and at multifarious scales.

Unfortunately, in countries with ineffective systems of governance and excessive reliance on top-down bureaucratic models, it is challenging to inter-link sectoral management measures to provide a holistic approach to protecting and managing coastal ecosystems, including providing for the NBA. Moreover, in most states, there is a complex, pluralistic maze of laws and regulations originating from various government institutions that need integration for a wholesome response. In sum, if we are to realize the full potential of nature-based adaptation truly, integrated approaches and a supportive legal and policy environment are a *sine qua non*.

*Conflict of3 interest* – The authors declare that there exist no conflict of interest in this study.

### Author contributions

**Meinhard Doelle**: Conceptualization (equal); Investigation (equal); Methodology (equal); Project administration (equal); Writing-original draft (equal).. **Tony G. Puthucherril**: Conceptualization (equal); Investigation (equal); Methodology (equal); Project administration (equal); Writing-original draft (equal).

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